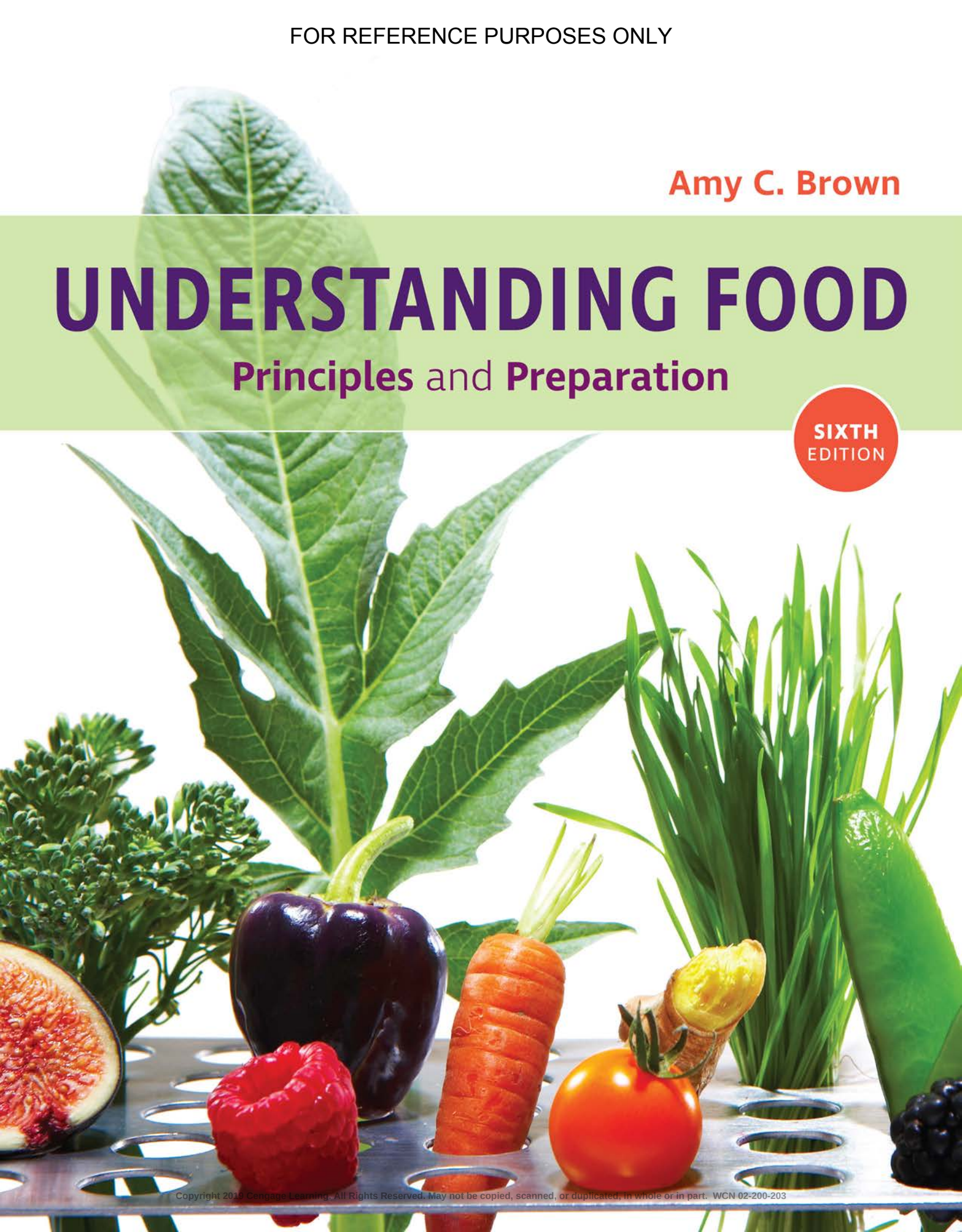
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Amy C. Brown

UNDERSTANDING FOOD

Principles and Preparation

SIXTH EDITION



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Understanding Food Principles and Preparation

SIXTH EDITION

Amy C. Brown
University of Hawaii at Manoa

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Brief Contents

PART I FOOD SCIENCE AND NUTRITION

1 Food Selection 1
2 Food Evaluation 20
3 Chemistry of Food Composition 27

PART II FOOD SERVICE

4 Food Safety 61
5 Food Preparation Basics 91
6 Meal Management 113

PART III FOODS

PROTEIN—MEAT, POULTRY, FISH, DAIRY, & EGGS

7 Meat 131
8 Poultry 163
9 Fish and Shellfish 177
10 Milk 197
11 Cheese 218
12 Eggs 236

PHYTOCHEMICALS—VEGETABLES, FRUITS, SOUPS, & SALADS

13 Vegetables and Legumes 256
14 Fruits 284
15 Soups, Salads, and Gelatins 310

COMPLEX CARBOHYDRATES—CEREALS, FLOUR, BREADS

16 Cereal Grains and Pastas 326
17 Flours and Flour Mixtures 346
18 Starches and Sauces 369
19 Quick Breads 385
20 Yeast Breads 395

DESSERTS—REFINED CARBOHYDRATES & FAT

21 Sweeteners 411
22 Fats and Oils 428
23 Cakes and Cookies 453
24 Pastries and Pies 471
25 Candy 489
26 Frozen Desserts 505

WATER—BEVERAGES

27 Beverages 518

PART IV FOOD INDUSTRY

28 Food Preservation 541
29 Government Food Regulations 555
30 Careers in Food and Nutrition 570

APPENDIXES

A Food Preparation Equipment A-1
B Food Yields B-1
C Substitution of Ingredients C-1
D Flavorings and Seasonings D-1
E Common Food Additives E-1
F Answers to Multiple-Choice Questions F-1

GLOSSARY G-1
INDEX I-1

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Contents

Preface xxiv

About the Author xxvii

PART I FOOD SCIENCE AND NUTRITION

Chapter 1 Food Selection 1

Sensory Criteria 1
Sight 1
Odor 2
- Classification of Odors 2
- Detecting Odors 2

Taste 3
- Mechanism of Taste 3
- The Six Taste Stimuli 3
- Taste Interactions 4
- Factors Affecting Taste 4
- Definition of Flavor 4

Touch 4
Hearing 6

Nutritional Criteria 6
Weight Management 6
Dietary Guidelines for Americans 6
ChooseMyPlate 6
- SuperTracker 8
- Previous Food Group Plans 8
- Vegetarianism 8

Consumer Dietary Changes 9
- Kcalories on Menus 9
- Complementary and Integrative Medicine 9
- Functional Foods 10
- Nutrigenomics 11

Cultural Criteria 11
Ethnic Influences 11
Place of Birth 11
Geography and Climate 12
Cultural Influences on Manners 12

Religious Criteria 12
Buddhism 12
Hinduism 12
Seventh-Day Adventist Church 12
Church of Jesus Christ of Latter-Day Saints (Mormon Church) 12
Judaism 13
Islam 13

Psychological and Sociological Criteria 14
Bioengineering 14
History of Biotechnology 14
- Foods Created with Biotechnology 14
- Concerns about GMO Foods 15
- Acceptance/Rejection of GM Foods 16

Organic Foods 16
- Organic Certification 16

"Natural" Foods 17
Processed Foods 17

Budgetary Criteria 17

Chapter 2 Food Evaluation 20

Sensory (Subjective) Evaluation 20
Two Types of Sensory Testing 20
Analytical (Effective) Tests 22
Affective (Acceptance or Preference) Tests 22
Taste Panels 22
Sample Preparation 23

Objective Evaluation 23
Physical Tests 23
Chemical Tests 24
- Electronic Noses 25

Comparison of Sensory and Objective Evaluations 25

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FOR REFERENCE PURPOSES ONLY

Chapter 3 Chemistry of Food Composition 27

Basic Food Chemistry: The Six Key Atoms (CHNOPS) 27

Water 28
Water Content in Foods 29
Composition of Water 29
Measuring Heat Energy 30
Specific Heat 30
Freezing Point 30
Melting Point 31
Boiling Point 31
- Elevation and Boiling Point 31

Hard vs. Soft Water 31
Functions of Water in Food 31
- Heat Transfer: Moist-Heat Cooking Methods 32

Solvent 32
- Dispersions 32
- Solutions 33
- Colloidal Dispersions 33
- Coarse Dispersions (Suspensions) 34
- Dispersion Destabilization 34

Chemical Reactions 34
- Ionization 34
- Changes in pH—Acids and Bases 34
- Salt Formation 35
- Hydrolysis 35
- Carbon Dioxide Release 35
- Food Preservation 35
- Water Activity 35
- Osmosis and Osmotic Pressure 36

Carbohydrates 36
Foods High in Carbohydrates 36
Composition of Carbohydrates 36
- Monosaccharides 37
- Disaccharides 38
- Oligosaccharides 38
- Polysaccharides 38

Functions of Carbohydrates in Foods 43

Lipids (Fats) 43
Foods High in Lipids 43
Composition of Lipids 43
Triglycerides 43
Fatty Acids 43
- Fatty Acid Structure 43
- Fatty Acids in Foods 44
- Fatty Acid Nomenclature 45

Phospholipids 45
- Food Industry Uses 45

Sterols 45
- Plant Sterols 45

Functions of Lipids in Foods 47

Proteins 47
Protein Quality in Foods 47
Composition of Proteins 47
Amino Acids 48
Functions of Proteins in Food 49
- Hydration 49
- Denaturation/Coagulation 49
- Enzymatic Reactions 49
- Buffering 51
- Browning 51

Vitamins and Minerals 52
Foods High in Vitamins and Minerals 52
Composition of Vitamins and Minerals 53
Functions of Vitamins and Minerals in Food 53
- Enrichment and Fortification 53
- Antioxidants and Their Food Industry Uses 53
- Sodium and Its Food Industry Uses 53

Nonnutritive Food Components 53
Food Additives 54
Purposes of Food Additives 54
- Additives that Improve Appeal 54
- Additives that Extend Storage Life 56
- Additives that Maximize Performance 56
- Additives that Protect Nutrient Value 57

Plant Compounds 57
- Beneficial 57
- Harmful 57
- Caffeine 57

PART II FOOD SERVICE

Chapter 4 Food Safety 61

What is a Foodborne Illness? 62
What Causes Foodborne Illness? 62

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FOR REFERENCE PURPOSES ONLY

Biological Hazards—Living Culprits 62
Bacteria: Number-One Cause of Foodborne Illness 63
Food Infections 63
Food Intoxication 64
Toxin-Mediated Infection 64

Bacterial Food Infections 65
Salmonella 65
Listeria monocytogenes 65
Yersinia enterocolitica 65
Shigella 66

Bacterial Food Intoxications 66
Clostridium perfringens 66
Staphylococcus aureus 66
Clostridium botulinum 66

Bacterial Toxin-Mediated Infections 66
Escherichia coli 67
Campylobacter jejuni 68
Vibrio 68
Hepatitis A Virus 68
Molds 68
Viruses 68
Norovirus 69
Parasites 69
Roundworms 69
Protozoa 69
Prions—Mad Cow Disease 70
New Virulent Biological Hazards 71
Advanced Techniques for Detecting Contamination 71

Chemical Hazards—Harmful Chemicals in Food 71
Seafood Toxins: Chemicals from Fish/Shellfish 72
Ciguatera Fish Poisoning 72
Histamine Food Poisoning 73
Puffer Fish Poisoning 73
Red Tide 73

Physical Hazards—Objects in Food 73

Food Allergy, Intolerance, and Sensitivity 73
Allergic Reaction Prevention 73
Labeling of Common Food Allergens 73
Cross-Contamination 73

Preventing Foodborne Illness 74
Prevention Factors Overview 74
Personnel 74
Training 74
Personal Hygiene Habits 74
Food Flow 75
Purchasing: Written Specifications 75
Inspection 76
Storage 76
Temperature 76
Proper Refrigerator and Freezer Use 77
Storage Times 77
Vulnerable Foods 78
High-Risk Foods 78
Foods with High Water Activity 78
Foods with Low Acidity 78
Exceptions to the High-Protein/Water/pH Rules 79
Oxygen and Food 79
Preparation 79
Pre-preparation 79
Cooking (Heating) 80
Holding 80

Proper Use of Thermometers 82
Types of Thermometers 82
Testing Temperatures 82
Care of Thermometers 83
Calibration of Thermometers 83
Cooling 84
Reheating 84
Serving 84
Sanitation 84
Dishes 84
Scheduling 85
Euipment 85
Facilities 85
Pest Control 86
Food Safety Monitoring 86
Health Department Inspections 86
HACCP 87
HARPC 88
Foodborne Illness Surveillance 88
World Health Organization 88

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Chapter 5 Food Preparation Basics 91

Heating Foods 91
Moist-Heat Preparation 92

Types of Moist-Heat Preparation 92
Scalding 92
Poaching 92
Simmering 92
Stewing 92
Braising 92
Boiling 93
Steaming 93
Microwaving 93
Dry-Heat Preparation 93

Types of Dry-Heat Preparation 94
Baking 94
- Rack Position 94
- Pan Color 94

Roasting 94
Broiling 94
Grilling 94
Barbecuing 94
Frying 95
- Sautéing and Stir-Frying 95
- Pan-Broiling and Pan-Frying 95
- Deep-Frying 95

Types of Heat Transfer 95
- Conduction 95
- Convection 96
- Radiation 96
- Induction 96

Measuring Heat 96

Cutlery Techniques 97
Handling Knives 97
Cutting Styles 98

Measuring Ingredients 101
Measuring Weight vs. Volume 101
Using Scales 101
- Metric vs. Nonmetric 101

Selecting the Right Measuring Utensil 101
Using an Accurate Measuring Technique 101
- Liquids 101
- Eggs 102
- Fat 102
- Sugar 102
- Flour 103
- Other Ingredients and Substitutions 103
- Approximating Food Requirements 103

Mixing Techniques 104
Baked Products 104

Seasonings and Flavorings 104
Types of Seasonings and Flavorings 104
- Salt 104
- Salt Substitutes 106
- Pepper 106
- Herbs and Spices 106
- Flavor Enhancers 108
- Oil Extracts 108
- Marinades 108
- Rubs and Pastes 108
- Breadings 109
- Batters 109
- Condiments 110

Adding Seasonings and Flavorings to Food 110
- How Much to Add? 110
- When to Add? 110
- Food Industry Uses 110

Chapter 6 Meal Management 113

Food-Service Organization 113
Commercial Food-Service Organization 114
- Escoffier's System of Organization via Stations 114
- Administrative Positions 115

Hospital Food-Service Organization 115

Types of Meal Planning 116
USDA Menu Patterns 116
Hospital Menu Patterns 117
Types of Menus 117
- Cycle Menus 117
- Nutrition 118

Purchasing 118
Buyers 121
Food Stores and Vendors/Suppliers 121
- Supermarkets 122
- Warehouse Stores 122

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Co-ops 122
Smaller Outlets 122
Food-Service Vendors 122
Cost Control 122
Meats 122
Fish 122
Dairy 122
Bread/Grains 122
Fruits and Vegetables 122
Price Comparisons 122
Reading Label Product Codes 123
Reducing Waste Saves Costs 123
As Purchased vs. Edible Portion 123
Percentage Yield 123
Portion Control 123

Time Management 124
Estimating Time 124
Efficient Meal Preparation 124
Recipes 124

Types of Meal Service 125
Russian Service 125
French Service 127
English Service 127
American Service 127
Family Service 127
Buffet Service 127

Table Settings 127
Cover and Linens 127
Flatware/Dinnerware/Glassware 127
Accessories 127
Centerpieces 128

PART III FOODS

Chapter 7 Meat 131

Types Of Meats 131
Beef 131
Veal 132
Lamb and Mutton 132
Pork 132

Composition of Meats 132
Structure of Meat 132
Muscle Tissue 132
Connective Tissue 133
Adipose (Fatty) Tissue 133
Bone 134
Antibiotics and Hormones 134
Pigments 136
Effect of Oxygen on Color 136
Effect of Heat on Color 137
Extractives 137

Purchasing Meats 137
Inspection 137
Grading 139
Quality 139
Yield 140
Tenderness of Meats 141
Natural Tenderizing 141
Artificial Tenderizing 143
Cuts of Meat 144
Terminology of Retail Cuts 144
Beef Retail Cuts 144
Veal Retail Cuts 146
Pork Retail Cuts 146
Lamb Retail Cuts 147
Variety Meats 147
Kosher Meats 149
Halal Meats 149
Organic Meats 149
Processed Meats 149
Processing Methods 149
Food Additives in Processed Meats 150
Types of Processed Meat 152
Mechanically Deboned Meat 152
Restructured Meat 153

Preparation Of Meats 153
Changes during Heating 153
Tenderness and Juiciness 153
Searing 153
Flavor Changes 154
Flavor Enhancements 154
Determining Doneness 154
Internal Temperature 154
Time/Weight Charts 155
Color Changes 155
Touch 156
Dry-Heat Preparation 156
Roasting 156
Broiling and Grilling 156

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Pan-Broiling 157
Frying 157
Deep-Frying 158
Moist-Heat Preparation 158
Braising 158
Simmering or Stewing 158
Steaming 159
Microwaving 159
Carving 159

Storage of Meats 159
Refrigerated 159
Wrapping Meat 159
Refrigeration Times 159
Packaging 160
Frozen 160

Chapter 8 Poultry 163

Classification of Poultry 163

Composition of Poultry 163

Purchasing Poultry 163
Inspection 163
Grading 165
Types and Styles of Poultry 165
Processed Poultry 165
Labeling 166
Standardized Poultry Buying 166
How Much to Buy 167

Preparation of Poultry 168
Preparation Safety Tips 168
Thawing Frozen Poultry 168
Stuffing 168
Brining 168
Changes during Preparation 169
Determining Doneness 170
Internal Temperature 170
Color Change 170
Touch 170
Time/Weight Charts 170
Dry-Heat Preparation 170
Roasting or Baking 170
Broiling or Grilling 172
Frying 173
Moist-Heat Preparation 173
Braising 173
Stewing 173
Poaching 173
Microwaving 173

Storage of Poultry 174
Refrigerated 174
Frozen 174

Chapter 9 Fish and Shellfish 177

Classification of Fish and Shellfish 177
Vertebrate or Invertebrate 177
Vertebrates 178
Invertebrates 178
Saltwater or Freshwater 178
Lean or Fat 178

Composition of Fish 178
Structure of Finfish 178
Collagen 179
Amino Acid Content 179
Muscle Structure 179
Pigments 179

Purchasing Fish and Shellfish 180
Inspection/Grading 181
Shellfish Certification 181
Selection of Finfish 181
Fresh and Frozen Fish 181
Canned Fish 184
Cured Fish 185
Fabricated Fish 185
Caviar 186
Selection of Shellfish 186
Purchasing Live Shellfish 186
Purchasing Processed Shellfish 187
Shucking Shellfish 187
Oysters 187
Clams 188
Scallops 188
Mussels 188
Abalone 188
Lobsters 188
Shrimp 189
Crab 189
Crayfish 190

Preparation of Fish and Shellfish 190
Dry-Heat Preparation 190

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FOR REFERENCE PURPOSES ONLY

Baking 190
Broiling 191
Grilling 191
Frying 191
Moist-Heat Preparation 191
Poaching 191
Simmering 192
Steaming 192
Microwaving 192
Raw Fish Preparation 193
Sashimi 193
Sushi 193
Ceviche 193
Food Safety Concerns 193

Storage of Fish and Shellfish 193
Fresh Finfish 194
Refrigerated 194
Spoilage Factors 194
Storing Caviar 194
Fresh Shellfish 194
Frozen 194
Thawing 194
Canned and Cured 194

Chapter 10 Milk 197

Functions of Milk in Foods 198

Composition of Milk 198
Nutrients 198
Carbohydrate 198
Protein 199
Fat 199
Vitamins 200
Minerals 200
Color Compounds 200
Food Additives 201

Purchasing Milk 202
Grades 202
Pasteurization 202
Ultrapasteurization 202
Ultrahigh-Temperature Processing 202
Homogenization 203

Types of Milk 204
Fresh Fluid Cow Milks 204
Whole Milk 204
Reduced-Fat and Low-Fat Milks 204
Fat-Free or Nonfat Milk 204
Fresh Fluid Milks from Other Animals 204
Flavored Fluid Milks 204
Chocolate Milk 205
Eggnog 205
Ultrahigh-Temperature Milk (UHT) 205
Nutritionally Altered Fluid Milks 205
Imitation Milk 206
Filled Milk 206
Low-Sodium Milk 206
Reduced-Lactose Milk 206
Plant-Based "Milks" 206
Soy Milk 206
Rice Milk 206
Almond Milk 206
Nut Milks 207
Hemp Milk 207
Grain Milk 207
Coconut Milk 207
Canned Fluid Milks 207
Whole Milk 207
Evaporated Milk 207
Sweetened Condensed Milk 208
Dry Milk 208
Nonfat Dry Milk 208
Instant Milk 208
Cultured Milk Products 208
Cultures Added to Milk 208
Buttermilk 209
Yogurt 210
Functional Foods—Probiotics 211
Acidophilus Milk 211
Kefir 211
Sour Cream 211
Creams and Substitutes 212
Cream 212
Cream Substitutes 212

Milk Products in Food Preparation 212
Flavor Changes 212
Coagulation and Precipitation 212
Heat 212
Acid 212
Enzymes 213
Salts 213
Whipped Milk Products 213

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FOR REFERENCE PURPOSES ONLY

Whipped Cream 213
Whipped Evaporated Milk 214
Whipped Reconstituted Nonfat Dry Milk 215

Storage of Milk Products 215
Refrigerated 215
Dry Storage 215

Chapter 11 Cheese 218

Classification of Cheeses 218
Place of Origin 219
Moisture Content 219

Cheese Production 219
Milk Selection 221
Coagulation 221
Enzyme Coagulation 221
Acid Coagulation 223
Curd Treatment 223
Curing and Ripening 224
Whey and Whey Products 226
Whey Cheeses 228
Dry Whey 228
Modified Whey Products 228
Process (Processed) Cheeses 228
Process Cheese 228
Cold-Pack Cheese 228
Process Cheese Food 229
Process Cheese Spread 229
Imitation Cheese 229
Tofu and Other Nondairy Cheeses 229
Food Additives in Cheese 229

Purchasing Cheese 229
Grading 229
Forms of Cheese 230

Food Preparation with Cheese 230
Selecting a Cheese 230
Shreddability 230
Meltability 230
Oiling Off 231
Blistering 231
Browning 231
Stretchability 231
Temperatures 231
Cutting Cheese 232

Storage of Cheese 232
Dry Storage 232
Refrigeration 232
Frozen 233

Chapter 12 Eggs 236

Composition of Eggs 236
Yolk 236
Albumen 237
Shell Membranes 237
Air Cell 237
Shell 238

Purchasing Eggs 238
Inspection 238
Eggs Failing USDA Inspection 238
Grading 238
Grading Methods 238
Sizing 240
Egg Substitutes 240
Value-Added Eggs 240

Types of Eggs 241

Functions of Eggs in Foods 241
Emulsifying 241
Binding 241
Foaming 241
Beating Technique 243
Temperature 243
Bowl Selection 244
Separation of Eggs 244
Additives 244
Interfering 244
Clarifying 244
Color 244

Preparation of Eggs 244
Changes in Prepared Eggs 245
Effects of Temperature and Time 245
Effects of Added Ingredients 245
Color Changes 245
Dry-Heat Preparation 246
Frying 246
Baking 247
Moist-Heat Preparation 248
Hard or Soft "Boiling" 248
Coddling 249
Poaching 249

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FOR REFERENCE PURPOSES ONLY

Custards 250
Microwaving 250

Storage of Eggs 251
Refrigerator 251
Whole Eggs 251
Storage Eggs 251
Pasteurized Eggs 251
Frozen 251
Dried 252
Rehydrating Dried Eggs 252
Safety Tips 252
Purchase 253
Preparation 253
Consumption 253
Storage 253

Chapter 13 Vegetables and Legumes 256

Classification of Vegetables 256

Composition of Vegetables 256
Structure of Plant Cells 256
Cell Wall 256
Storage Structures in Parenchyma Cells 257
Intercellular Air Spaces 258
Plant Pigments 258
Carotenoids 258
Chlorophyll 258
Flavonoids 259
Plants as Functional Foods 259
Additives 261

Purchasing Vegetables 263
Grading Vegetables 263
Selecting Vegetables 263
Artichoke 263
Asparagus 266
Beans (Green Snap, Green, Wax, and Yellow Wax-Pod Beans) 266
Beets 266
Broccoli 266
Brussels Sprouts 266
Cabbage 266
Carrots 266
Cauliflower 266
Celery 266
Corn 266
Cucumbers 266
Eggplant 267
Exotic Vegetables 267
Garlic 267
Ginger 268
Greens 268
Leeks 268
Lettuce 268
Mushrooms 268
Okra 269
Onions 269
Parsley 270
Parsnips 270
Peas 270
Peppers, Hot 270
Peppers, Sweet 270
Potatoes 270
Radishes 271
Rutabagas 271
Spinach 271
Sprouts 271
Squash 272
Sweet Potatoes 272
Tomatoes 273
Turnips 273

Legumes 273
Textured Vegetable Protein 274
Meat Analogs 274
Tofu 274
Fermented Soybean Foods 274

Preparation of Vegetables 275
General Guidelines 275
Changes During Heating 275
Texture 275
Flavor 275
Odor 276
Color 276
Nutrient Retention 277
Dry-Heat Preparation 277
Baking 277
Roasting 278
Frying 278
Moist-Heat Preparation 278
Simmering 278

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FOR REFERENCE PURPOSES ONLY

Steaming 278
Braising 279
Microwaving 279
Preparing Legumes 279
Preparing Sprouts 280
Growing Sprouts 280
Storing Sprouts 280

Storage of Vegetables 280
Refrigerated 281
Special Storage Requirements 281
Maintaining Moisture 281
Freezing 281
Dry Storage 281
Storing Potatoes 281
Controlled-Atmosphere Storage 281

Chapter 14 Fruits 284

Classification of Fruits 284
Classification Exceptions 285

Composition of Fruits 285
Organic Acids 285
Acidity of Fruits 285
Pectic Substances 285
Use of Pectin by the Food Industry 286
Pectin Formation in Ripening Fruit 286
Pectic Substances and Juice Cloudiness 286
Phenolic Compounds 286
Phenolic Compounds and Enzymatic Browning 286
Fruits as Functional Foods 287
Food Additives in Fruits 288

Purchasing Fruits 289
Grading Fruit 289
Selecting Fruits 290
Apples 290
Apricots 290
Avocados 290
Bananas 291
Berries 291
Cherries 292
Dates 292
Figs 292
Grapefruit 293
Grapes 293
Guavas 293
Kiwifruit 293
Kumquats 293
Lemons 293
Limes 293
Mandarins 293
Mangoes 294
Melons 294
Nectarines 294
Olives 295
Oranges 295
Papayas 296
Peaches 296
Pears 296
Persimmons 296
Pineapple 296
Plums 297
Pomegranates 298
Rhubarb 298
Tangerines—see Mandarins 298
Tropical Fruits 298
Superfruits 298
Processed Fruits 299
Canned 299
Frozen 300
Dried 300
Fruit Juices 300
Fruit/Vegetable Juice Processing 300

Preparation of Fruits 302
Limiting Enzymatic Browning 302
Denaturing Enzymes 302
Reducing pH 302
Lowering Temperature 302
Coating Fruits with Sugar or Water 302
Adding Antioxidants 302
Changes during Ripening and Heating 302
Color 302
Texture 303
Flavor 304
Dry-Heat Preparation 304
Baking 304
Broiling 304
Frying/Sautéing 304
Moist-Heat Preparation 304
Stewing/Poaching 304

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Applesauce Preparation 305
Preparing Dried Fruit 305
Fruit Spreads 305
Types of Fruit Spreads 305
Ingredients 305
Preparing Fruit Spreads 306

Storage of Fruits 307
Storing Fresh Fruit 307
Storing Canned Fruit 307
Olives 307

Chapter 15 Soups, Salads, and Gelatins 310

Soups 310
Types of Soups 310
Stocks 311
White and Brown Stocks 311
Water: The Main Ingredient 311
Flavoring Ingredients 312
Meat Stocks 312
Poultry Stocks 312
Fish Stocks 312
Vegetable Stocks 313
Storage of Soup Stocks 313
Clear and Thin Soups 313
Bouillon 313
Consommé 313
Thin Soups 313
Thickened Soups 313
Cream Soups 314

Salads 315
Salad Ingredients 316
Garnishes 316
Toasting Nuts 316
Principles of Salad Preparation 316
Leafy Green Salads 316
Vegetable Salads 318
Fruit Salads 318
Protein Salads 319
Pasta/Grain Salads 319
Salad Dressings 319
Oil and Vinegar Dressings 320
Emulsified Dressings 320
Other Dressings 320
Adding Dressings to Salads 321

Gelatins 321
What Is Gelatin? 321
Is Gelatin Nutritious? 321
Preparation of a Gel 321
Phases of Gel Formation 321
Phase 1—Hydration 321
Phase 2—Dispersion 321
Phase 3—Gelation 322
Unmolding a Mold 322
Factors Influencing Gel Formation 322
Gelatin Concentration 322
Temperature 322
Added Ingredients 323
Whipping 323
Storage of Gelatin 323

Chapter 16 Cereal Grains and Pastas 326

Composition of Cereal Grains 327
Structure 327
Husk 327
Bran 327
Endosperm 327
Germ 328
Food Additives in Grain Products 328

Uses Of Cereal Grains 329
Flour 329
Pasta 329
Breakfast Cereal 329
Alcoholic Beverages 329
Animal Feeds 329

General Types of Cereal Grains 329

Cereal Grains Containing Gluten 330
Wheat 330
Classification of Wheat 330
Forms of Wheat 331
Ancient Wheat Grains 331
Barley 331
Forms of Barley 331
Oats 332
Forms of Oats 332
Rye 332
Triticale 333

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Gluten-Free Cereal Grains 334
Amaranth 334
Buckwheat 334
Chia Seeds 334
Corn 334
- Classification of Corn 334
- Forms of Corn 335

Indian Rice Grass 336
Millet 336
Quinoa 336
Rice 336
- Classification of Rice 336
- Forms of Rice 337

Sorghum 337
Teff 337

Preparation of Cereal Grains 338
Moist-Heat Preparation: Boiling/Simmering 338
- Preparation 338
- Cooking the Grain 338
- Determining Doneness 339
- Standing Time 339

Sautéing and Baking 339
Microwaving 339

Storage of Cereal Grains 339
Dry 339
Refrigerated 340
Frozen 340

Pastas 340
Types of Pasta 340

Preparation of Pasta 341
Moist-Heat Preparation 341
Microwaving 342

Storage of Pasta 342

Chapter 17 Flours and Flour Mixtures 346

FLOURS 347
Starch 347
Gluten 347
- Purpose of Gluten 347
- Steps to Gluten Formation 348
- Dried Gluten 349

Cereal-Grain Food Sensitivities 350
- Baker's Asthma 350
- Wheat Allergy 350
- Celiac Disease 350
- Nonceliac Gluten Sensitivity (NCGS) 350

What Does "Gluten-Free" Mean? 350
Milling 350
- Five Steps of Milling 351
- Wet Milling 352

Wheat Flour Classifications 352
- Percent Protein Content 352
- Mineral Content 352

Types of Wheat Flour 352
- Whole-Wheat Flour 352
- Bread Flour 352
- White Flour 353
- Graham Flour 353
- Ancient Grain Flours 353
- High-Gluten Flour 353

Types of Nonwheat Grain Flours Containing Gluten 354
- Rye Flour 354
- Triticale Flour 354

Types of Gluten-Free Grain Flours 354
- Amaranth 354
- Buckwheat Flour 354
- Cornmeal Flour 354
- Rice Flour 355
- Sorghum Flour 355
- Gluten-Free Flour 355

Types of Nongrain, Gluten-Free Flours 355
- Tuber-Based: Potato Flour 355
- Legume-Based 355
- Nut-Based 355

Treated Wheat Flours 355
- Aged Flour 355
- Bleached Flour 355
- Phosphated Flour 355
- Self-Rising Flour 356
- Instant or Agglomerated Flour 356
- Enriched Flour 356

Flour Mixture Ingredients 356
Leavening Agents 356
- Air and Steam 356
- Yeast 356
- Bacteria 358

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Baking Soda 358
Potassium Bicarbonate 359
Baking Powder 359
Too Much/Too Little Leavening 360
Too Much/Too Little Flour 360
Sugar 360
Functions of Sugar 360
Types of Sugar 360
Too Much/Too Little Sugar 360
Salt 361
Salt Controls Yeast Growth 361
Too Much/Too Little Salt 361
Flavorings 361
Liquid 361
Milk 361
Too Much/Too Little Liquid 361
Fat 361
Functions of Fat 362
Types of Fat Used in Baked Goods 362
Temperature of Fat 363
Lower-Fat Alternatives 363
Too Much/Too Little Fat 363
Eggs 363
Too Much/Too Little Egg 363
Commercial Additives 363
Aging or Maturing Agents 363
Dough Conditioners 363
Food Additives in Flours 364

Preparation of Baked Goods 365
Doughs and Batters 365
Doughs 365
Batters 365
Changes during Heating 365
High-Altitude Adjustments 366

Storage of Flour And Flour Mixtures 366
Dry Storage 366
Frozen 366

Chapter 18 Starches and Sauces 369

Starch Characteristics 369
Sources of Starch 369
Cornstarch 370
Starch in Food Products 370
Thickening Agent 370
Edible Films 370
Dextrose 370
Starch Syrups 371
Starch Structure 371

Starch Transformations 372
Gelatinization 372
Factors Influencing Gelatinization 372
Gel Formation 373
Retrogradation 374
Dextrinization 374
Instant or Pregelatinized Starches 375
Resistant Starches (RS) 375
RS4 Modified (Chemically) Starches 375

Sauces 376
Functions of Sauces in Foods 376
Types of Sauces 376
Mother Sauces 376
Small Sauces 376
Preparation of Thickened Sauces 377
Ingredients of Thickened Sauces 377
Preparing Thickeners 378
Preparing a Sauce from a Roux 379
Preventing Lumps 379
Preparation of Unthickened Sauces 380
Gravy 380
Hollandaise Sauce 381
Barbecue Sauce 381
Butter Sauce 381
Fruit Sauce 381
Tartar Sauce 381
Tomato Sauce 382

Storage of Starches And Sauces 382

Chapter 19 Quick Breads 385

Preparation of Quick Breads 385
The Muffin Method 386
Additives Used in Quick Breads 386

Varieties of Quick Breads 386
Pour Batters 386
Pancakes 386
Crêpes 386
Waffles 387
Popovers 387
Drop Batters 387

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Muffins 388
Muffin Breads 389
Coffee Cakes 390
Dumplings 390
Doughs 390
Unleavened Breads 390
Biscuits 391
Scones 392
Crackers 392

Chapter 20 Yeast Breads 395

Preparation of Yeast Breads 395
Ingredients 395
Food Additives in Baked Products 396
Mixing Methods 397
Straight Dough Method 398
Sponge Method 398
Batter Method 398
Rapid Mix 398
Kneading 398
Proofing: Fermentation Causes the Dough to Rise 399
Changes during Fermentation 400
Optimal Fermentation Conditions 400
Avoid Overfermentation 400
Punching Down and Second Proofing 401
Shaping 401
Selecting a Baking Pan 402
Decorating 402
Baking 402
Changes during Baking 402
Crumb Development 403
Problems with Texture 403
Testing for Doneness 403
Microwave Preparation 404
High-Altitude Adjustments 405

Types of Yeast Breads 405
Loaf Breads 405
Wheat (White) Bread 405
Whole-Wheat Bread 406
Sourdough Bread 406
Malt Breads 406
Specialty Breads 406
Rolls 406
Pita Bread 406
Bagels 407
English Muffins 407
Pizza Crust 408
Pretzels and Bread Sticks 408
Raised Doughnuts 408

Storage of Yeast Breads 408
Fresh 408
Staling 408
Preventing Staling 408
Fresh Bread Additives 408
Refrigerated 408
Frozen 408

Chapter 21 Sweeteners 411

Natural Sweeteners 412
Sugars 413
Sucrose 413
Lactose 414
Maltose 414
Glucose 415
Fructose 415
Syrups 415
Corn Syrup 415
High-Fructose Corn Syrup 416
Honey 416
Molasses 417
Maple Syrup 417
Agave Syrup 418
Invert Sugar 418
Sugar Alcohols 418
Sugar Alcohols in Foods 418
Problems with Sugar Alcohols 419

Nonnutritive Sweeteners 419
Use in Foods and Beverages 419
Safety 419
Food Functions 421
Saccharin 421
Aspartame 421
Acesulfame-K 421
Sucralose 421
Neotame 422
Stevia and Its Derivatives 422
Luo Han Guo 422
Other Nonnutritive Sweeteners 423

Functions of Sugars In Foods 423
Sweetness 423

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Solubility 424
Crystallization 424
Browning Reactions 424
Caramelization 425
Moisture Absorption (Hygroscopicity) 425
Texture 425
Fermentation 425
Preservation 425
Leavening 425
Other Uses 425

Chapter 22 Fats and Oils 428

Functions of Fats In Food 429
Heat Transfer 429
Shortening Power 429
Emulsions 430
- Emulsifiers 430
- Stability of Emulsions 431

Melting Point 431
- Degree of Saturation 431
- Length of the Fatty Acids 432
- Cis–Trans Configuration 432
- Crystalline Structure 433

Plasticity 433
Solubility 433
Flavor 433
Texture 433
Appearance 433
Satiety or Feeling Full 434

Types of Fats 434
Butter 434
Margarine 434
- Composition of Margarine 434
- Types of Margarine 435

Shortenings 436
Oils 436
- Oil Production 437
- Types of Oils 439
- Winterized Oils 440
- Hydrogenated Oils 440

Lard/Tallow/Suet 441
- Interesterification 441

Cocoa Butter 441

Fat Replacers 441
Types of Fat Replacers 441
Composition of Fat Replacers 441
- Carbohydrate-Based Fat Replacers 441
- Protein-Based Fat Replacers 441
- Lipid-Based Fat Replacers 441

Food Preparation with Fats 443
Selection and Care of Frying Fats 443
- Fats Suitable for Frying 443
- Smoke Point 443
- Flash Point and Fire Point 443
- Controlling the Temperature of Frying Fats 444
- Recommended Equipment 444
- Optimal Frying Conditions 444

Lower-Fat Preparation Techniques 445
- Fats Preferred for Health 445
- Reducing Fat by Healthy Methods 445
- Modifying Recipes to Reduce Fat 445
- Pretreatments to Reduce Absorbed Oil 446

Storage of Fats 446
Rancidity 447
- Types of Rancidity 447
- Flavor Reversion 448
- Preventing Rancidity 448

Chapter 23 Cakes and Cookies 453

Types of Cakes 453
Shortened Cakes 453
- Bundt Cake 454
- Butter Cake 454
- Carrot Cake 454
- Cheesecake 454
- Ciambellone 454
- Coffee Cake 454
- Cupcake 454
- Devil's Food Cake 454
- Fruitcake 454
- German Chocolate Cake 454
- Ice Cream 455
- Mooncake 455
- Muffin 455
- Pound Cake 455
- Upside-Down Cake 455

Unshortened Cakes 455
- Angel Food Cake 455
- Boston Cream Pie 455
- Dacquoise (da-kwoz) 455
- Génoise (zh-eh-nwoz) 455
- Meringue (mer-rang) 455

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Petit Four 455
Roulade (roo-lahd) 455
Tiramisu (teer-a-me-sue) 455
Chiffon Cakes 456

Preparation of Cakes 456
Ingredients 456
Flour 456
Sugar 456
Fats 457
Eggs 457
Milk 457
Leavening Agent 457
Additional Ingredients 457
Other Factors 458
Preparing Shortened Cakes 458
Selection and Preparation of Pans 458
Temperature/Timing 459
Changes during Baking 459
Testing for Doneness 460
Cooling 460
High-Altitude Adjustments 461
Microwave Preparation 461
Preparing Unshortened and Chiffon Cakes 461
Angel Food Cake 461
Sponge Cake 462
Chiffon Cake 462
Selection and Preparation of Pans 462
Temperature/Timing 463
Testing for Doneness 463

Frostings/Icings 463
Flat Frostings 463
Decorating Frosting 463
Cooked Frosting 463
Whipped Cream Frosting 463
Ganache 463
Garnishes 464

Storage of Cakes 464

Types of Cookies 464
Bar Cookies 465
Brownies 465
Lemon Bars 465
Dropped Cookies 465
Chocolate Chip Cookies 465
Cialde (chee-al-day) 465
Florentines 465
Fortune Cookies 465
Macarons 465
Macaroons 465
Madeleines 465
Meringues 465
Wafers 465
Pressed Cookies 466
Ladyfingers 466
Russian Tea Cookies (Mexican Wedding Cakes) 466
Molded Cookies 466
Almond Cookies 466
Biscotti di Prato 466
Peanut Butter Cookies 466
Rolled Cookies 466
Butter Cookies 466
Cannoli Shell 466
Gingerbread 466
Linzer Cookies 466
Mandelbrot 466
Shortbread 466
Sugar 466
Icebox/Refrigerator Cookies 466
Cookies as Functional Foods 466

Preparation of Cookies 467
Ingredients and Mixing Methods 467
Food Additives in Cookies 467
Baking Cookies 467
Selection and Preparation of Pans 467
Temperature/Timing 468
Testing for Doneness 468
High-Altitude Adjustments 468
Microwave Preparation 468

Storage of Cookies 468

Chapter 24 Pastries and Pies 471

Types of Pastry 471
Pastry Classification 471
Nonlaminated Pastries 471
Plain Pastry 471
Brioche Pastry 472
Choux Pastry 472
Laminated Pastries 473

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Puff Pastry 473
Quick (Blitz) Pastry 473
Phyllo (Filo) Pastry 473
Croissant Pastry 473
Danish Pastry 473

Preparation of Pastry 474
Ingredients of Pastry 474
Flour 475
Fat 475
Liquid 476
Eggs 477
Salt 477
Sugar 477
Flavorings 477
Thickeners (for Fillings) 477
Mixing Methods 478
Plain (Pie) Pastry 478
Puff Pastry 478
Rolling 479
Chilling the Dough 479
Rolling Surface 480
General Technique 480
Rolling Plain Pastry 480
Rolling Puff Pastry 481
Fillings 483
Fruit Fillings 483
Cream Fillings 483
Custard Fillings 483
Chiffon Pies 484
Meringue Pies 484
Pastry Fillings 484
Toppings 484
Glazes 484
Crumb Toppings 484
Baking 485
Pan Selection and Preparation 485
Temperature and Timing 485
Testing for Doneness 485

Storage of Pastry 485

Chapter 25 Candy 489

Classification of Candies 489
Syrup Phase versus Fat Phase 489
Crystalline versus Noncrystalline (Amorphous) 490

Preparation of Candy 490
Confectionery Preparation Overview 490
Crystalline Candies 491
Candies Start with a Syrup Solution 491
Heating the Syrup 491
Cooling and Beating 493
Types of Crystalline Candies 494
Noncrystalline Candies 495
Concentrating the Sugar Solution 495
Interfering Agents 495
Types of Noncrystalline Candies 495
Food Additives in Candy 496

Chocolate 496
Cacao Tree 496
History 496
Chocolate Production 497
Cocoa Beans Produce Chocolate Liquor 497
Chocolate Liquor 498
Conching 498
Tempering 498
Factors Affecting Tempering 499
Types of Chocolate Products 501
Baking Chocolate 501
Cocoa 501
Semisweet or Sweet Chocolate 501
Milk Chocolate 501
Imitation Chocolate 501
White Chocolate 501
Functional Chocolate 501

Storage of Candy 502
Shelf Life of Chocolate 502

Chapter 26 Frozen Desserts 505

Types of Frozen Desserts 505
Ice Cream 506
Ice Cream Ingredients 506
Low-Fat Ice Cream 507
Ice Cream as a Functional Food 507
Imitation Ice Cream 507
Gelato 507
Frozen Yogurt 507
Sherbet 507
Sorbet 508
Water Ices 508
Popsicles 508
Granitas and Granités 508

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FOR REFERENCE PURPOSES ONLY

Frappés 508
Still-Frozen Desserts 508

Preparation of Frozen Desserts 508
Factors Affecting Quality 508
Flavor 508
Texture 508
Body 510
Mixing and Freezing 511
Ice Cream 511
Frozen Yogurt 513
Sherbet 513
Sorbet 513
Water Ices 514
Still-Frozen Desserts 514
Food Additives in Frozen Desserts 514

Storage of Frozen Desserts 514
Texture Changes 514
Scooping Frozen Desserts 515

Chapter 27 Beverages 518

Water 518
Bottled Water 518
Sources of Water 519
Water Treatment Methods 519
Purified Water 519
Deionized Water 519
Distilled Water 519
Reverse Osmosis Water 519
Soft Drinks Marketed as "Water" 519

Carbonated Soft Drinks 520
Early Soft Drinks 520
Soft Drink Processing 520
Soft Drink Health Concerns 520
Diet Soft Drinks 521
Food Additives in Soft Drinks 521

Functional Beverages 521
Nutraceutical Beverages 521
Nutraceutical Trends 522
Sports Beverages 522
Smart Beverages 522
Energy Beverages and Shots 523

Coffee 523
Coffee Processing 524
Removing the Hull 524
Roasting 524
Grinding 524
Decaffeination 524
Instant Coffee 524
Composition of Coffee 524
Volatile Compounds 524
Bitter Substances 525
Methylxanthines 525
Types of Coffee 525
Types of Beans 525
Types of Processing 525
Types of Ingredients 526
Preparation of Coffee 526
Coffee Freshness 526
Water-to-Coffee Ratio 526
Water Type 526
Water Temperature 526
Brewing Time 526
Brewing Equipment 527
Holding Time 527
Storage of Coffee 527

Tea 528
Tea Processing 528
Withering 528
Rolling 528
Oxidizing 528
Firing 528
Types of Tea 528
Black Tea 528
Green Tea 528
Oolong Tea 528
White Teas 529
Flavored Teas 529
Herbal Teas 529
Specialty Teas 529
Grades of Tea 529
Composition of Tea 529
Health Benefits of Tea 529
Preparation of Tea 529
Brewing Tea 530
Iced Tea 530
Instant Tea 530
Microwaving 530
Storage of Tea 530

Dairy Beverages 530
Cocoa Beverages 530

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FOR REFERENCE PURPOSES ONLY

Alcoholic Beverages 530
Beer 531
- Beer Production 531
- Classifications of Beer 532
- Specialty Beers 532
- Serving Beer 532
- Storing Beer 532

Wine 532
- Wine Production 533
- Evaluating Wines 533
- Selecting a Wine 534
- Food Additives in Wines 537

Spirits 537
- Proof 537
- Common Spirits 537

PART IV FOOD INDUSTRY

Chapter 28 Food Preservation 540

Food Spoilage 540
Biological Changes 540
Chemical Changes 541
Physical Changes 541

Food Preservation Methods 542
Drying 542
- Sun-Drying 542
- Commercial Drying 542

Curing 543
Smoking Cured Meats 543
Fermentation 544
Pickling 544
- Weak Organic Acids 544

Edible Coatings 545
- Composition of Edible Coatings 545
- Commonly Coated Foods 545
- Micro-encapsulation 545

Canning 545
- Preparing Food for Canning 545
- Two Methods of Canning 546

Cold Preservation 546
Refrigeration 546
- Refrigerating Food 546
- Refrigeration Temperatures and Times 546

Freezing 546
- Foods Suitable for Freezing 546
- Freezer Storage Times 546
- Four Problems with Frozen Food 547

Heat Preservation 544
Boiling 548
Pasteurization 548
- High-Temperature Pasteurization 548
- Sous-vide 548

Ohmic Heating 548

Other Preservation Methods 548
Irradiation (Cold Pasteurization) 548
- The Irradiation Process 549
- Effects of Irradiation on Foods 549
- Irradiation Pros and Cons 550

Radio Frequency 551
Pulsed Light 551
High-Pressure Processing 551
Ozonation 551
Aseptic Packaging 552
- Modified-Atmosphere Packaging (MAP) 552
- Controlled-Atmosphere Packaging (CAP) 552
- Vacuum Packaging 552

Nutrient Retention 552

Chapter 29 Government Food Regulations 555

Federal Food Laws 555
Pure Food and Drug Act (1906) 556
Federal Food, Drug, and Cosmetic Act (1938) 556
Numerous Government Agencies 556

Food And Drug Administration 557
Research/Education 557
The Code of Federal Regulations 557
FDA Inspections 557
- FDA Enforcement of Its Laws 557
- Allowable Contaminants 558

FDA Standards 558
- Standards of Identity 558
- Standards of Minimum Quality 558
- Standards of Fill 559

Food Labeling 559
- Nutrition Facts Label 559
- Food Labeling Exemptions 560

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FOR REFERENCE PURPOSES ONLY

Food Allergen Labeling 560
Genetically Modified Organisms (GMOs) 561
FDA-Allowed Claims on Labels 561
Dietary Supplements 562
Food Additives 563
Safety of Food Additives 563
Ingredients Not Defined as Additives 563
The Delaney Clause 563
The Bioterrorism Preparedness Act 563

U.S. Department of Agriculture 564
USDA Inspections 564
USDA Grading 565
Quantity Grades or Yields 565
Quality Grades 565
Product Labeling 565
Irradiated Foods 565
Organic Foods 565
Country of Origin Labeling (COOL) 565

Environmental Protection Agency 566

Centers for Disease Control and Prevention 566

Other Regulatory Agencies 567
U.S. Department of Commerce 567
Federal Trade Commission 567
Department of the Treasury 567
State Agencies 567

International Agencies 567
The Food and Agriculture Organization 567
The World Health Organization 567
European Regulation 567

Chapter 30 Careers in Food and Nutrition 570

Three Major Food and Nutrition Areas 570

Nutrition Science and Dietetics 571
Nutrition Science 572
Nutritionist 572
Dietetics 572
Registered Dietitian Nutritionist (RDN) 572
Types of Registered Dietitian Nutritionists 575
Dietetic Technician, Registered (DTR) 576
Dietary Clerk or Dietary Aide 577

Food Science 577
Food Scientist 577
Academic Requirements 577
Types of Food Scientists 578
Food Science Technician 579

Food Service 579
Academic Preparation for Culinary Arts 579
Types of Food-Service Positions 579
Chef 580
Food-Service Manager 580
Sales and Marketing 580
Dietary Manager 580
Food-Service Certifications 580

Graduate School 580
Prerequisites 580
Academic Requirements 581
Examination Requirements 581
Professional Schools 582
Graduate-Degree Jobs 582
Researcher 582
Professor 582
Pharmaceutical and Nutraceutical Industries 583

APPENDIXES

A Food Preparation Equipment A-1
B Food Yields B-1
C Substitution of Ingredients C-1
D Flavorings and Seasonings D-1
E Common Food Additives E-1
F Answers to Multiple-Choice Questions F-1

GLOSSARY G-1
INDEX I-1

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Preface

***Comprehensive* is the word that describes *Understanding Food: Principles and Preparation,* the best-selling textbook in its field. It brings together the most current information in food science, nutrition, and food service. Founded on research from more than thirty-five journals covering these disciplines, the text incorporates the very latest information on food—its science and its application. *Understanding Food: Principles and Preparation*, 6th edition, provides students with a broad foundation to launch a career in any of these food-related fields.**

ORGANIZATION OF CONTENT

Understanding Food: Principles and Preparation is organized according to the various food disciplines. Part I represents information related to food science and nutrition, such as food selection, sensory and physical evaluation, and food chemistry. Part II covers aspects of food service from food safety to food preparation basics to meal management. Part III covers all of the standard food items arranged into proteins (meat, poultry, fish, dairy, and eggs); phytochemicals (vegetables, fruits, soups, salads, and gelatins); complex carbohydrates (cereals, flour, and breads); refined carbohydrates and fat (sweeteners, fats and oils, cakes and cookies, pies and pastries, candy, and frozen desserts); and water (beverages) groupings. Part IV relates to the food industry in terms of food preservation, government food regulations, and food careers. The last chapter, on food careers, is an invaluable advisement session introducing students to the many careers in food and nutrition. In addition, the Career Corner feature found in many chapters spotlights individuals working in various areas of the nutrition and food industry, so students really get a hands-on understanding of various career opportunities. Extensive appendixes provide additional key information, including approximate food measurements, weights and measures, storage temperatures, ingredient substitutions, flavorings and seasonings, and more.

FEATURES

The unique features of this text allow flexibility in teaching and create a dynamic learning environment for students.

- **Career Corner** features provide interviews with people working in the food and nutrition arena to help students on their career path.
- **How & Why** inserts answer the questions most frequently asked by students, sparking natural curiosity and exercising the mind's ability to answer.
- **Chemist's Corner** features provide more advanced information on food chemistry for students and instructors who want to explore this topic further, allowing flexibility in the level of food chemistry presented within the individual course.
- **Calorie Control** teaches students how to identify food sources of kcalories, how many daily kcalories are recommended, and how to practice portion control.
- **Nutrient Content** boxes provide an overview of the nutritional composition of the foods.
- **Pictorial Summaries** are a proven favorite with readers. These pictorial chapter summaries use a combination of art and narrative text to encapsulate the key concepts in each chapter for student review.
- **Key terms,** boldfaced in the text, are defined on the same page to allow for quick review of the essential vocabulary in each chapter. A glossary at the end of the book assembles all of the key terms in one place.
- **Functions of ingredients** are highlighted in the introduction to each chapter to aid students in successful food product development and food preparation. They introduce a focus of the food industry that is often missing in other books.
- **Food additive information** has been incorporated throughout the book.
- **Problems and causes tables** summarize the problems that may occur when preparing specific food products and describe the possible causes, providing students with a handy reference tool for deciphering "what went wrong."
- **Chapter review questions** help students prepare for both their class exams and the Academy of Nutrition and Dietetics registration examination.

The dynamic world of food changes rapidly as new research constantly adds to its ever-expanding knowledge base. *Understanding Food: Principles and Preparation,* 6th edition, is designed to meet the needs of this evolving and expanding discipline and to provide students with a strong foundation in any food-related discipline that they select.

NEW TO THIS EDITION

Each chapter of *Understanding Food* has been revised to reflect updates in research, government guidelines, consumer preferences, and food-service practices since the publication of the prior edition. Specific additions and other enhancements for the sixth edition follow:

- **COLOR.** This is the first time *Understanding Food: Principles and Preparation* is published in color as requested by many students.

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- **MINDTAP.** Another first-time feature, MindTap, is included for online interactive textbook learning.
- **Chapter 1 Food Selection.** Added the NEW information from the 2015-2020 *Dietary Guidelines for Americans,* including MyPlate, updated statistics on diversity in the U.S. population, added new definitions for oleogustus, whole foods, processed foods, natural foods, discussed kcalorie requirements for restaurants, GMO crops, and food phytochemicals.
- **Chapter 2 Food Evaluation.** Added new food analyzer photograph.
- **Chapter 3.** Chemistry of Food Composition. Added standardized numbering system for food additives.
- **Chapter 4 Food Safety.** Added how HACCP was replaced by HARPC, the WHO (FERG) – Foodborne disease burden epidemiological reference group, how Norovirus is #1 with Salmonella close behind, defined Integrated Pest Management (IPM) Program, added gluten as a possible problem.
- **Chapter 5 Food Preparation Basics.** Added menu calorie requirements, mixing method table, photos of culinary herbs, induction cook top option, additional cutting styles (Batonnet, chiffonade, chop, pariseinnes), meniscus information, new rubs and pastes, mondoline figure, melon baller figure, and metric tables.
- **Chapter 6 Meal Management.** Inserted NEW 2016 USDA Adult Care Meal Pattern, updated terminology for registered dietitian nutritionist, and nutrition dietetic nutritionist, registered, modified nutrient box [removed decreasing dietary cholesterol, added decreasing saturated fat (10% kcal), decreasing added sugars (10% kcal)], removed the Exchange List, and added Use By, Best By and Sell By dates.
- **Chapter 7 Meat.** Color inserts were removed and inserted into this chapter for easier reference.
- **Chapter 8 Poultry.** The poultry classification table was upgraded with pics and new information, and salmonella amounts were modified (¾ and not ¼).
- **Chapter 9 Fish & Shellfish.** NEW FDA mercury fish eating guidelines were added along with sushi definitions and photos.
- **Chapter 10 Milk.** New definitions were added for kefir, yogurt consistency, coconut milk vs water was clarified, camel milk was removed, Table 10-5 was corrected from 71.5 to 72 C, and a figure was added on probiotic food.
- **Chapter 12 Eggs.** Updates included egg consumption changing to 90 to 80 billion eggs, FDA safe egg handling tips, the number of whole eggs/whites/yolks per cup, along with new color figures to clarify information.
- **Chapter 11 Cheese.** Added two official government sources of cheese classification, a beautiful graphic of commercial cheese production, additional methods of inhibiting mold formation, yeast as a contributor to ripening, and quark cheese, common in Europe, to soft cheeses. Appendix E was moved to Table 11-1 showing origins of cheeses. Camel was removed as a source of cheese in Iran.
- **Chapter 13 Vegetables & Legumes**. Removed vitamin D as antioxidant, updated the Exchange List, NCI was updated to 'no' recommendations, improved descriptions of Fermented Soy Foods, and inserted the Color Inserts of vegetables into to this chapter.
- **Chapter 14 Fruits.** Two color inserts moved to this chapter (apples and exotic fruits), more fruits were added to Table 14-10 Climacteric and Non-climacteric fruits, and different types of olive processing were added.
- **Chapter 15 Soups, Salads, & Gelatins.** Two color inserts were moved to this chapter, koji definition was clarified, and additional herbs were depicted in color figures.
- **Chapter 16 Cereals Grains & Pasta.** Expanded Figure 16-1 to include colorful drawings of cereals on the stalk, Figure 16-7 illustrated different kernel types, inserted researching showing oats decrease blood cholesterol and glucose, updated cereal production figure, added chia seeds (popular new food), clarified the addition of oil to cooking pasta and improved the definition of "noodles" vs "Asian noodles."
- **Chapter 17 Flours & Flour Mixtures.** Added Emmer (farro) grain to types of flour, psuedo-grains were better defined, added folic acid to masa flour recently approved by FDA, gluten-free definition by FDA reached final approval, clarified difference between semolina and durum flour, percentages of protein in text matched Table 17-1, and added Registered Trademark to kamut.
- **Chapter 18 Starches.** Clearer photographs on making a reduction were added.
- **Chapter19 Quick Breads.** Added NEW table explaining different types of flatbreads.
- **Chapter 21 Sweeteners.** Updated NEWLY FDA approved Advantame sweetener, and improved the sugar alcohol table.
- **Chapter 22 Fats & Oils.** Improved chemistry by adding NEW chemistry figures describing fatty acid saturation and length, acrolein, hydrogenation, oxidation and antioxidant examples.
- **Chapter 23 Cakes & Cookies.** Inserted numerous photos of cakes and cookies.
- **Chapter 24 Pastries & Pies.** Inserted NEW photos of pies and pastries.
- **Chapter 25 Candy.** Improved definition of unsweetened, bittersweet, semi-sweet chocolates
- **Chapter 29 Government Food Regulations.** Included NEW FDA 2016 food label, NEW health claims, NEW topic of "Food Fraud," and updated pesticide information.
- **Chapter 30 Careers in Food & Nutrition.** Updated terminology of RD to RDN, and DT to NDTR. Inserted salary updates.

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ANCILLARY MATERIALS

Assorted student and instructor support materials, thoroughly updated for the sixth edition, are available as follows:

- The print **Lab Manual,** revised by Janelle M. Walter (Baylor University), presents food experiments and recipes to demonstrate the principles discussed in the text. Pretest questions and materials/time needed information for instructors enhance the lab units, which parallel the organization and content of the text.
- **Cengage Learning Testing powered by Cognero.** A flexible, online system allows you to author, edit, and manage test bank content from multiple Cengage Learning solutions. Create multiple test versions in an instant. Deliver tests from your LMS, your classroom, or wherever you want. Test questions for this edition were written by Joan Aronson (New York University).
- An **Instructor's Manual** written by Joan Aronson and Cheryl Houston (Fontbonne University), available electronically, features engaging classroom activities, objectives, recommendations, and lecture outlines.
- **Instructor Companion Website.** Everything you need for your course in one place! This collection of book-specific lecture and class tools is available online at www.cengage.com/login. Access and download PowerPoint presentations, images, instructor's manual, videos, and more.

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Many individuals assisted me in the development of this textbook. I want to thank Krista Mastroianni, the lead editor who masterfully brought this book to the completion of yet another edition, infused the book with new life by adding "color," and inserted the online MindTap option for the very first time. Lauren Oliveira, Associate Content Development Manager for Life and Earth Sciences, got the book started on the right track.

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Finally, I wish to express my appreciation to the students. Were it not for them, I would not have taken pen to paper. I am grateful to be a part of your academic journey.

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Amy Christine Brown received her PhD from Virginia Polytechnic Institute and State University in Human Nutrition and Foods. She has been a college professor and a registered dietitian with the Academy of Nutrition and Dietetics since 1986. Dr. Brown currently teaches at the University of Hawaii's John A. Burns School of Medicine in the Department of Complementary and Integrative Medicine. Her research interests are in the area of medical nutrition therapy and bioactive plant substances beneficial to health. Some of the studies she has conducted include "Diet and Crohn's disease," "Potentially harmful herbal supplements," "Kava beverage consumption and the effect on liver function tests," and "The effectiveness of kukui nut oil in treating psoriasis." Selected research journal publications include "Position of the American Dietetic Association: Functional foods" (*Journal of the American Dietetic Association*); "The Hawaii Diet: Ad libitum high carbohydrate, low fat multi-cultural diet for the reduction of chronic disease risk factors" (*Hawaii Medical Journal*); "Lupus erythematosus and nutrition: A review" (*Journal of Renal Nutrition*); "Dietary survey of Hopi elementary school students" (*Journal of the American Dietetic Association*); "Serum cholesterol levels of nondiabetic and streptozotocin-diabetic rats" (*Artery*); "Infant feeding practices of migrant farm laborers in northern Colorado" (*Journal of the American Dietetic Association*); "Body mass index and perceived weight status in young adults" (*Journal of Community Health*); "Dietary intake and body composition of Mike Pigg—1988 Triathlete of the Year" (*Clinical Sports Medicine*); and numerous newspaper nutrition columns.

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To Betsy Brown

The person who I love dearly, is one of the nicest people I know, sacrificed unflinchingly for me, and worked harder her whole life, as most Moms do, than I ever will. I deeply respect and love you for eternity. May the shining light that you created, brighten many candles to bring more light and love (Aloha) into the world.

Always and Forever,

Amy Christine Brown

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Food Selection

Sensory Criteria 1
Nutritional Criteria 6
Cultural Criteria 11
Religious Criteria 12
Psychological and Sociological Criteria . . 14
Budgetary Criteria 17

Not too long ago, **whole foods,** such as meats, milk, grains, nuts, vegetables, and fruits, were the only foods available for consumption. Today, food companies offer thousands of prepared and packaged foods, which are primarily mixtures of these basic ingredients, but often include natural and/or artificial additives. This wide assortment of **processed foods** makes planning a nutritious diet more difficult, rather than easier. Food companies compete fiercely to develop ever newer and more attractive products. The food scientists they employ focus on why people eat, what they eat, and which food characteristics entice consumers to choose one brand over another.

People choose foods and beverages for at least five basic reasons: how foods look and taste; health, cultural, and religious values; environment; psychological and social needs; and budgetary concerns (16). This chapter addresses the factors influencing consumer food selection.

SENSORY CRITERIA

People choose foods primarily by how they look, smell, taste, feel, and even sound (Figure 1-1). Sensory criteria are discussed first because how a food or beverage affects the senses is more important to most consumers than food selection criteria. The sensory criteria of sight, odor, and taste are now briefly summarized.

Sight

The eyes see the first impression of foods: shapes, colors, consistency, serving size, and presence of any outward defects. Black bananas, barely yellow lemonade, meat cooked red raw, a cockroach eating cheese left out on the counter, and scorched macaroni send visual signals that may alter a person's choices. Color can be deceiving; if the colors of two identical fruit-flavored beverages are different, people often perceive them

Whole Foods Foods as you find them in their natural state, minimally processed, and free from additives or artificial ingredients.

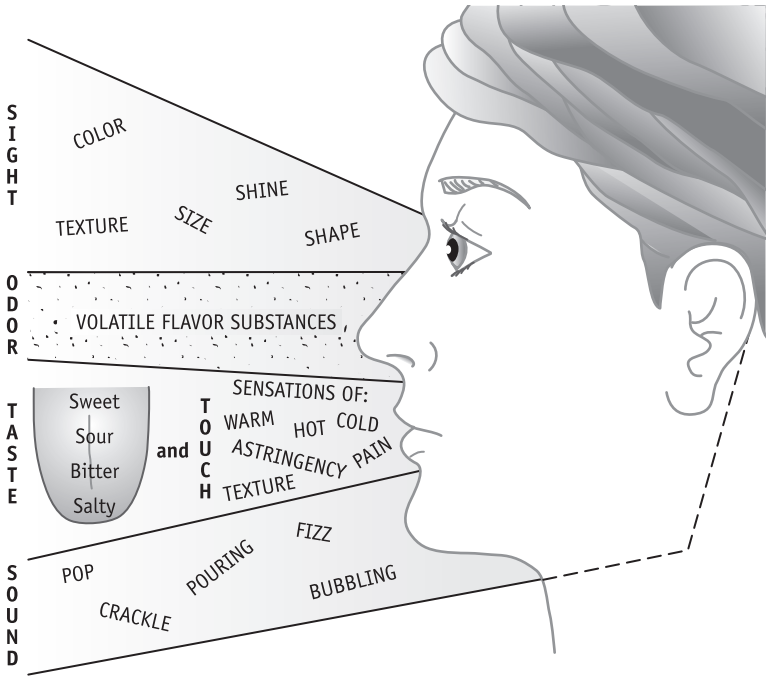
Processed Foods Any deliberate change to a food before it is available to eat, such as salting, fermenting, drying, canning, freezing, packaging, or other types of processing.

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FIGURE 1-1 Sensory impressions of food provided by the five senses.



as tasting different even though they are exactly the same (80). People may judge milk's fat content by its color. For instance, if the color of reduced-fat (2%) milk is improved, it is often judged to be higher in fat content, smoother in texture, and better in flavor than the reduced-fat milk with its original color (5).

Chefs know that the color of foods on a plate is either appealing or detracting. Imagine being served a plate of baked flounder, mashed potatoes, boiled cabbage, and vanilla ice cream, and then compare it to one that contains a nicely browned chicken breast, orange sweet potatoes, green peas, and blueberry cobbler. Based on eye appeal alone, most people would prefer the latter.

Odor

Chocolate chip cookies baking in the oven, coffee brewing, and spoiled meat makes smell almost as important as appearance when evaluating foods and beverages for quality and desirability. Although the sense of smell is not as acute in human beings as it is in many other mammals, most people can differentiate between many thousands of odors. Recent research suggests that people's ability to distinguish smells is much greater than once thought. Researchers found the number of olfactory receptors to far exceed the 10,000 originally thought to be present with the number being as high as 1 trillion (4).

Classification of Odors

Naming each of these thousands of odors separately would tax even the most fertile imagination, so researchers categorized them into major groups. One classification system recognizes six groups of odors: spicy, flowery, fruity, resinous (eucalyptus), burnt, and foul. The other widely used grouping scheme consists of four categories: fragrant (sweet), acid (sour), burnt, and caprylic (goaty) (4). A newer proposed classification divides odors into categories based on whether they are perceived as edible (e.g., fruit, candy, bakery, or spice) or inedible (e.g., clean, flower, and cosmetic) and overlaps with previous classification systems (94).

Detecting Odors

Regardless of which classification is used, most odors are detected at very low concentrations. Vanillin can be smelled at 2×10^{-10} (0.0000000002) mg per liter of air (11). However, if an odor is repeatedly detected, the ability to distinguish between various odors diminishes over the time; and this perception of a continuously present smell gradually decreasing over time is called *adaptation*. People living near a noxious-smelling paint factory will, over time, come not to notice it, whereas visitors to the area may be taken aback by the odor.

How do we smell odors? They are detected when **volatile molecules** travel through the air, and some of them reach the yellowish-colored **olfactory** epithelium, an area the size of a quarter located inside the upper part of the nasal cavity. This region is supplied with olfactory cells that number from 10 million to 20 million in a human and about 100 million in a rabbit (11), reflecting the difference in importance

Volatile molecules Molecules capable of evaporating like a gas into the air.

Olfactory Relating to the sense of smell.

How & Why?

Imagine the scent of chocolate chip cookies wafting through the house as they bake. How does this smell get carried to people? Why is the odor of something baking more intense than the odor of cold items like ice cream or frozen peaches?

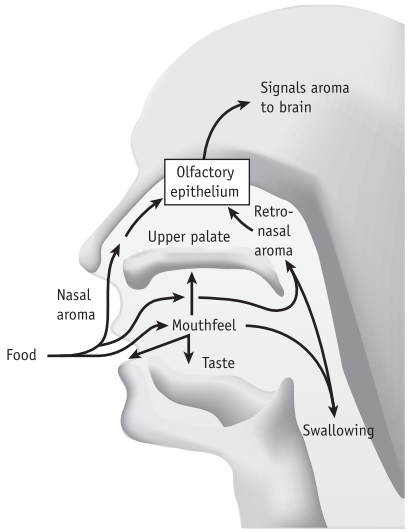
Heat converts many substances into their volatile form. Because only volatile molecules in the form of gas carry odor, it is easier to smell hot foods than cold ones. Hot coffee is much easier to detect than cold coffee. Relatively large molecules such as proteins, starches, fats, and sugars are too heavy to be airborne, so their odors are not easily noticed. Lighter molecules capable of becoming volatile are physically detected by the olfactory epithelium by one of two pathways: (1) directly through the nose, and/or (2) during eating when they enter the mouth and flow retronasally, or toward the back of the throat and up into the nasal cavity (Figure 1–2) (65).

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FIGURE 1-2 Detecting aroma, mouthfeel, and taste.



of the sense of smell between people and rabbits. The exact function of these specialized cells in the sense of smell is not well understood.

Interestingly, molecules can sometimes reach the olfactory epithelium by first going through the mouth and then back up to the nose. Who has not experienced the feeling of bubbles tingling in the nose brought on by drinking a carbonated beverage while simultaneously being made to laugh unexpectedly?

Taste

Taste is usually the most influential factor in people's selection of foods (52). Taste buds—so named because the arrangement of their cells is similar to the shape of a flower bud—are located primarily on the tongue but are also found on the mouth palates and in the pharynx. These taste detectors are not found on the flat, central surface of the tongue, but rather on the tongue's underside, sides, and tip.

Mechanism of Taste

What is actually being tasted? Many tasted substances are a combination of nonvolatile and volatile compounds. In order for a substance to be tasted, it must be dissolved in liquid or saliva, which is 99.5% water. In the middle of each taste bud is a pore, similar to a little pool, where saliva collects.

When food comes into the mouth, bits of it are dissolved in the saliva pools and they come into contact with the cilia, small hair-like projections from the gustatory cells. The **gustatory** cells relay a message to the brain via one of the cranial nerves (facial, vagus, and glossopharyngeal). The brain, in turn, translates the nervous electrical impulses into a sensation that people recognize as "taste." As people age, the original 9,000 to 10,000 taste buds begin to diminish in number, so people over age 45 often find themselves using more salt, spices, and sugar in their food. Genetics also plays an important role in taste; for example, some people can detect monosodium glutamate (MSG) in foods because it contains glutamate. Another important factor influencing the ability of a person to taste is the degree to which a compound can dissolve (56). The more moisture or liquid is present, the more the molecules triggering flavor can dissolve and spread over the tongue to contact the taste buds (29).

The Six Taste Stimuli

The common concept of a "tongue map," in which different areas on the tongue are associated with the basic types of tastes—sweet, sour, bitter, and salty—has been largely discredited (12). Nonetheless, the four basic tastes, along with a fifth known as savory (*umami,* a Japanese word meaning "delicious"), and now a sixth taste for fat (**oleogustus** a Latin word meaning "taste for fat"), have been proposed (52). All are perceived in response to certain chemical stimuli. The time it takes to detect taste stimuli varies from a split second for salt to a full second for bitter substances (11). Bitter tastes, therefore, have a tendency to linger. The chemical basis of these five categories of taste is as follows:

- **Sweet.** The sweetness of sugar comes from the chemical configuration of its molecule. A long list of substances yield the sweet taste, including sugars, glycols, alcohols, and aldehydes. Little is known, however, about the sweet taste receptor and how "sweetness" actually occurs (29).
- **Sour.** Food acids deliver the sour taste found in food. It is related to the concentration of hydrogen ions (H^+), which are found in the natural acids of fruits, vinegar, and certain vegetables. The perceived unpleasantness of too much sour food may protect against disrupting the body's acid-base balance (12).
- **Bitter.** Bitterness is imparted by compounds such as caffeine (tea, coffee), theobromine (chocolate), and phenolic compounds (grapefruit). Many other substances yield bitter tastes, including the alkaloids often found in poisonous plants (6). Thus, the ability to taste bitterness can warn us against ingesting some toxins.
- **Salty.** Salty taste comes from ionized salts—for example, from the sodium ions (Na^+) in sodium chloride (NaCl) or other salts found naturally in some foods.
- **Umami (savory).** This taste was first identified in 1908 by researchers at Tokyo Imperial University. *Umami* is attributed to glutamate, an amino acid that imparts the taste of beef broth but without the salt (46).
- **Oleogustus.** This wordy mouthful is Latin for "taste for fat." It's new. Purdue University researchers recently identified and added oleogustus as the sixth taste. They demonstrated that medium- and long-chain esterified fatty acids produce a unique taste sensation separate from the basic tastes already identified above (52).



Stockbyte/Jupiter Images

Gustatory Relating to the sense of taste.

Oleogustus A proposed sixth taste for the unique flavor of fat, from the Latin for "taste for fat."

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Taste Interactions

Each item used in food preparation contains several compounds, and bringing these items together creates new tastes when all their compounds interact.

Factors Affecting Taste

Not everyone perceives the taste of apple pie the same way. There is considerable genetic variation among individuals in sensitivity to basic tastes (52). Tasting abilities may also vary within the individual, depending on a number of outside influences. One such factor affecting taste is the temperature of a food or beverage. Taste buds operate best at temperatures of around 86°F (30°C). As the temperature of foods or beverages goes below 68°F (20°C) or above 86°F (30°C), it becomes harder to distinguish their tastes accurately. For example, very hot coffee tastes less bitter, whereas slightly melted ice cream tastes sweeter. Other factors influencing taste include the color of the food; the time of day it is eaten; and the age, sex, and degree of hunger of the taster (30). Psychological factors, such as preconceived ideas based on appearance or on previous experiences with a similar food, also affect a person's perception of taste. For instance, cherry-flavored foods are expected to be red, but if they are colored yellow, they become difficult to identify as cherry. In addition, unpleasant experiences associated with a food may influence the perceived taste of that food in the future.

Variety in available food choices also affects taste. This can be seen when the "taste," or appetite, for a food eaten day after day starts to diminish. Even favorite foods can eventually lose their appeal when consumed daily. Some weight-reducing fad diets that severely restrict choices are based on the idea that people will get tired of eating just one type of food and therefore eat less. A routine of grapefruit for breakfast, grapefruit for lunch, and grapefruit for dinner quickly becomes boring and unappetizing.

Definition of Flavor

It's important to know that taste is not the same thing as **flavor.** Taste depends solely on the taste buds' connection to the brain via nerve cells to signal the sensations of sour, salt, sweet, bitter, umami (savory), and oleogustus (fat). Flavor is a broader concept that encompasses taste, odor, and mouthfeel. The perception of odor is triggered by volatile compounds reaching the nose and provides about 75 to 95% of the impression of flavor (79). Thus, a food without aroma has very little flavor. To get some idea of how the ability to smell affects flavor perception, think of having a cold with a badly stuffed-up nose. Everything tastes different. The nasal congestion interferes with the function of the olfactory sense, impairing the ability to detect the aromas contributing to the perception of flavor. Some people apply this principle to their advantage by pinching their nostrils shut to lessen the bad flavor of a disagreeable medicine they must swallow.

Whether in a package or on a plate, a commercial food's flavor is the single most important factor determining marketplace success (52).

Flavor The combined sense of taste, odor, and mouthfeel.

How & Why?

Why does a dash of salt make some foods sweeter?

Taste sensitivity depends on a number of factors, including (1) the amount of time allowed to taste a substance, (2) the concentration of the substance generating the taste, and (3) the individual's ability to detect various tastes. The threshold concentration is the minimum concentration required to detect a substance. This is not easy to determine because people more sensitive to a particular taste than others can detect it at a lower concentration. Below the threshold concentration are subthreshold concentrations that are not detected but may influence the person's ability to perceive other tastes. For example, subthreshold salt levels increase perceived sweetness while decreasing perceived acidity, even though the actual amount of sugar or acid in the food is unchanged. Conversely, subthreshold sugar or acid concentrations make a food taste less or more salty, respectively. This principle can be applied to foods when too much salt is added to soups or stews. Even though the salt cannot be removed, adding a small amount of sugar will make the dish taste less salty (60). Trace additions of sugar also make acids taste less sour and coffee or tea less bitter. Small amounts of salt sprinkled on grapefruit or added to fruit pies tend to decrease tartness and enhance sweetness. Some compounds, such as monosodium glutamate (MSG), often used in Chinese cooking, actually improve the taste of meat and other foods by making them sweeter (34).

How & Why?

How are food flavors preserved during storage?

Flavors, regardless of the medium in which they are dissolved, do not stay at the same intensity day after day but diminish over time. Sensory chemists and flavor technologists know that one way to keep the food products sold by manufacturers from losing their appeal is to prevent the volatile compounds responsible for flavor from deteriorating, escaping, or reacting with other substances. In devising flavor preservation strategies, they look at processing, storage, and cooking methods, all of which affect the volatile flavor compounds. One of the major functions of protective packaging is to retain a food's flavor. Packaging guards flavor in several ways. It protects against vaporization of the volatile compounds and against physical damage that could expose food to the air and result in off odors. It keeps unpleasant odors from the outside from attaching to the food. It also prevents "flavor scalping"—the migration of flavor compounds from the packaging (sealers, solvents, etc.) to the food or vice versa (44).

Touch

The sense of touch, whether it operates inside the mouth or through the fingers, conveys to us a food's texture, consistency, astringency, and temperature. These terms are important to the

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CAREER CORNER

Ben Cohen and Jerry Greenfield—Cofounders of Ben & Jerry's



Steve Liss/Time Life Pictures/Getty Images

Ben Cohen and Jerry Greenfield

It's hard to believe, but some people taste food for a living. "Taste testers" have such sensitive taste buds or olfactory detection that they are hired by food companies to taste new products being developed. Food companies need to be sure that the absolute best product is being produced for consumers. The first taste tester at Ben & Jerry's Ice Cream was the company's cofounder, Ben Cohen. He had such weak taste buds that he kept asking the flavor developers for more sugar, salt, chocolate cookies, or caramel. His challenged taste buds made Ben & Jerry's ice creams famous for their intense flavors.

Ben & Jerry's started small. Ben Cohen and Jerry Greenfield were high school friends, and Ben drove an ice cream truck selling ice cream pops to kids. He went to college, dropped out, and returned to his ice cream job. Ben also taught crafts in a residential school for emotionally disturbed children, where he began experimenting with making ice cream as a craft activity for the students. This led to him selling ice cream with Jerry, whose application to medical school had been rejected twice. Their first store was "Ben & Jerry's Homemade Ice Cream Parlor" in a renovated gas station in Vermont. The rest is ice cream history (www.benjerry.com).

food industry, which constantly evaluates its food products for these qualities using surveys or other measuring instruments.

Texture is critical for consumer acceptance and is based on a combination of perceptions, with the eyes giving the first clue. The second comes at the touch of fingers and eating utensils, and the third is mouthfeel, as detected by the teeth and the tactile nerve cells in the mouth. Textural or structural qualities are especially obvious in foods such as apples, popcorn, liver, crackers, potato chips, tapioca pudding, cereals, and celery, to name just a few. Textures can be described as coarse (grainy, sandy, mealy), crisp, fine, dry, moist, greasy, smooth (creamy, velvety), lumpy, rough, sticky, solid, porous, bubbly, or flat. Tenderness, which is somewhat dependent on texture, is judged by how easily the food gives way to the pressure of the teeth.

Consistency is only slightly different from tenderness; it is expressed in terms of brittleness, chewiness, viscosity, thickness, thinness, and elasticity (rubbery, gummy).

Astringency, which causes puckering of the mouth, is possibly due to the drawing out of proteins naturally found in the mouth's saliva and mucous membranes (11). Foods such as cranberries, lemon juice, and vinegar have astringent qualities.

Another term used in the sensory perception of foods is **chemesthesis.** Chemesthesis defines how certain foods that are not physically hot or cold appear to give the impression of being "hot" (hot salsa) or "cooling" (cucumbers) when placed on the tongue (32). Although extremely hot temperatures can literally burn the taste buds (they later regenerate), the other kind of "heat" experienced with food results from eating "hot" peppers (Chemist's Corner 1-1). Capsaicin (cap-SAY-iss-in) is the chemical responsible for the "heat" that many people enjoy in moderation, as well as the real pain experienced when an excess irritates nerves in the nose and mouth. In fact, this compound is so caustic when concentrated

How & Why?

Why do flavors differ in how quickly they are detected or how long they last?

The amount of fat in a food or beverage determines how intense the flavor is over time. Flavor compounds dissolved in fat (fat-soluble compounds) take longer to be detected and last longer than flavor compounds dissolved in water (water-soluble compounds), which are quickly detected but also disappear much more quickly (17). This explains why a reduced-fat product is unlikely to duplicate the flavor of the original food: the original fat's flavor compounds are missing, causing an imbalance of the other flavors present. Reduced-fat cookies, for example, taste sweeter unless they are modified to compensate for this difference (44). It is even more difficult to replace certain fats that have their own distinctive flavor, such as butter, olive oil, and bacon fat.

CHEMIST'S CORNER 1-1

Hot Peppers and Body Chemistry

The warming sensation experienced by some people eating hot peppers (or foods made with them) is due to the body's secreting catecholamines, a group of amines composed of epinephrine (adrenaline), norepinephrine (noradrenaline), and dopamine. These catecholamines activate the "fight-or-flight" response, which normally triggers an increased respiration rate, a faster heartbeat, slowed digestion, widened pupils, and enhanced energy metabolism (67).

Consistency A food's firmness or thickness.

Astringency A sensory phenomenon characterized by a dry, puckery feeling in the mouth.

Chemesthesis The ability to feel a food's chemical properties (e.g., cool mints or hot chili peppers).

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that it is used by many law enforcement agencies in place of mace-like sprays.

Hearing

The sounds associated with foods can play a role in evaluating their quality. How often have you seen someone tapping a melon to determine its ripeness? Sounds such as sizzling, crunching, popping, bubbling, swirling, pouring, squeaking, dripping, exploding (think of an egg yolk in a microwave), and crackling can communicate a great deal about a food while it is being prepared, poured, or chewed. Most of these sounds are affected by water content, and their characteristics thus give clues to a food's freshness and/or doneness.

NUTRITIONAL CRITERIA

Over the past several decades, emerging scientific evidence about health and nutrition has resulted in changing food consumption patterns in the United States (64). Past surveys reveal that at least half of all consumers were reportedly making a major change in their diets, with nutrition being second only to taste in importance to shoppers (83). Currently, about 71% of Americans say they are trying to limit the intake of some type of fats, and 66% of Americans say they are trying to limit their consumption of saturated fats and/or trans fatty acids. More than half of Americans are trying to limit their consumption of sugars (40). Attempts to improve food habits are related to the increased awareness that a poor diet can be related to some of the leading causes of death—heart disease, cancer, and diabetes—as well as to other common health conditions such as osteoporosis, diverticulosis, and obesity (33).

Calorie The amount of energy required to raise 1 gram of water 1°C (measured between 14.5°C and 15.5°C at normal atmospheric pressure). A *kilocalorie* (kcalorie, kcal), the unit commonly used to measure food energy, is equal to 1,000 calories.

Weight Management

Obesity has reached epidemic proportions in the United States (33). As a risk factor for heart disease, cancer, type 2 diabetes, and other health conditions, obesity is one of the biggest and costliest health problems in the nation. Health-care costs are higher for people who are obese as compared to people of normal weight; it is estimated that the direct medical cost of overweight and obesity is 5 to 10% of all health-care spending (81). In addition, billions are spent annually by millions of North Americans seeking "quick fix" weight-loss solutions, most of which achieve no permanent results. According to an International Food Information Council survey, most Americans (69%) are trying to reduce or maintain their weight (41). They consider this a strong factor influencing their decision to make dietary changes and remain physically active.

Generally, individuals must restrict their intake of food energy and increase their expenditure of energy (e.g., through bodily movement) in order to lose weight. Energy can be correlated to heat and is measured in units called **calories** (or joules or Btu; see Chemist's Corner 1-2). Food energy is measured in kilocalories (abbreviated kcalories or kcal). The "Measuring Heat Energy" section in Chapter 3 provides further details. Because a calorie is a unit of measure, not a component of foods (or of the body), it is more accurate to speak of energy rather than calories, unless a specific amount is being discussed. The "Calorie Control" features found in many chapters of this book explain the basics of weight management and provide practical guidelines for making lower-kcalorie food choices to reduce energy intake.

CHEMIST'S CORNER 1-2

Other Units of Measurement for Energy

The metric equivalent of the calorie is the joule (J) or kilojoule (kJ). One joule is defined as the work or energy required to move 1 kilogram of mass 1 meter. One calorie is equivalent to 4.184 joules, whereas 1 kilocalorie equals 4.2 kilojoules. Another measure of heat is the British thermal unit (Btu), which is the amount of energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit. The Btu is more commonly used to measure the heating capacity of fuels used in various industries (heating, power, steam, and air conditioning).

Dietary Guidelines for Americans

In an effort to reduce dietary risk factors for some of the major health conditions affecting Americans, the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (DHHS) have published the *Dietary Guidelines for Americans* every 5 years since 1980 (86). The 2015–2020 *Dietary Guidelines* for healthy adults published in January 2016 represents the federal government's evidence-based nutritional guidance to promote health, reduce the risk of chronic diseases, and reduce the prevalence of overweight and obesity through improved nutrition and physical activity. They also serve to guide federal food programs and nutrition education programs (84). They encourage people to follow the recommendations available at http://health.gov/dietaryguidelines/2015/guidelines/executive-summary. In general, a healthy diet emphasizes the following:

- Following a healthy eating pattern across the life span
- Focusing on a variety of nutrient-dense foods in an amount to meet nutrient needs within calorie limits
- Limiting calories from added sugars and saturated fats while reducing sodium intake
- Shifting to healthier food and beverage choices
- Supporting healthy eating patterns for all

Everyone has a role in helping to create and support healthy eating patterns in multiple settings nationwide.

ChooseMyPlate

MyPlate is a pictorial illustration of the concepts of the 2010 *Dietary Guidelines*. It shows people what to put on

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CALORIE CONTROL
Calorie Balance

One out of every three people in the United States was classified as "obese" in 2014 according to the Centers for Disease Control and Prevention (CDC) (9). A website link at the end of this chapter allows each person to calculate his or her body mass index (BMI). This number is a ratio based on a person's weight to height that classifies him or her as underweight, normal weight, overweight, or obese.

The CDC is concerned about obesity because of the health consequences, high health-care costs, increased absenteeism, and work-related injuries (43). Although many other factors such as environment, genetics, disease, and drugs may contribute to obesity, this book focuses on the primary cause of obesity—too many kcalories (Figure 1-3).

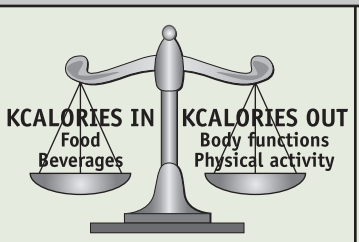
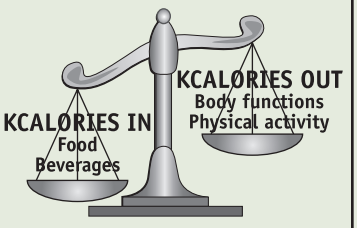
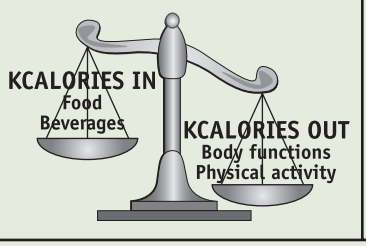
The purpose of the "Calorie Control" sections in this book is to address the obesity epidemic by providing readers with kcalories found in foods and healthful ways to modify their diets. Specific topics to be included are (1) average daily caloric intakes by Americans (see below), (2) kcalorie sources (see Chapter 3, "Chemistry of Food Composition"), (3) the average number of kcalories found in foods (see individual chapters), (4) suggestions for practicing portion control (see Chapter 5, "Food Preparation Basics" and various individual chapters), and (5) healthful preparation methods (various chapters).

How Many Kilocalories Do People Consume Each Day?
The Dietary Reference Intakes (DRI) for kcalories (2,403 per day for women and 3,067 for men) exceed those reported by the National Health and Nutrition Examination Survey (2009–2010), which measures the actual kcaloric intakes (1,778 for women and 2,512 for men over 20 years of age) of a population in which one-fourth are obese (9). Although it's best for people to determine their specific caloric and nutrient needs by seeing a registered dietitian (RD) or using the USDA's SuperTracker (www.choosemyplate.gov/SuperTracker/CreateProfile.aspx), the intakes below serve as general guidelines for healthy adults who want to "reach" and "maintain" a healthy goal weight:

Women	Approximately 1,600 kcalories for each day
Men	Approximately 2,400–2,600 kcalories for each day

This estimate includes exercising three times a week for at least 20 minutes each session. A person will need more kcalories if he or she exercises more than three times a week—approximately 300 to 600 kcalories for each hour of aerobic exercise. The exceptions are active (athletes) and larger people, who need more calories; sedate and shorter people, who need fewer calories; and older people, who need fewer kcalories (after 40, people need 100 fewer kcalories for each 10 years of age) (86).

FIGURE 1-3 Caloric balance is like a scale. To remain in balance and maintain your body weight, the kcalories consumed (from foods) must be balanced by the kcalories used (in normal body functions, daily activities, and exercise).

If you are:		Your caloric balance is:
Maintaining Weight		• "IN BALANCE" • You are eating roughly the same number of kcalories that your body is using. • Your weight will remain stable.
Gaining Weight		• "IN KCALORIC EXCESS" • You are eating more kcalories than your body is using. • You will store these extra kcalories as fat and you'll gain weight.
Losing Weight		• "IN KCALORIE DEFICIT" • You are eating fewer kcalories than you are using. • Your body is pulling from its fat storage cells for energy, so your weight is decreasing.

(*Continued*)

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How Many Kilocalories for Each Meal?
Because it's challenging to count total daily kcalories, the easier method is to break it down for each "meal." For example, a woman requiring 1,600 kcalories (kcal) a day could divide this into three 400-kcalorie meals plus one 400-kcalorie snack (or two 200-kcalorie snacks). The snacks are best eaten midmorning and midafternoon but can be taken in any combination of kcalories during any part of the day and even as part of a meal. A man requiring 2,400 kcalories a day could divide this into three 600-kcalorie meals plus one 600-kcalorie snack (or two 300-kcalorie snacks).

Starving Is a Bad Idea
About two-thirds of a person's kcalories are used to sustain life: heart beating, lungs breathing, body temperature at 97.6°F (36.4°C), and other bodily functions. Most of the remaining 30% of kcalories are burned by activity.

The bottom line is that based on gender, a person should not consume less than the following amount of daily kcalories:

Women	1,200 kcalories (about 70% of 1,600)
Men	1,600 kcalories (about 70% of 2,400)

How to Gain or Lose Weight
The recommended method of gaining or losing weight is to either increase or decrease caloric intake, respectively, by at least 500 kcalories a day. This should result in a weekly 1-pound weight gain or loss, respectively.

How Many Kilocalories Equal a Pound?
3,500 kcalories = 1 pound

To lose 1 pound = Consume 3,500 kcalories less and/or burn it off with exercise

To gain 1 pound = Consume 3,500 kcalories over what your body burns

Combination of Diet and Exercise
If a person can achieve a deficit of 500 kcalories per day through diet and/or exercise, he or she will lose approximately 1 pound a week.

Successful Weight Loss Is Usually Slow
Consistency is the goal. The slower you lose the weight, the more likely it will stay off.

1 pound a week for 1 month = 4 weeks = 4 pounds

1 pound a week for 1 year = 52 weeks = 52 pounds

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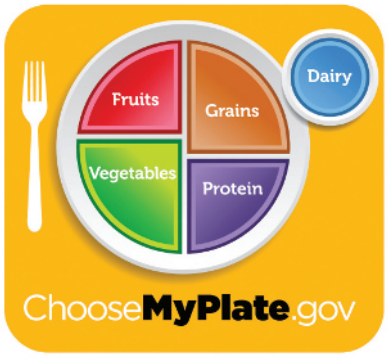
their plate by dividing it into four sections—vegetables, fruits, grains, and protein foods (Figure 1-4) (85). The www.choosemyplate.gov website provides interactive tools to assist people in creating a personalized **food group plan** based on the *Dietary Guidelines* and taking small steps toward making better daily food and lifestyle choices. One such step could be to shift from beverages with added sugars to no-sugar added drinks, especially because almost half of all sugar is consumed from sugar-sweetened soft drinks, fruit drinks, coffee, tea, energy drinks, and flavored water (75).

SuperTracker

The SuperTracker is an online diet and physical activity tracking tool available at www.supertracker.usda.gov. Here, consumers can look up individual foods to see or compare their nutritional values, find recommendations for what and how much to eat, and compare food choices to these recommendations and their personal nutrient needs (70). The USDA's Food Composition Databases, from where most nutrient analysis software is derived, lists the nutrient ingredients of many foods and can be found at https://ndb.nal.usda.gov/ndb.

Food group plan A diet-planning tool that groups foods together based on nutrient and/or kcalorie content and then specifies the amount of each group a person should consume based on their recommended kcalorie intake.

FIGURE 1-4 MyPlate: A pictorial demonstration of the 2010 *Dietary Guidelines*.



Source: U.S. Department of Agriculture.

Previous Food Group Plans

MyPlate is a successor to several previous food plans, including MyPyramid (released in 2005) and the Food Guide Pyramid (1992), all developed to encourage Americans to improve their diets. One of the first food group plans was the basic four food groups of milk, meat, vegetable/fruit, and bread/cereal (28). Other countries have their own versions of dietary guidelines; Canada's version is available online (see websites at the end of chapter).

Vegetarianism

About 3 to 4% of the U.S. population does not consume meat, poultry, or seafood, and approximately 1% of adults are vegan (25), compared to approximately 15% of college students who define themselves as vegetarians. The Academy of Nutrition and Dietetics has suggested that properly planned vegetarian diets may reduce the risk of certain chronic, degenerative diseases and conditions, including heart disease, some cancers, diabetes mellitus, obesity, and high blood pressure (38). Other factors, however, may contribute to the decreased morbidity and mortality from these diseases among vegetarians. These include positive lifestyle differences such as lower rates of smoking and drinking. Nevertheless, the benefits of vegetarian diet probably come from lower intakes of fat, saturated fat, cholesterol, and animal

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protein, balanced by higher levels of phytochemicals, fiber, complex carbohydrates, **antioxidants** such as vitamins C and E, carotenoids, and folate (a B vitamin) (53). The World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) cancer-prevention strategies state that one's risk of cancer can be reduced by maintaining a healthy weight throughout life, consuming a diet high in plant-based foods, limiting intakes of red meat, avoiding salty foods and processed meat, and consuming alcohol in modest amounts, if at all (42).

Consumer Dietary Changes

As a result of these dietary guidelines and other influences, consumers have shifted their dietary concerns and intakes, and more people are reading the Nutrition Facts on food labels to understand what they are consuming (Chapter 29). Throughout the 1990s, consumers reported that their biggest nutritional concern was fat (76). Today, Americans are ingesting less milk and more poultry, fish, fresh vegetables, and grains. As a result, fat consumption has dropped from 42% of kcalories in the mid-1960s to less than 33% today (10). Despite some positive dietary trends, progress remains to be made by Americans in order to meet the *Dietary Guidelines for Americans,* as shown in Figure 1-5.

Kcalories on Menus

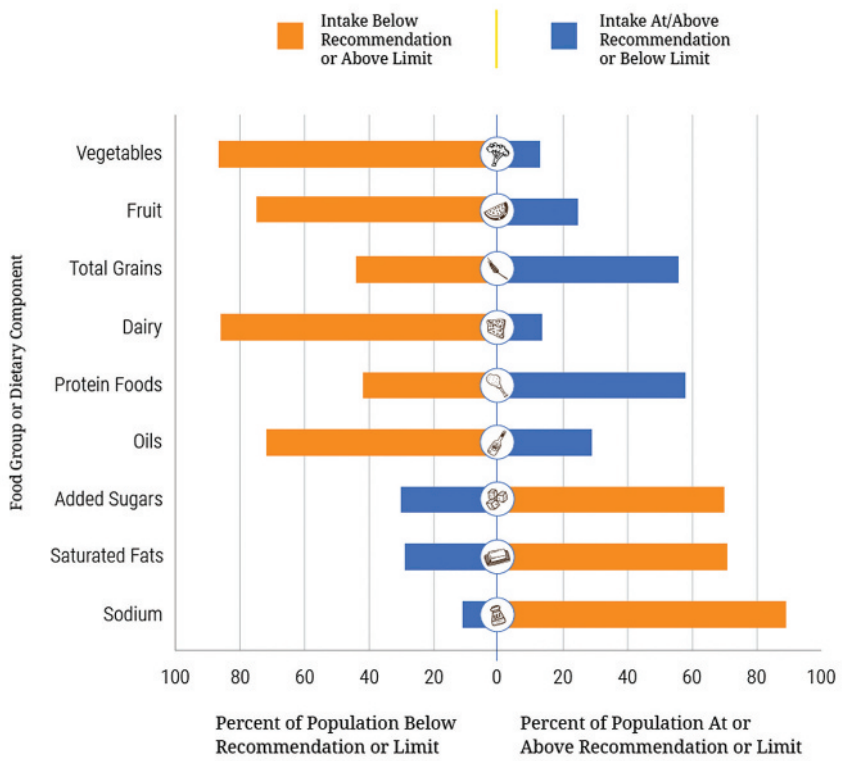
The latest assistance with diet comes from the FDA's requirement to list kcalories on menu items in restaurants with 20 or more locations (61).

Complementary and Integrative Medicine

Another influence on consumer dietary changes is complementary and integrative medicine (CIM), or complementary and alternative medicine (CAM), which is making permanent inroads in the U.S. medical landscape. Terms such as **nutraceuticals** and **functional foods** (described more fully following this section) are becoming commonplace. In the United States, *nutraceuticals* is used to refer to dietary supplements (includes herbs), while the official definition in Canada is "a product isolated or purified from foods, and generally sold in medicinal forms not usually associated with food and demonstrated to have a physiological benefit or provide protection against chronic disease" (35). About 50% of Americans take a multivitamin supplement, while about 30% have used herb products (3). The use of herbal medicinal products and supplements has increased tremendously over the past three decades with not less than 80% of people worldwide relying on them for some part of primary health care (19).

Europe and Japan lead the way in complementary medicine. In Germany, the E Commission was created in 1978 to ensure product standardization and safe use of herbs and phytomedicines. Composed of a body of experts from the medical and pharmacology professions, the pharmaceutical industry, and laypersons, the E Commission studies the scientific literature for research data on herbs based on clinical trials, field studies, and case studies. It has created a collection of **monographs** representing the most accurate information available in the world on the safety and efficacy (power to produce effects or "does it work?") of herbal products. Germany

FIGURE 1-5 What Americans eat versus what the 2010 *Dietary Guidelines* recommends they should eat.



*SoFAS = solid fats and added sugars.

Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2010.* 7th ed. U.S. Government Printing Office, Washington, DC: December 2010.

Antioxidant A compound that inhibits oxidation, which can cause deterioration and rancidity.

Nutraceutical A bioactive compound (nutrient or nonnutrient) that has health benefits.

Functional food A food or beverage that imparts physiological benefits that enhance overall health, prevents or treats a disease or condition, and/or improves physical/mental performance.

Monograph A summary sheet (fact sheet) describing a substance in terms of name (common and scientific), chemical constituents, functional uses (medical and common), dosage, side effects, drug interactions, and references.

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defines herbal remedies in the same manner as it does drugs because its physicians, and others in Europe, often prescribe herbal remedies that are paid for by government health insurance.

Functional Foods

Overall, more and more people are viewing foods as an integral part of maintaining their health (41). The "food is medicine" concept is common to many cultures, and the shift from treating an established disease to possibly delaying or even preventing it is slowly gaining ground globally. The functional food concept first developed in Japan in the late 1980s. In Japan, Foods for Specified Health Use (FOSHU) are functional foods produced, selected, or consumed for reasons beyond basic caloric and nutrient content. Purported uses for which functional foods have been manufactured include cancer risk reduction, heart health (blood pressure and blood cholesterol levels), and maintenance of gastrointestinal health (1). Both Japan and Europe appear to surpass the United States in their interest in how foods can benefit health beyond providing carbohydrates, protein, fat, and vitamins/minerals. In fact, Japan is the only country that recognizes functional foods as a distinct category, and its functional food market is the most advanced in the world (90). However, both Canada and the European Commission have working definitions for functional foods (14).

The United States has no official definition for "functional foods," and they are not recognized as a regulatory category by the FDA. The largest organization of food and nutritional professionals in the United States, the Academy of Nutrition and Dietetics (AND; formerly the American Dietetic Association, or ADA), classifies all foods as functional because they provide nutrients or other substances that furnish energy, sustain growth, and/or maintain and repair the body. However, functional foods move beyond basic survival needs. They provide additional health benefits that may reduce disease risk and/or promote optimal health. Specifically, the AND defines functional foods as including conventional foods, modified foods (fortified, enriched, or enhanced), and food ingredients that are synthesized (Table 1-1) (14). These functional food categories—published in a 2013 AND Position Paper—include the following:

1. ***Conventional Foods.*** These foods containing natural bioactive food compounds include most vegetables, fruits, grains, dairy, fish, and meats. They contain bioactive food compounds that provide benefits beyond basic nutrition. Examples are the antioxidant vitamins in orange juice, isoflavones in soy-based foods, and prebiotics and probiotics in yogurt. A few of the many examples of health benefits linked to conventional foods by emerging evidence include the following:

Cancer Risk Reduction
- Cruciferous vegetables reduce the risk of several types of cancers (82).
- Tomato products rich in lycopene may reduce the risk of prostate, ovarian, gastric, and pancreatic cancers (45).
- Citrus fruit may reduce the risk of stomach cancer (2).

Heart Health
- Dark chocolate reduces high blood pressure (51).
- Tree nuts and peanuts reduce the risk of sudden cardiac death (51).

Intestinal Health Maintenance
- Fermented dairy products (probiotics) may reduce irritable bowel syndrome symptoms (71).

Urinary Tract Function
- Cranberry juice reduces bacterial concentrations in the urine (57).

Some other health conditions affected by conventional foods include

TABLE 1-1 Functional Food* Categories and Selected Food Examples

Functional Food Category	Selected Functional Food Examples
Conventional foods (whole foods)	Garlic
	Nuts
Modified foods	
Fortified	Calcium-fortified orange juice
	Iodized salt
Enriched	Folate-enriched breads
Enhanced	Enhanced energy bars, snacks, yogurts, teas, bottled water, and other functional foods formulated with bioactive components such as lutein, fish oils, ginkgo biloba, St. John's wort, saw palmetto, and/or assorted amino acids
Synthesized foods	Oligosaccharides
	Resistant starch

*As defined by the Academy of Nutrition and Dietetics (AND).

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osteoporosis, diabetes, arthritis, brain health (mood, memory, depression, insomnia, stress, anxiety, and alertness), weight (appetite, weight loss or gain), eyesight, and enhanced energy and sports performance (55).

2. ***Modified Foods.*** Functional foods can also include those that have been modified through fortification, enrichment, or enhancement. These include calcium-fortified orange juice (for bone health), folate-enriched breads (for proper fetal development), and foods enhanced with bioactive components, such as margarines containing plant stanol or sterol esters (for lowering cholesterol), and beverages enhanced with "energy-promoting" ingredients such as ginseng, guarana, or taurine.
3. ***Synthesized Foods.*** Food ingredients that are synthesized, such as indigestible carbohydrates, provide prebiotic benefits such as oligosaccharides or resistant starch.

Although functional foods are emerging as one of the latest trends in food and nutrition, this concept is not entirely new; about 2,500 years ago, Hippocrates said, "Let food be thy medicine, and medicine be thy food" (62).

Nutrigenomics

Someday, people might receive diet plans tailored to their genes thanks to **nutrigenomics,** which first appeared in the scientific literature in 2001 (68). Before the term was coined, nutrigenomics existed undefined within the study of metabolic disorders (inborn errors of metabolism). These genetic errors often occur because of the lack of an enzyme within a biochemical pathway resulting in a need for dietary intervention, as is the case with phenylketonuria (PKU). Nutrigenomics not only includes these diseases but all others in which less dramatic genetic differences result in different dietary needs—such as heart disease, diabetes (types 1 and 2), osteoporosis, rheumatoid arthritis, hypertension, bipolar disorder, and myriad inflammatory disorders—and any other disease or condition with a genetic link that may be improved by dietary modification (15). Nutrigenomics relies on nutritional biochemistry to explain why differences in genes cause variations in absorption, circulation, or metabolism of essential nutrients. This knowledge enables people to select certain foods for optimal health or reduced risk of chronic disease (28). Some suggest that this science, still in its infancy, may take some time to contribute to human health (63).

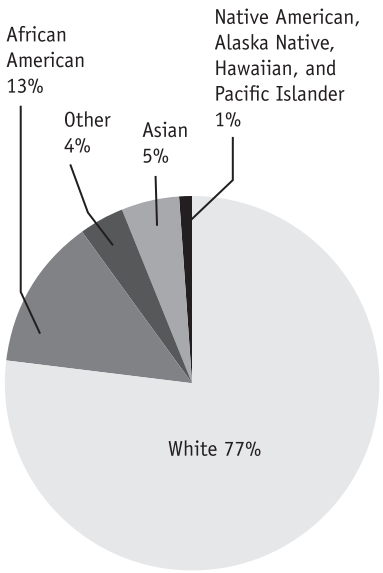
CULTURAL CRITERIA

Culture is another factor influencing food choice. Culture influences food habits by dictating what is or is not acceptable to eat. Foods that are relished in one part of the world may be spurned in another. Grubs, which are a good protein source, are acceptable to the Aborigines of Australia. Whale blubber is used in many ways in the arctic region, where the extremely cold weather makes a high-fat diet essential. Dog is considered a delicacy in some Asian countries. Escargots (snails) are a favorite in France. Sashimi (raw fish) is a Japanese tradition that has been fairly well accepted in the United States. Locusts, another source of protein, are considered choice items in the Middle East. Octopus, once thought unusual, now appears on many American menus.

Ethnic Influences

Ethnic minorities make up approximately 40% of the U.S. population of approximately 324 million people, with the five major groups being African, other (includes two or more races), Asian, Native/Alaskan Americans, and Native Hawaiian/Pacific Islanders (Figure 1-6). The U.S. Census does not classify "Hispanic" or "Latino" as a race. Rather, those taking the survey are asked whether or not they are "Spanish/Hispanic/Latino" and to select the race with which they identify. The belief is that people from this group may be of any race, but this makes the overall percentage picture a little confusing. The latest U.S. Census reported 17% of the American population being of "Hispanic or Latino" descent. An increasingly diverse population in the United States, accompanied by people traveling more and communicating over longer distances, has contributed to a more worldwide community and a food industry that continues to "go global" (72). Within the boundaries of the United States alone, many foods once considered ethnic are now commonplace: pizza, tacos, beef teriyaki, pastas, and gyros. More recently arrived ethnic foods, such as Thai, Indian, Moroccan, and Vietnamese, are constantly being added to the mix to meet the escalating demands for meals providing more variety, stronger flavors, novel visual appeal, and less fat (77).

FIGURE 1-6 Percent distribution of racial/ethnic groups in the United States. Sixteen percent of Americans report themselves to be "Spanish/Hispanic/Latino."



Source: U.S. Census Bureau.

Place of Birth

Birthplace influences the foods to which a person will be exposed and helps shape the dietary patterns that are often followed for life. Salsa varies in flavor, texture, and color depending on whether it was prepared in Mexico,

Nutrigenomics A field of study focusing on genetically determined biochemical pathways linking specific dietary substances with health and disease.

Culture The ideas, customs, skills, and art of a group of people in a given period of civilization.

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Guatemala, Puerto Rico, or Peru. Curry blends differ drastically depending on where in the world the recipe evolved. In Mexican cuisine, the same dish may taste different in different states.

Geography and Climate

Not so long ago, geography and climate were the main determinants of what foods were available. People ate foods that were grown close to where they lived and very rarely were presented with the possibility of eating those of a more exotic nature. For example, guava fruit grown in tropical regions was not even a consideration in an area such as Greenland. Now the wide distribution of formerly "local" foods throughout the world provides many people with an incredible variety of food choices.

Cultural Influences on Manners

Culture not only influences what types of foods are chosen but also the way they are consumed and the behavior surrounding their consumption. In some parts of India, for example, only the right hand is used for eating and manipulating utensils; the left hand is reserved for restroom duties. Foods may be served on banana leaves or wrapped in cornhusks. It may be eaten with chopsticks, as is the custom throughout Asia, or with spoons, forks, and knives as in Europe and the Americas. It is considered impolite in China not to provide your guest with a bountiful meal, so an unusually large number of food courses is served when guests are present.

RELIGIOUS CRITERIA

Religion is another important influence on food choices. Religious beliefs affect the diets of many by declaring which foods are acceptable and which are unacceptable and by specifying preparation procedures. By designating certain foods for specific occasions and assigning symbolic value to some, religious principles wield further influence.

More than 76% of the American population claims to be Christian, and the bread (wafers) and wine served by many denominations during communion symbolize the body and blood of Christ. A traditional holiday meal with a turkey or ham as the main entrée is usually served at Christmas and/or Easter. The eggs used at Easter symbolize new life and were originally painted red to represent Christ's blood. Early Christians exchanged these eggs to recognize each other. Another food important to Catholics is fish, which, in the past, was served on Fridays instead of meat.

Some of the food practices of Buddhists, Hindus, Seventh-Day Adventists, Mormons, Jews, and Muslims explored in further detail follow.

Buddhism

There are more than 100 million Buddhists in China and 300 million worldwide. Buddhists believe in *karuna* (compassion) and karma (a concept that implies that "good is rewarded with good; evil is rewarded with evil; and the rewarding of good and evil is only a matter of time") (39). Many Buddhists consider it uncompassionate to eat the flesh of another living creature, so vegetarianism is often followed; however, not all Buddhists are vegetarian. Whether Buddhists are vegetarian depends on their personal choice, the religious sect to which they belong, and the country where they live (20).

Hinduism

Most of the 930 million followers of Hinduism live in India, and the Hindu American Foundation estimates that there are 2 million Hindus in the United States. Like Buddhism, Hinduism also promotes vegetarianism among some, but not all, of its followers (49). Buddhism actually originated in India before being disseminated to Asia and surrounding areas. The goal of both Hinduism and Buddhism is to reach "enlightenment" or "nirvana," in which the soul transcends "individual" ego and unites with the higher state of consciousness of the cosmos (sometimes described as One, Supreme God). It is believed that souls which do not reach this state on earth are reincarnated. As a result, some Hindus believe that the soul is all-important, uniting all beings as one, so it is against their beliefs to injure or kill a person or an animal. Thus, strict Hindus reject poultry, eggs, and the flesh of any animal. The cow is not considered sacred among Hindus as is widely believed, but it is an animal, so it is not slaughtered for food. However, dairy products from cattle are acceptable and even considered spiritually pure (20). Coconut and *ghee,* or clarified butter, are also accorded sacred status but may be consumed after a fast. Some strict Hindus do not eat garlic, onions, mushrooms, turnips, lentils, or tomatoes.

Seventh-Day Adventist Church

A vegetarian diet is recommended but not required for members of the Seventh-Day Adventist Church. About 40% of its members are vegetarians, the majority of them lacto-ovo-vegetarians, meaning that they allow milk and egg products. Consumption of between-meal snacks, hot spices, alcohol, tea, and coffee is discouraged (48).

Church of Jesus Christ of Latter-Day Saints (Mormon Church)

The Church of Jesus Christ of Latter-Day Saints discourages the consumption of alcohol, coffee, and tea. Section 89:12 of the Doctrine and Covenants written in 1833 states, "Yea, flesh also of beasts and of the fowls of the air . . . they are to be used sparingly." Although not all Mormons follow these lifestyle recommendations, several studies suggest that they are healthier as a group when compared with average Americans. A significant number of Mormons live in Utah, and several studies have shown that the death rate attributed to specific diseases for Utah residents is 40% below the average U.S. rate because of lower rates of heart disease and cancer. Other factors possibly affecting the death rate are the discouragement of smoking and illegal drug use, the recommendations of regular physical activity and proper sleep, and a positive religious outlook (69). The lower saturated fat content of some vegetarian diets and the strength of Utah's health-care system also

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cannot be ignored as possible contributing factors.

Judaism

The *kashrut* (or *kashruth*) is the list of dietary laws adhered to by Orthodox Jews. **Kosher** dietary laws focus on three major issues (73):

1. Kosher animals allowed
2. Blood not allowed
3. Mixing of milk and meat not allowed

Foods are sorted into one of three groups: meat, dairy, or *pareve* (containing neither meat nor dairy). Milk and meat cannot be prepared together or consumed in the same meal. In fact, separate sets of dishes and utensils are used to prepare and serve them, and a specified amount of time (1 to 6 hours) must pass between the consumption of milk and meat. Foods considered kosher include fruits, vegetables, grain products, and, with some exceptions during Passover, tea, coffee, and dairy products from kosher animals, as long as they are not eaten simultaneously with meat or fowl (74). Kosher animals are ruminants such as cattle, sheep, and goats that have split hooves and chew their cud. Other meats that are considered kosher are chicken, turkey, goose, and certain ducks.

Orthodox Jews are not allowed to eat nonkosher foods such as carnivorous animals, birds of prey, pork (bacon, ham), fish without scales or fins (shark, eel, and shellfish such as shrimp, lobster, and crab), sturgeon, catfish, swordfish, underwater mammals, reptiles, or egg yolk containing any blood. These foods are considered unclean or *treif*. Even the meat from allowed animals is not considered kosher unless the animals have been slaughtered under the supervision of a rabbi or other authorized individual who ensures that the blood has been properly removed. Foods that are tainted with blood, a substance considered by Jews to be synonymous with life, are forbidden (20).

Kosher foods are labeled with a logo such as those of the kosher-certifying agencies shown in Figure 1-7. Manufacturing facilities are inspected by a rabbi before a kosher certification can be given for a food (8). People other than Jews who often purchase kosher foods include Muslims, Seventh-Day Adventists, vegetarians, individuals with allergies (shellfish) or food intolerances (milk), and anyone who perceives kosher foods as being of higher quality (74).

FIGURE 1-7 Examples of kosher and halal food symbols.

Kosher	Halal
Organized Kashruth Laboratories Brooklyn, NY	Islamic Services of America Cedar Rapids, IA
OU Kosher Supervision Service New York, NY	

Food figures prominently in the celebration of the major Jewish holidays. Rosh Hashanah, the Jewish New Year, is celebrated in part with a large meal. Yom Kippur, or the Day of Atonement, requires a day of fasting preceded by a bland evening meal the night before. Passover, which is an 8-day celebration marking the Exodus from Egypt, is commemorated in part by a meal whose components represent different aspects of the historic event. Because the Jews left Egypt without enough time for their bread to leaven (rise) and to commemorate this event, leavened bread is prohibited during the Passover celebration. As a result, the five prohibited grains are wheat, rye, oats, barley, and spelt. The only grain allowed during Passover is unleavened bread (matzo).

Islam

Worldwide, there are more than 1.5 billion Muslims, versus 13 million Jews (20). The Koran, the divine book of Islam, contains the **halal** dietary food laws recommended for Muslims that describe halal (permitted) or haram (prohibited) foods. The five major areas addressed by the halal are as follows (74):

1. Kosher and halal animals allowed
2. Blood not allowed
3. Improper slaughtering method not allowed
4. Carrion (decaying carcass) not allowed
5. Intoxicants not allowed

Many of the halal dietary food laws are similar to the food laws of Judaism, and like kosher foods, halal foods are identified with symbols (Figure 1-7). However, the most striking similarity is that the kosher meat consumed by Jews is permitted for Muslims because the animal has been slaughtered in a manner that allows the blood to be fully drained. Halal meat is also permitted and defined as any meat from approved animals processed according to Muslim guidelines. Most meat is allowed, except pork, carnivorous animals with fangs (lions, wolves, tigers, dogs, etc.), birds with sharp claws (falcons, eagles, owls, vultures, etc.), land animals without ears (frogs, snakes, etc.), shark, and products containing pork or gelatin made from the horns or hooves of cattle (13). Alcohol and products containing alcohol in any form, including vanillin and wine vinegar, are forbidden. Stimulants such as tea and coffee are also discouraged.

Ramadan is a time of the year that significantly affects diet for Muslims. Islam teaches that the ninth month of the lunar calendar is the month in which the Prophet Muhammad received the revelation of the Muslim scripture, the Koran. This month, which depends on the sighting of the new moon, is a time of religious observances that include fasting from dawn to sunset.

Kosher (From Hebrew) Food that is "fit, right, proper" to be eaten according to Jewish dietary laws.

Halal An Arabic word meaning "permissible." Usually refers to permissible foods under Islamic law.

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PSYCHOLOGICAL AND SOCIOLOGICAL CRITERIA

Social and psychological factors strongly influence food habits. For most people, the knowledge that food is readily available provides a sense of security. The aim of every food company's advertising is to develop a sense of security among consumers about its products. A soft drink held in the hand of an athlete, a cereal touted by a child's favorite cartoon character, and diet foods offered by slim, vivacious spokespeople create positive associations in people's minds for these products and assure them of their quality. Social conscience and peer pressure sometimes influence food choices. One recent trend has seen consumers moving toward more environmentally sound purchases. At a buffet, the presence of other people may influence a person's choice of food and beverages.

Psychological needs intertwine with social factors when foods are used more for a display of hospitality or status than for mere nourishment. Caviar is just fish eggs but is esteemed by many as a delicacy. Beer tastes terrible to most people when they try it for the first time, but the social surroundings and pressures may cause it to become an acquired taste. Several studies have shown that information influences expectations, and expectations mold choices, so it is no surprise that older consumers report that television is their predominant source of information about nutrition, followed by magazines, and newspapers (59). However, young people get most of their information from online sources (41).

Biotechnology The alteration of a gene in a bacterium, plant, or animal for the purpose of changing one or more of its characteristics; previously called *genetic engineering.*

Genetically modified organisms (GMOs) Plants, animals, or microorganisms that have had their genes altered through genetic engineering using the application of recombinant deoxyribonucleic acid (rDNA) technology.

Gene A unit of genetic information in the chromosome.

Psychological factors also influence people's response to three relatively recent additions to the food market: genetically modified, organic, and "natural" foods.

Bioengineering

Psychological and social factors are involved in the formation of public attitudes toward the **biotechnology** (i.e., genetic engineering) of foods (89). The resulting **genetically modified organisms (GMOs)** or genetically modified (GM) crops are slowly gaining ground, but not everyone is knowledgeable about or accepting of these new foods (1).

History of Biotechnology

People have been selecting for particular genetic traits in plants and animals since the beginning of agriculture. In the past, it took years to accomplish hybridization, or crossbreeding, by matching "the best to the best" in the plant, livestock, and fishery worlds to achieve the desired results. Cattle, corn, and even dogs were bred this way to yield desirable results. The many breeds of dogs would not look the way they do without humans modifying their genes through many years of selective breeding. Depending on the desired results, it could take decades or even centuries to develop a certain "look" and/or function in an animal or plant. Traditional ways of breeding to combine the genes of two species in order to obtain a specific trait were thus time-consuming, cumbersome, and unpredictable (89).

The age of food biotechnology started in the early 1970s when DNA was isolated from a bacterium, duplicated, and inserted into another bacterium. The resulting DNA, known as recombinant deoxyribonucleic acid (rDNA), allows researchers to transfer genetic material from one organism to another (Figure 1-8) (36). The direct manipulation of genetic material started with bacteria, then plants, and finally animals. Instead of crossbreeding for years, researchers can now identify the **genes** responsible for a desired trait and reorganize or insert them from the cells of one bacterium, plant, or animal into the cells of other bacteria, plants, or animals (7). The goal of this process is to produce new species or improved versions of existing ones. GM crops have only been commercially available since the mid-1990s (89).



Jeffrey Coolidge/Getty Images

GMO foods are common

Foods Created with Biotechnology

The USDA used food biotechnology to increase production potential, develop more nutritious plant and animal products, and increase crop resistance to the following food-related problems (89):

- Pests (less pesticide required)
- Disease (lower crop losses)
- Herbicides
- Harsh growing conditions (drought, salty soil, climate extremes)
- Transport damage (less bruising allows more produce to make it to market)
- Spoilage (longer shelf life)

Foods using biotechnology can be grouped into one of the following categories (7):

1. Actual food (e.g., corn)
2. Foods derived from or containing ingredients of actual food (e.g., cornmeal)
3. Foods containing single ingredients or additives from GM foods (e.g., amino acids, vitamins, colors)
4. Foods containing ingredients obtained from enzymes produced through GM foods

What actual foods have been produced using biotechnology? Some

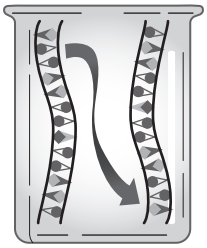
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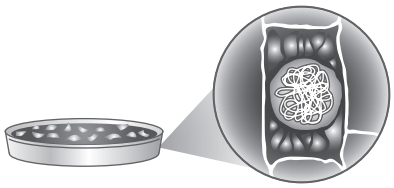
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FIGURE 1-8 Genetically engineering a tomato to soften more slowly.

1. Ripe tomatoes contain an enzyme, polygalacturonase (PG), that causes them to soften. The PG gene that forms this enzyme is isolated and cloned. Scientists reverse the PG gene sequence and place it into bacteria.



2. The bacteria are grown in a petri dish filled with cut tomato leaves. The leaves' edges absorb the bacteria and the PG gene becomes part of the tomato plant cells' genetic material.



3. Tomato plants are regenerated from leaf cuttings containing the reversed PG gene.



4. The genetically engineered tomatoes can now ripen more fully on the vine prior to harvest and be transported later with less concern about rotting due to softening.



Source: Adapted from Hoban TJ. How Japanese consumers view biotechnology. *Food Technology 96*(5): 85–88, 1996.

FIGURE 1-9 Genetically modified foods



Hurst Photo/Shutterstock.com; Valentina Razumova/Shutterstock.com; spline_x/Shutterstock.com; spline_x/Shutterstock.com; Kenishirotie/Shutterstock.com; Luis Carlos Jimenez del rio/Shutterstock.com; Viktar Malyshchyts/Shutterstock.com; Abramova Elena/Shutterstock.com; Tim UR/Shutterstock.com; Anna Sedneva/Shutterstock.com; Deep OV/Shutterstock.com; Anastasia_Panait/Shutterstock.com

examples of GM foods include ripening-delayed fruits, celery without strings, grains with a higher protein content, potatoes that absorb less fat when fried, insect-resistant apples, and more than 50 other plant products. Currently, some of the most popular GM crops among U.S. farmers are listed in Figure 1-9. More than 93% of all U.S. soybean, cotton, and sugar beets are grown from GM seeds (89).

Clones: Not GMOs

Some people may think that cloned animals or plants are genetically engineered; however, that is not the case. The Biotechnology Industry Organization describes cloning as a "breeding method that does not manipulate the animal's genetic make-up nor change an animal's DNA; it is simply another form of sophisticated assisted reproduction. Cloning allows livestock breeders to create a genetic copy of an existing animal—essentially an identical twin. Animal clones are not 'biotech' or 'genetically engineered' animals; and their offspring are considered 'conventional' animals."

Concerns about GMO Foods

Some consumers view genetic engineering as an invasion of nature's domain, and they fear that scientists are treading on dangerous ground. The vast majority of GM crops are grown in the United States, while Europe and Japan have much stricter rules. GMO labeling is voluntary in the United States but mandatory in Europe, Japan, and New Zealand (88). Increasing consumer concerns include allergies, gene contamination, effects on the environment, and religious/cultural objections.

- **Allergies.** The concern most commonly expressed to the FDA by consumers is the possibility that the proteins produced by these new genes could cause allergic reactions. In one study, soy was infused with a gene from Brazil nuts, a known allergen, or allergy-causing substance (50). Some people participating in the experiment became ill, but this was a preliminary research study, and the modified soy never reached the market (89). Researchers would be prudent to avoid food allergens in the process of genetically engineering foods because they can cause significant problems for the small percentage of the population with food allergies (31).
- **Gene Contamination.** Another concern is that genetically engineered plants might "escape" into the wild,

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take over, and change the environment. Scientists assure us, however, that such plants are no more dangerous than traditionally bred crops. The greatest fear for some is that food biotechnology will lead to genetic manipulation to try to "improve" the human race (47).

- **Pesticide Residues.** An increasing number of crops have been genetically engineered to tolerant glyphosate, an herbicide that kills weeds growing around the crops. Right before harvest, extra amounts of glyphosate are spread on the wheat to dry it out for the purposes of creating a larger harvest. Controversy exists surrounding the amounts of plant residues that end up in the food supply, and whether or not they affect human health.
- **Religious/Cultural Concerns.** Some people, for religious or cultural reasons, do not want certain animal genes appearing in plant foods. For example, if swine genes were inserted into vegetables for some purpose, those vegetables would not be considered kosher. In one instance, a group of chefs refused to use a genetically engineered tomato when they found out that its disease resistance was obtained from a mouse gene. Vegetarians may object to a fish gene being placed in a tomato to provide resistance to freezing (36). Hawaiians objected when researchers tried to modify the gene sequence of their sacred taro plant, which is commonly used to make poi (a starchy paste made from the plant's corm, its thickened underground stem).

Acceptance/Rejection of GM Foods

Despite the controversy over animal genes being inserted in plant foods, the line between "plant genes" and "animal genes" is already blurred. Bacteria, plants, and animals share a large number of the more than 100,000 genes found in higher organisms. Nevertheless, research into people's attitudes about food repeatedly reveals that consumers are more likely to accept biotechnology conducted on plants rather than on animals or fish and are also more accepting of modifications made from within a species rather than inserting a new gene from another species (37). Amid opposition from consumer and environmental groups, in November of 2015, the FDA approved the first GMO animal product for human consumption, AquaAdvantage salmon (24).

The FDA accepts genetically engineered foods as posing no risk to health or safety, and for this reason, it does not require mandatory labeling, unless the foods contain new allergens, have modified nutritional profiles, or represent a new plant. The National Academy of Sciences has stated that genetic transfers between unrelated organisms do not pose hazards or risks different from those encountered by natural selection or crossbreeding. Although some contend there is no evidence that transferring genes will convert a harmless organism into a hazardous one (18), that is not the case. Researchers have documented lectin modified potatoes affecting the gastrointestinal crypts in rats (21), and human deaths from toxic oil syndrome in 1983 (a modified rape oil with toxic effects) and transgenic trypotophan in a Japanese amino acid dietary supplement in 1989 (18). Some suggest more long-term experiments are necessary on the effects of biotechnology on human health and that the topic remains controversial (27). People who want to avoid GM crops can ensure that their foods are free of this type of genetic modification (and produced without antibiotics, hormones, or pesticides) by purchasing organic foods (88).

Organic Foods

Some people prefer to select *organic foods,* a term that had no official definition until 2002, following the Organic Foods Production Act of 1990 (88). This act created the U.S. National Organic Standards Board (NOSB), which in turn makes organic definition recommendations to the National Organic Program (located in the USDA's Agricultural Marketing Service). Terms commonly used in the marketplace that do not have official definitions or certification by the government include "free-range," except with poultry where producers must demonstrate to the Agency that the poultry has been allowed access to the outside, "hormone-free," "natural," "organically produced," "pesticide-free," "raised without antibiotics," or even "certified organic." Prior to 2002, products were often labeled "organic" by growers without any real certification, or they were certified by private agencies according to a patchwork of regulations that varied from state to state. Now, for a food to be labeled "organic," it has to fit one of the four official definitions listed by the USDA, as shown in Table 1-2. The USDA's definition of what is organic goes beyond just describing foods that are not sprayed with chemicals. The word *organic* now refers to food products that have been produced without most synthetic pesticides and fertilizers (including sewage sludge); crops that have not been genetically modified (no GMOs or bioengineering); food products not exposed to irradiation; and livestock produced without antibiotics or hormones, raised on 100% organic feed, allowed to graze on pasture at least 4 months of the year, and provided with 30% of their feed through grazing (78). Organic milk is derived from cows that have not been treated with antibiotics or hormones such as recombinant bovine somatotropin (rBST) to facilitate production (58).

One concern related to organic foods is the cost to consumers, as organics are typically more expensive than their conventionally grown counterparts. Another is that some proponents mislead the public with "scare tactics," suggesting that only organic foods and beverages are healthy or safe. A concern for organic advocates is that in 2007, the USDA allowed thirty-eight nonorganic ingredients into foods that were 95% or less organic.

Organic Certification

The government agency certifying that a food is organic is the USDA. A USDA certifier inspects the facilities where the food is grown, determines whether organic standards were met, and, if so, allows the producer to label food products with the organic seal shown in Figure 1-10. Both 100% and 95% organic products may use the USDA organic seal, while those made with less than 95% organic ingredients may not (see Table 1-2). USDA agents determine whether food is organic by following the guidelines set by the USDA's Agricultural Marketing Service (AMS), published as the National Organic Program (NOP) in the *Federal Register* (December 21, 2000). Producers selling less than $5,000 in organic products are exempt from certification, but they

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TABLE 1-2 The U.S. Government's Criteria for Defining Organic Food Products

What does the label mean? The USDA Organic seal tells you a product is at least 95% organic.

Organic Term	Definition	Labeling Allowed
100% Organic	All ingredients of the finished product are certified 100% organic.	USDA ORGANIC
Organic	95% of finished product ingredients meet organic criteria.	USDA ORGANIC
Made with Organic Ingredients	70% of finished product ingredients meet organic criteria.	"Made with Organic Ingredients"
Contains Organic Ingredients	Less than 70% of finished product ingredients meet criteria.	May only list organic ingredients on the information panel.

FIGURE 1-10 USDA's official organic seal.



USDA

must still follow the standards (78). Only food products that were organically grown or processed and certified by an accredited USDA organic–certifying agent can carry the organic seal. Violators making false claims can be fined $10,000 per offense.

"Natural" Foods

The word *natural* on a food label may or may not mean anything about how the food was produced or what it contains. This is because *natural* has no official definition in the United States except for when it is used to describe meat, poultry, and eggs overseen by the USDA. *Natural* is defined by the USDA for its products by answering two questions: (1) Does the product contain any artificial or synthetic ingredients, such as a chemical preservative? (2) Are the product and its ingredients only minimally processed? The product is natural if the answer to the first question is no, and the answer to the second question is yes (23). The lack of an official definition for *natural* for all other foods and beverages can lead to inconsistent claims and consumer confusion. In direct response to consumer requests that the FDA explore the use of the term "natural," a public comment period on the use of natural in the labeling of food products closed in May, 2016. The FDA has considered the term "natural" to mean that nothing artificial or synthetic (including all color additives regardless of source) has been included in or added to a food that would not normally be expected to be there. This policy does not address food production methods or food processing or manufacturing methods. The FDA also did not consider whether the term "natural" should describe any nutritional or other health benefit (87).

Processed Foods

Some people who select natural foods may also prefer to avoid processed foods. The term *processed* is often used to refer to highly refined packaged foods, but technically, any food changed beyond its raw state has been "processed." The International Food Information Council has divided processed foods into the following five categories (26):

- Minimally processed foods (e.g., washed and/or packaged fruits and vegetables)
- Foods processed for preservation (e.g., canned or frozen fruits and vegetables)
- Mixtures of ingredients (e.g., cake mixes, salad dressings)
- Ready-to-eat foods (e.g., breakfast cereals, lunch meats, carbonated beverages)
- Convenience foods (e.g., frozen meals and pizzas)

BUDGETARY CRITERIA

Cost is a very important limiting factor in food purchasing. In fact, the monetary values of debit cards obtained through the USDA's Supplemental Nutrition Assistance Program (SNAP) are limited by the "Thrifty Food Plan" that calculates what an average family needs to spend on food (84).

Cost helps determine the types of foods and brands that are bought and the frequency of restaurant patronage. People feeling financial strain may still eat beef, but they may choose ground beef over prime rib. "Can I afford this?" is a question that also applies to time, which can make convenience foods effectively more economical, even if the dollar price is higher. Budgeting and time management are discussed in greater detail in Chapter 6.

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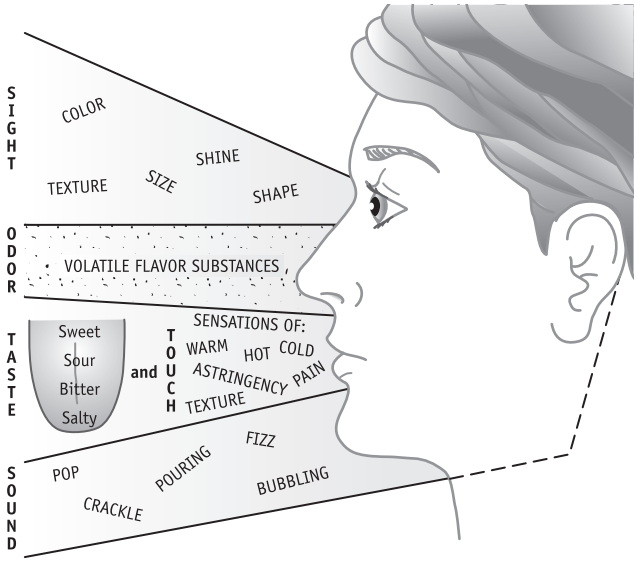
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PICTORIAL SUMMARY / 1: Food Selection

People choose foods that satisfy their senses of sight, smell, taste, touch, and hearing; their nutrient needs; cultural and religious values; psychological and social influences; and budget.

SENSORY CRITERIA

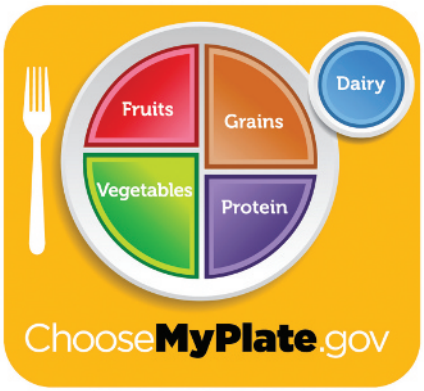
When most people choose a particular food, they evaluate it using the sensory reactions illustrated below rather than by considering its nutritional content.



NUTRITIONAL CRITERIA



Over the past several decades, emerging awareness of health and nutrition has resulted in many consumers making a major change in their diets. Guidelines that reinforce an emphasis on better health through nutrition include the U.S. Government's *Dietary Guidelines* and MyPlate food guide. Portion control starts with understanding average daily caloric intakes. Although no official U.S. regulatory definition for functional food exists, the AND defines them as conventional foods, modified foods (fortified, enriched, or enhanced), and foods ingredients that are synthesized.



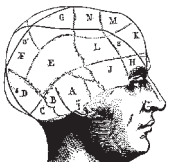
Source: U.S. Department of Agriculture.

CULTURAL AND RELIGIOUS CRITERIA



An increasingly diverse population, with greater access to travel and expanded global communication, has resulted in a huge increase in the variety of foods that are available in the United States today. Familiar taste preferences acquired in childhood as well as religious tenets affect many people's food habits throughout their lives.

PSYCHOLOGICAL AND SOCIOLOGICAL CRITERIA



Advertising, social conscience, and peer pressure can all play a part in an individual's food choices. The controversies surrounding genetically modified, organic, "natural," and processed foods are examples of how food products can be affected by these criteria.

BUDGETARY CRITERIA



Cost helps determine the types of foods and brands that are bought and the frequency of restaurant patronage. A shortage of time for food preparation or consumption can result in greater use of convenience foods and fast food, even if they are often more expensive and less nutritious.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. *Olfactory* is a word that best describes the sense of _____.
   a. taste
   b. smell
   c. touch
   d. sight

2. The definition of *flavor* best describes _____.
   a. taste
   b. taste and mouthfeel
   c. taste and odor
   d. taste, odor, and mouthfeel

3. Which religion(s) encourages a vegetarian diet?
   a. Buddhism
   b. Hinduism
   c. Seventh-Day Adventist
   d. All of the above

4. Which statement is true about genetically modified (GMO) foods?
   a. Genes are programmed by sequencing the amino acids.
   b. Food can be genetically modified to delay ripening.
   c. In the United States, all genetically modified foods must be labeled.
   d. No genetically modified foods have been approved by the FDA.

5. What is the approximate daily kcalorie intake for women and men in North America?
   a. 1,400 for women; 2,200 – 2,400 for men
   b. 1,600 for women; 2,400 – 2,600 for men
   c. 1,800 for women; 2,600 – 2,800 for men
   d. 2,000 for women; 2,800 – 3,000 for men

6. How many kcalories in excess or deficit does it take to gain or lose respectively a pound of body weight?
   a. 500
   b. 1,000
   c. 2,500
   d. 3,500

7. A produce grower can place the USDA Organic label on its product if _____ or more of the ingredients are organic.
   a. 50%
   b. 75%
   c. 85%
   d. 95%

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

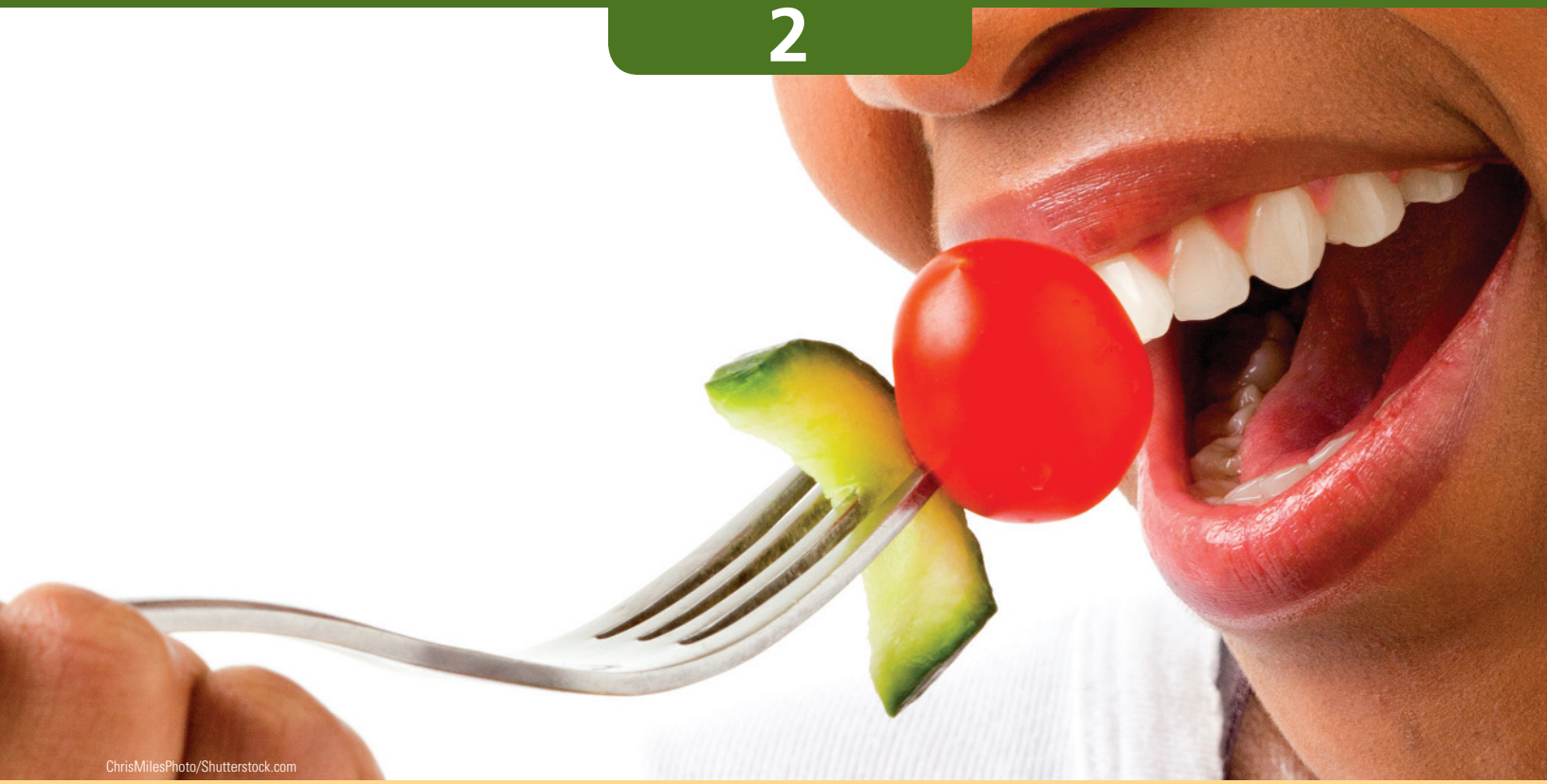
1. List the six taste stimuli and the proposed mechanism of taste for each.
2. Why is the odor of just-baked bread more intense than the odor of cold foods such as ice cream?
3. Give two examples of taste interactions.
4. How does taste differ from flavor?
5. Obesity is a rising problem. Discuss the basics of the energy balance equation.
6. How does the Academy of Nutrition and Dietetics define functional foods?
7. Discuss three examples of cultural influences on food intake.
8. Discuss the possible influences that religions such as Buddhism, Judaism, and Islam may have on food intake.
9. Describe the process of biotechnology. Discuss the pros and cons of this process.
10. Describe the four categories of organic food and the labeling allowed for each category.

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2



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Food Evaluation

Sensory (Subjective) Evaluation 20
Objective Evaluation . . . 23

The food industry uses many testing methods to measure the sensory factors used to select foods and to evaluate food quality. These tests are conducted for research and development (R&D), product improvement, sales and marketing, quality assurance, nutrient content analysis for labeling requirements (Nutrition Facts), and detection of contamination or adulteration (6). Food is evaluated using both **sensory (subjective) tests** and **objective tests** (5). This chapter reviews the specific types of tests and tools used by the food industry to evaluate the palatability of food for consumers.

Sensory (subjective) tests Evaluations of food quality based on sensory characteristics and personal preferences as perceived by the five senses.

Objective tests Evaluations of food quality that rely on numbers generated by laboratory instruments that are used to quantify the physical and chemical differences among foods.

SENSORY (SUBJECTIVE) EVALUATION

Sensory evaluation (or analysis) is the scientific discipline of measuring the responses of people to food products as perceived by their senses of sight, taste, touch, smell, and hearing (19). This type of testing is termed *subjective* because it relies on the opinions of selected individuals.

Although certain machines are designed to replicate the ability to perceive the five senses, very few succeed in matching the senses of a human being. As a result, sensory evaluation tests are often used by large food companies in their R&D departments for the purposes of evaluating potential and/or established consumer products. Human panels are required to evaluate the products through various types of established scientific sensory tests. The results are then statistically analyzed to determine consumer preference and/or acceptability.

Two Types of Sensory Testing

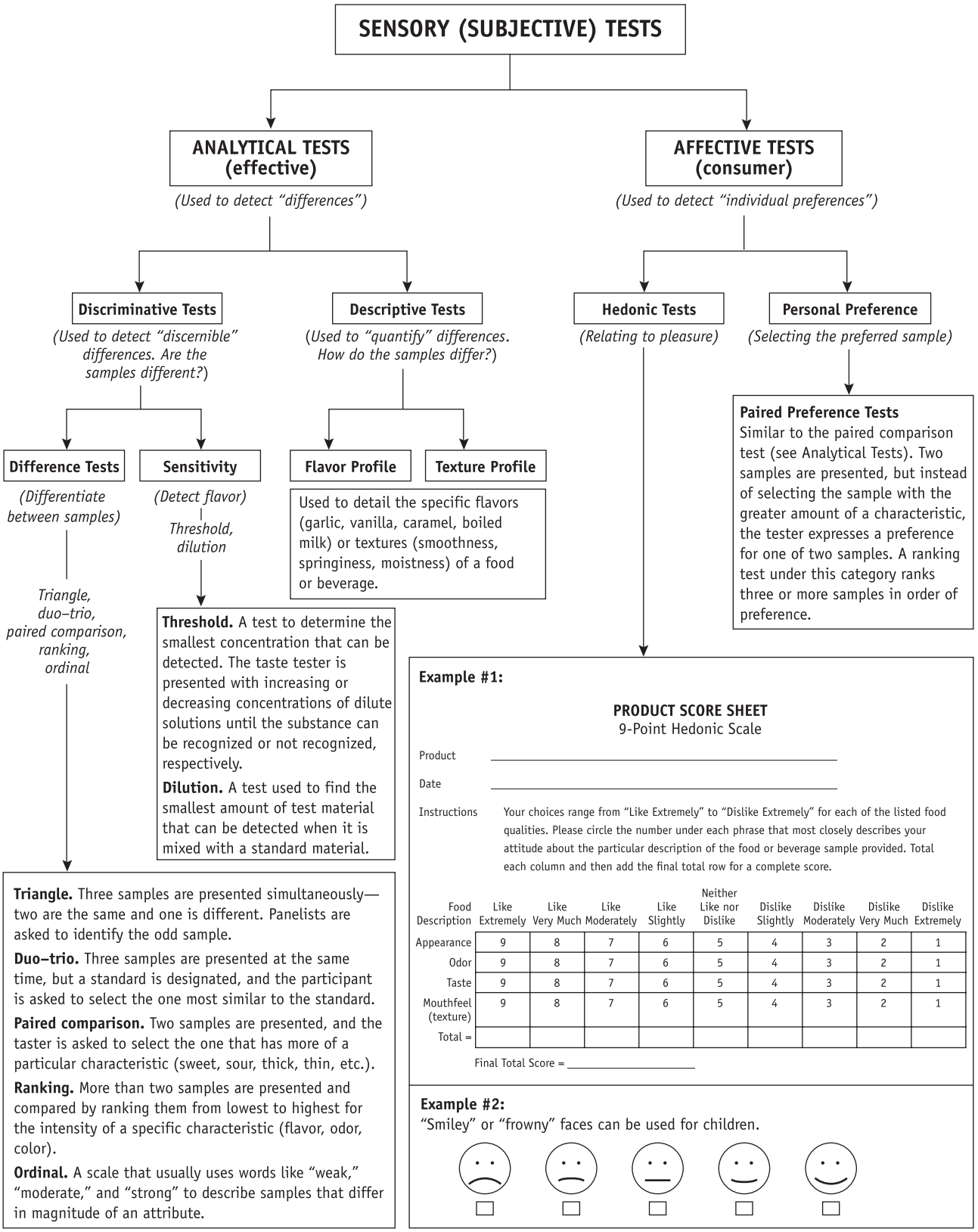
The two basic types of sensory tests are analytical (effective) and affective (also known as acceptance or preference tests) (16). Analytical tests are more objective and based on discernible differences, whereas affective tests are more subjective and based on individual preferences (Figure 2-1). Generally,

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FIGURE 2-1 Summary of subjective tests for food evaluation.



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affective testing is carried out using a large number of untrained consumers to find out whether a particular population segment prefers one product over another. Analytical tests are conducted using smaller groups of people who may or may not be trained. In both types of testing, food samples are presented to taste panel participants, who evaluate the foods according to specific standards for appearance, odor, taste, texture, and sound.

Analytical (Effective) Tests

The more objective analytical tests are usually conducted by a trained panel that evaluates food products through either discriminative (Are the samples different?) or descriptive tests (How much do the samples differ?). The most common difference tests are the triangle and duo–trio tests, in which the person compares three samples and has to determine whether a difference exists (2). Descriptive tests rely on a trained panel to document a product's sensory characteristics (10).

Affective (Acceptance or Preference) Tests

Affective or consumer testing focuses on whether or not a person prefers a certain aspect of a food. Because anyone can have an opinion, these types of tests are usually given to untrained consumers. Basically, affective test subjects are asked to state their opinion of a product or to rank samples in order of preference. The test instruments range from simple questions (Which of the two samples do you prefer?) to complex nine-point hedonic product score sheets evaluating one or more qualities of a food on a scale from "like extremely" to "dislike extremely" (Figure 2-1).

Taste Panels

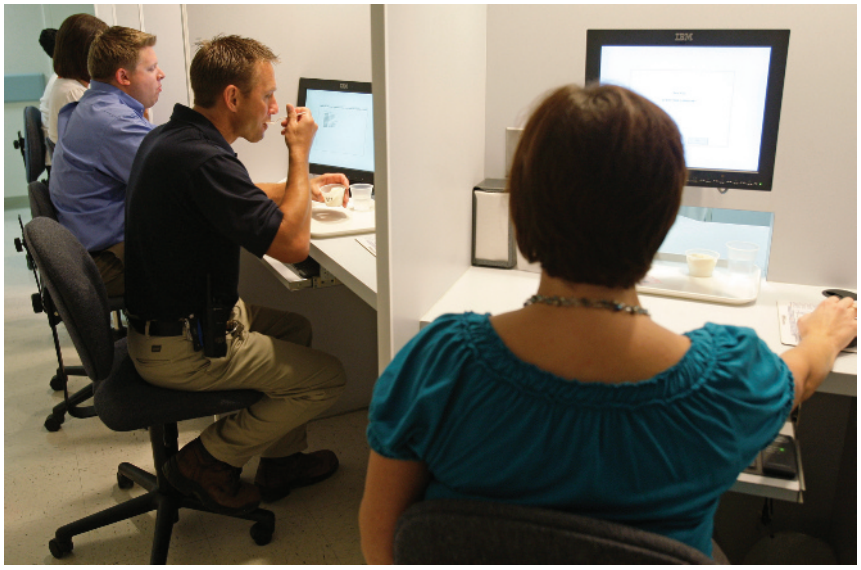
The individuals on a taste panel can range from randomly selected members of the population to experts who are highly trained in tasting a particular food or beverage (Figure2-2) (17). Vintners and brewers rely on the latter types of skilled tasters to evaluate the proper timing for each step in the process of making wine or beer (17). The ability to detect slight differences in specific foods is a sought-after trait; in fact, they are prized so much that the taste buds of one gourmet ice cream taste expert are insured for $1 million. General taste panels usually consist of at least five people who meet the following criteria: they are free of colds, chew no gum immediately before testing, have not ingested any other food for at least 30 minutes to 1 hour before testing (1), are nonsmokers, are not color-blind, and have no strong likes or dislikes for the food to be tested. Any psychosocial or cultural influences should also be considered (4). An equal distribution in gender is preferred because women can usually detect sweetness better than men can. Age distribution of the panel is also considered because it may affect test results. As far as possible, panelists are representative of the consumers who will be using the product. For example, a product marketed to people over fifty should be tested by individuals in that group, whereas a product aimed at children is tested by a much younger group.

FIGURE 2-2 Taste test panel at NASA.



NASA

FIGURE 2-3 Testers evaluating samples in private booths that minimize outside influences.



AP Images/Al Behrman

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Sample Preparation

The environment in which the taste panel evaluates foods or beverages is also carefully controlled (20). Panelists may be seated at tables, in cubicles (Figure 2-3), or in booths, and the food is presented in a uniform fashion. Food samples must be of the same size (enough for two bites), from the same portion of the food (middle vs. outside), equally fresh, at the same temperature, and presented in containers or plates that are of the same size, shape, and color. White or clear containers are usually chosen so as not to influence panelists' perceptions of the food's color. If samples differ in color, red lighting may be used to mask those differences so that color intensity will not influence the tasters' perception of flavor (17).

Care is taken that the lighting in the room is uniform, the ambient temperature is comfortable, and the surroundings are quiet and odor-free. Midmornings or midafternoons are considered the best times for sampling because, at these times, people are not usually overly hungry or full. Samples are randomly coded and are kept to a reasonable number to avoid "taste fatigue." Room-temperature water and plain bread or salt-free crackers are made available for panelists to eat between samples to prevent carryover tastes, and at least a 30-second rest period is scheduled between samples. Because swallowing the food or beverage influences the taste of subsequent samples, small containers into which samples may be spit are provided, along with paper towels or napkins.

CHEMIST'S CORNER 2-1

Viscosity

Evaluation of certain foods is based on a branch of physics called rheology, which is the study of the flow and deformation of matter (both liquids and solids). Viscosity is a key term in rheology. The nature, concentration, and temperature of a liquid all affect its viscosity, which can be defined as apparent or relative. Apparent viscosity is the time required for a substance such as ketchup to flow between two marks on the stem of a funnel. Relative viscosity compares the rate of a liquid's flow against a reference liquid (usually water). The thickness of fluids can determine, for example, how easily dip is deposited on chips, how smoothly mayonnaise spreads onto a slice of bread, or how long a tomato will hold its shape.

CHEMIST'S CORNER 2-2

Analyzing Food with Chromatography

Compounds in foods can be measured using chromatography (*chrom* means color). It was first used at the turn of the century to separate plant pigments into different colored bands on a spectrum. In chromatography, a moving phase (gas or liquid) is passed over a solid or liquid stationary phase (9). The constituents in a mixture are chemically separated when they adsorb onto the material of the stationary phase, which can be silica, glass, or alumina packed on a glass or metal tube.

Gas chromatography measures the contents of the gas produced when a food sample is injected into the unit and vaporized. Substances separate and travel down a very narrow column, where, as in a race, the smaller, quicker molecules arrive first, and the larger ones finish last. This method is used to detect pesticides, cholesterol, certain fatty acids, and additives. In liquid chromatography, a liquid is created by making a solution out of the food sample. High-performance liquid chromatography (HPLC) is used to measure carbohydrates, lipids, vitamins, acids, pigments, flavor compounds, additives, and contaminants in food samples (minerals are commonly analyzed using atomic absorption) (3). Ion chromatography relies on ions being exchanged back and forth to detect sulfate, nitrate, and organic acids in fruit juices, as well as bread additives (benzoate, bromate) and sugar in various foods. Mass spectrometry takes the molecules leaving the gas chromatograph and breaks them down into ions. The pattern of ions unique to each chemical is used to identify the substance.

OBJECTIVE EVALUATION

In objective evaluations, laboratory instruments instead of humans are used to measure the characteristics of foods quantitatively. Most objective food evaluation is based on two major types of tests, physical and chemical, which sometimes attempt to mimic the five senses. These tests analyze for the presence of potentially harmful bacteria, yeast, and mold; create standards for maintaining quality control; and identify almost any chemical in foods used for nutrition labeling, moisture-content analysis, and detection of allergens or toxins, to name just a few examples.

Physical Tests

Physical tests measure certain observable aspects of food such as size, shape, weight, **volume**, **density**, moisture, texture, and **viscosity** (Chemist's Corner 2-1 and 2-2) (15). Instruments used vary from simple to complex (Table 2-1). For example, viscosity may be measured using a simple line-spread test, the observation of the distance a certain amount of food spreads on a surface, or with a Brookfield viscometer, a sophisticated instrument that more precisely

Volume A measurement of three-dimensional space that is often used to measure liquids.

Density The concentration of matter measured by the amount of mass per unit volume. Objects with a higher density weigh more for their size.

Viscosity The resistance of a fluid to flowing freely, caused by the friction of its molecules against a surface.

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TABLE 2-1 Selected Physical Tests for Food Evaluation

Visual Evaluation	
Microscope	Used to observe microorganisms as well as starch granules, the grain in meats, the crystals of sugar and salt, the fiber in fruits and vegetables, and for any texture changes in processed foods.
Colorimeter	Measures color by passing a light through a substance to measure its absorbance and/or transmittance.
Spectrophotometer	Measures color by detecting the amount and wavelength of light transmitted through a solution (13). Same principle as a colorimeter, but it can measure more than one wavelength, and not just in the visible range. Spectroscopy is based on the principle that the molecules in foods and beverages will absorb light at different wavelengths on the spectrum. The amount of absorption parallels the amount of substance found in the sample. Spectroscopy can be used to determine the amount of caffeine in coffee or the concentration of riboflavin (vitamin B_2) in milk.
Weight/Volume Measurements	
Weight	Weight is measured in pounds/ounces or milligrams/grams/kilograms.
Volume	Volume quantifies the area occupied by a mass, whereas density is the measure of mass (weight) in a given volume. Specific density relates a substance's density to an equal amount of water.
Texture Measurements	
Penetrometer	Simulates teeth biting into a food to measure its tenderness.
Warner–Bratzler Shear	Evaluates meat and baked product tenderness by measuring the force required to cut through a cylindrical sample.
Shortometer	Measures tenderness by determining the resistance of baked goods, such as cookies, pastries, and crackers, to breakage. Puncture testing evaluates the firmness of fruit or vegetable tissue.
Texture Analyzer	Instruments that can measure breaking or bending (a fulcrum comes down on the food until it breaks), compression (a plate is pressed against the food), extrusion (food is placed in a container and forced through a hole or grid), penetration, tension (food is pulled apart by jaws until it breaks), shear (see above) (14).
Viscosity Measurements	
Line-spread test	Measures the consistency of batters and other viscous foods. Food is placed in a hollow cylinder in the middle of the spread sheet; the cylinder is then lifted, allowing the food to spread, and the spreading distance is measured in centimeters.
Viscometer (or viscosimeter)	Measures the viscosity of food such as pudding, sour cream, salad dressings, sauces, cream fillings, cake batters, and ketchup.
Concentration Measurements	
Polarimeter	Measures the concentration of various organic compounds, especially sugars, in solution by determining the angle (refractive index) of polarized light passed through the solution. Refractometers, a type of polarimeter, are commonly used to measure sugar concentrations in soft drinks. The Brix/acid ratio is used to measure the palatability of fruit juices that depends on the delicate balance between sweetness (sugars) and tartness (acid). This ratio is obtained by measuring the degrees Brix (determined by the use of a refractometer) divided by the total acid concentration (determined by acid titration) (7, 8).
Atomic absorption	Used to measure mineral content.
Moisture analyzer	Determines water content of a product by measuring weight loss on drying (12).

FIGURE 2-4 A texture analyzer with a blade determines food resistance by cutting through samples; a microphone detects sound.



Courtesy of Texture Technologies Corp.

measures viscosity under controlled temperatures. Instruments (Figure 2-4) are available to measure many aspects of food texture, such as crispness, hardness, tenderness, crumbliness, firmness, compressibility, elasticity, and plasticity, and may come equipped with several attachments, allowing measurement of multiple attributes. For example, depending on the attachment used, the Instron Universal Testing Machine can measure the compressibility of bread or the force required to break a cookie or shear a piece of meat. Physical test instruments are sometimes purchased by companies that need to ensure their products meet certain quality control guidelines.

Chemical Tests

The number of chemical tests available for use on foods is almost limitless, but Table 2-2 lists some of them. Many are based on the work of the Association of Official Analytical Chemists (AOAC) International, which publishes a book on chemical tests, including those for determining various nutrient and nonnutrient substances in foods.

Chemical tests can be conducted within a corporation, but they can also be sent out to commercial food-testing companies. These food laboratories specialize in certain tests, such as the microbial evaluation often necessary for food safety testing. Many companies analyze their food products for certain bacteria, yeast, and/or molds. Food-testing companies can also provide

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TABLE 2-2 Selected Chemical Tests for Food Evaluation

Benedict and Fehling tests	Determines the presence of sugars (reducing) such as lactose and maltose, which are more likely to be involved in a chemical reaction that turns food brown.
Chromatography	See Chemist's Corner 2-2. Gas chromatography is the primary technique used in flavor analysis because most of these substances are volatile. Liquid chromatography is also used in flavor testing, especially for sugars, protein fragments (umami), and other substances (13).
Electrophoresis	Specific proteins are characterized by passing an electrical field through a gel containing proteins and measuring the rates at which the proteins migrate.
Enzyme tests	The peroxidase 1 test evaluates peroxidase enzyme activity in pasteurized foods: if the heat of pasteurization is adequate to destroy harmful bacteria, it should also inactivate the peroxidase enzyme. The effectiveness of briefly boiling food to destroy the enzymes responsible for vegetable deterioration can be determined by measuring the catalase enzyme activity.
Fuchsin test	Detects aldehydes in fats and oils.
Iodine value test	Measures the degree of unsaturation in fats.
Peroxide value test	Measures the extent of oxidation within a fat.
pH meter	Detects the amount of acidity or alkalinity in food mixtures or beverages.
Proximate analysis	A sequence of chemical tests determines the macronutrient (protein, fat, carbohydrate) content of food.

Source: U.S. Department of Agriculture.

corporations with Nutrition Facts labels by analyzing the nutrients in a new food product. The potential for contamination and adulteration is another reason why a food company or government agency tests a food; pesticides, herbicides, and industrial residues are just a few of the chemicals that can be analyzed. For example, after melamine was illegally used in pet food by certain Chinese manufacturers to elevate protein content, the Food and Drug Administration (FDA) and some private manufacturers began analyzing for melamine (18). Table 2-3 lists the chemical analysis services offered by one food laboratory.

TABLE 2-3 Examples of Chemical Tests Conducted by a Food Testing Company

Allergens	Maximum internal temperature
Ammonia	Moisture/protein ratio
Ash	Nitrate
Calcium	Nutritional analysis and labeling
Calories (by calculation)	Percent bone
Calories from fat	Oxidative rancidity
Carbohydrates (by calculation)	Pesticide residue
Collagen	pH
Crude fiber	Phosphate
Fat (Soxhlet)	Protein
Fatty acid content (saturated, unsaturated, trans)	Salt
Iron	Sodium nitrite
Heavy metals	Soy protein concentrate
Hydroxyproline	Thiobarbituric acid reactive substances (TBA)
Moisture (water)	Unknown compound identification

Source: abcr GmbH, HYPERLINK "http://www.abcr.de/"www.abcr.de

Electronic Noses

A new and emerging technology in the field of objective evaluation is the electronic nose, or e-nose. Scientists are developing e-nose instruments that detect certain chemicals responsible for aroma. An advantage of these devices is that they avoid some drawbacks of human noses, such as testing fatigue, subjectivity, great expense, and slow evaluations. The e-nose can detect how well wines, beers, and spirits have aged; the quality of wheat and baked goods; the presence of bacterial contamination; coffee freshness; and even the best picking date for peaches (21).

Comparison of Sensory and Objective Evaluations

Sensory testing is expensive and time-consuming because many individuals are required to test a single product. However, it is vital for product R&D because the consumer is the only true judge of the acceptability of a food and predictor of its marketplace success. On the other hand, objective methods are essential for routine quality control because they can produce quantitative measurements human senses cannot. Objective testing offers the advantages of being reliable and repeatable, not affected by human variability, and generally faster, cheaper, and more efficient than sensory testing.

To truly evaluate food quality, both sensory and objective tests are necessary because one cannot substitute for the other; in fact, they are complementary. Thus, the need to evaluate food quality opens up a world of exploration in food evaluation that is a rich array of both sensory and objective testing. Food corporations, certain government agencies, nutrition and food university departments, culinary schools, food marketing companies, and even individuals making daily food choices all use the principles of food evaluation.

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SUMMARY / 2: Food Evaluation

Food manufacturers use both sensory (subjective) and objective evaluation methods to help in determining consumer acceptance of new products in R&D, product improvement, sales and marketing, quality assurance, analysis of nutrient content for labeling requirements (Nutrition Facts), and detection of contamination or adulteration.

Sensory (subjective) tests evaluate food quality by relying on the sensory characteristics and personal preferences of selected individuals. Taste panels, consisting of either randomly chosen members of the population or experts trained in tasting a particular product, are used to conduct subjective tests:

- *Analytical tests* are based on discernible differences.
- *Affective tests* are based on individual preferences.

Objective tests rely on laboratory methods and equipment to evaluate foods through physical and chemical tests.

- *Physical tests* measure certain observable aspects of food such as size, shape, weight, volume, density, moisture, texture, and viscosity.
- *Chemical tests* are used to determine the various nutrient and nonnutrient substances in foods.

CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Which of the following is an example of a subjective food evaluation test?
   a. Triangle test
   b. Spectrophotometry
   c. Measuring volume
   d. Measuring weight

2. Which of the following is an example of a chemical test?
   a. Duo–trio
   b. Threshold
   c. Nutrient analysis
   d. Shortometer

3. Which analytical sensory test below finds the minimal detectable level of a substance?
   a. Triangle
   b. Flavor profile
   c. Hedonic
   d. Dilution

4. A line-spread test is a physical test for measuring _____.
   a. sweetness
   b. meat and baked product tenderness
   c. consistency of batters and other viscous foods
   d. degree of unsaturation in fats

5. A food evaluation in which panelists' responses range from "like extremely" to "dislike extremely" is best described as a _____ test.
   a. discriminative
   b. descriptive
   c. hedonic
   d. personal preference

6. Which chemical test evaluates the degree of unsaturation in fats?
   a. Electrophoresis
   b. Enzyme test
   c. Iodine value test
   d. Proximate analysis

7. Which method below determines the protein, fat, and carbohydrate content of foods?
   a. Proximate analysis
   b. Fuchsin test
   c. Benedict and Fehling tests
   d. Peroxide value test

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe the difference between sensory (subjective) and objective evaluation of foods.
2. How do discriminative and descriptive tests differ from one another?
3. Create a product score evaluation sheet for a cookie based on a nine-point hedonic scale.
4. Describe the general requirements for setting up a taste panel and the process of preparing samples to be subjectively tested.
5. List and describe three examples of difference testing.
6. List and describe three examples of physical testing.
7. List and describe three examples of chemical testing.
8. Describe viscosity and how it is used to test food quality.
9. How is chromatography used to evaluate certain foods?
10. Describe how a polarimeter and the Brix/acid ratio are used to test sweetness in liquids.

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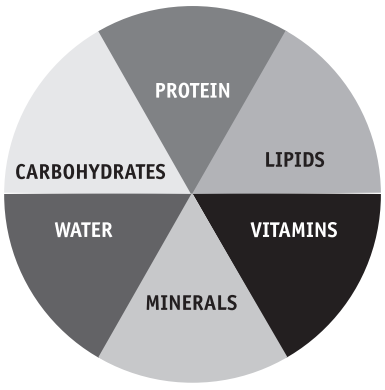
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Chemistry of Food Composition

Basic Food Chemistry . . . 27
Water 28
Carbohydrates 36
Lipids (Fats) 43
Proteins 47
Vitamins and Minerals . . 52
Nonnutritive Food Components 53

"You are what you eat." When the nineteenth-century German philosopher Ludwig Feuerbach coined this phrase, he probably did not realize how true it was. Foods and people are composed of the same chemical materials, and there was a time when people served as nourishment to other animals in the food chain. All foods, including people, consist of one or more of six basic nutrient groups: water, carbohydrates, lipids, protein, vitamins, and minerals (Figure 3-1). Most foods contain a combination of all six groups, but in varying proportions. For example, milk is 80% water, meats serve as primary sources of protein, potatoes and grains are rich in carbohydrates, and nuts are almost all fat. Figure 3-2 shows the proportion of these six nutrients in humans.

FIGURE 3-1 Nutrient groups.



Because people literally are what they eat, the main purpose of eating and drinking is to replace the nutrients used up in the body's maintenance, repair, and growth, as well as to obtain necessary energy. Energy-yielding nutrients are fuel to the body, as gas is fuel to a car.

BASIC FOOD CHEMISTRY: THE SIX KEY ATOMS (CHNOPS)

The body benefits from the energy and nutrients in foods at the cellular level. To comprehend how this occurs, it is necessary to know some biochemistry—the study of the chemistry that occurs within living organisms. Knowledge of biochemistry helps us understand how nutrients from foods and beverages are assimilated in living systems.

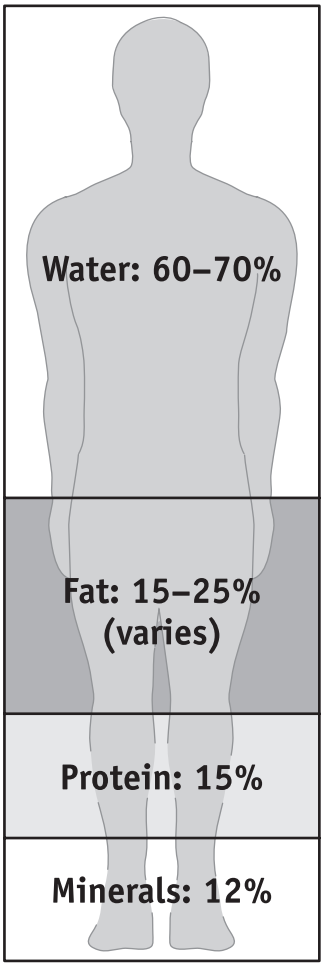
A basic principle of biochemistry is that all living things contain six key

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FIGURE 3-2 Approximate proportion of nutrients in the human body. Differences occur because of age, sex, and condition. The proportion shown represents percent by weight. Vitamins and carbohydrates contribute a minimal amount.



Atoms The basic building blocks of matter; individual elements found on the periodic table.

Molecule A unit composed of one or more types of atoms held together by chemical bonds.

Compound A substance whose molecules consist of unlike atoms.

Nutrients Food components that nourish the body to provide growth, maintenance, and repair.

Gram A metric unit of weight. One gram (g) is equal to the weight of 1 cubic centimeter (cc) or milliliter (mL) of water (at a specific temperature and pressure).

CALORIE CONTROL
Where Do Kilocalories Come From?

Some organic compounds can be broken down by the body to release the energy, measured in kcalories, needed to sustain life. Carbohydrates, fats, proteins, and alcohol are the only sources of kcalories from the diet. No kcalories are obtained from vitamins, minerals, or water. Both water and minerals are inorganic compounds, substances that do not contain carbon and cannot provide kcalories. The following table shows the kcalories provided per **gram**.

Kilocalorie Sources

Yes:		No:
Carbohydrate	= 4 kcal/gram	Vitamins
Protein	= 4 kcal/gram	Minerals
Fat	= 9 kcal/gram	Water
Alcohol	= 7 kcal/gram	Fiber*

*The carbohydrates in fiber are not digested by human enzymes, so they are not absorbed to provide kcalories.

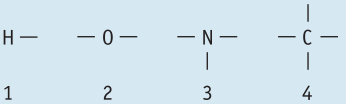
Conversion factors: 5 grams = 1 teaspoon
28.35 grams = 1 ounce
100 grams = ½ cup liquid

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CHEMIST'S CORNER 3-1
Atomic Structure

Everything physical in the universe is made from atoms, some of the smallest particles in existence. These smallest units of matter are identified by the number of protons and electrons that they contain. Protons are positively charged particles in the atom's nucleus, and electrons are negatively charged particles surrounding the nucleus. The number of electrons on the outside ring of an atom dictates how many bonds that particular atom can form and, therefore, what kind of substances it forms. For example, the carbon (C) atom, the backbone of carbohydrates, fats, and proteins, usually forms four bonds. Nitrogen (N) is capable of forming three bonds, whereas oxygen (O) can form two, and hydrogen (H) only one (Figure 3-3). The bond holding atoms together through the sharing of electrons is called a covalent bond.

FIGURE 3-3 The number of bonds that selected atoms can form with other atoms.



elements (or **atoms**): carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur (CHNOPS) (Chemist's Corner 3-1). These are the building blocks of organic material, carbon-containing compounds that are often living material. All the elements have the capacity to join together with similar or different elements to produce **molecules** or **compounds**, which then combine to create all the substances on earth, including the focus of this book—foods and beverages.

This chapter focuses on both organic and inorganic compounds by covering the six nutrient groups found in food and people: water, carbohydrates, fats, proteins, vitamins, and minerals. These **nutrients** serve as the foundation underlying all the principles in food and nutrition. They are discussed in this chapter with attention to what foods contain them, their chemical composition, and their functions in foods. Sugar (a form of carbohydrate) is discussed in greater detail in Chapter 21, and fat is covered further in Chapter 22.

WATER

Water is the simplest of all nutrients, yet it is the most important. Without it, life could not exist, and it is essential at every stage of growth and development. Water brings to each living cell the

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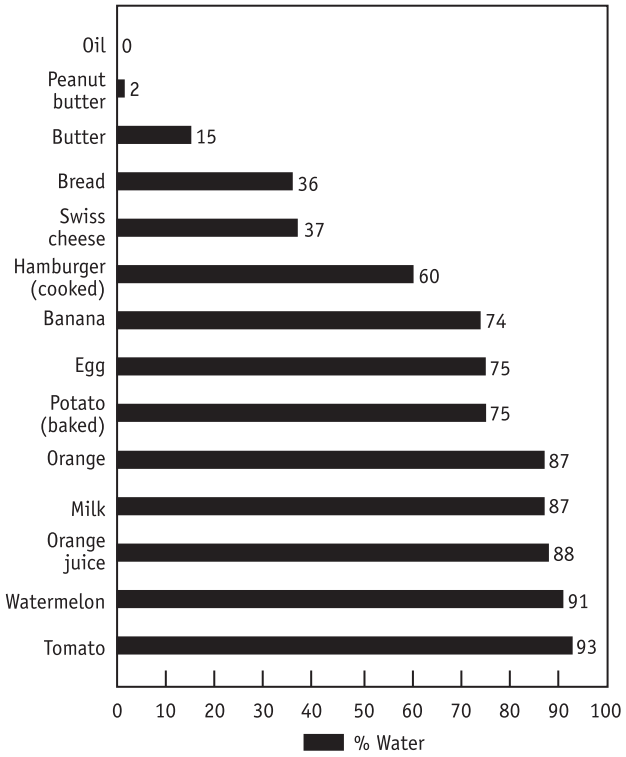
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ingredients that it requires and carries away the end products of its life-sustaining reactions. The life functions of assimilating, digesting, absorbing, transporting, metabolizing, and excreting nutrients and their by-products all rely on water. The body's cells are filled with water and are bathed in it. The human body is made up of an average 60 to 70% water; losing as little as 10% can result in death. Water balance is maintained by drinking fluids and by eating foods, all of which naturally contain at least some water. A small portion is also obtained through metabolic processes.

Water Content in Foods

People get the water they need from foods and beverages. Although it may not always be apparent, many foods contain more water than any other nutrient (Chemist's Corner 3-2). Foods have a water content of 0 to 95% or greater (Figure 3-4). Those that yield the most water are fruits and vegetables (70 to 95%), whole milk (over 80%), and most meats (average just under 70%). The foods with the least water are vegetable oils and dried foods such as grains and beans.

FIGURE 3-4 The percent water content of certain foods—0 to 95+.



Composition of Water

Water is a very small molecule consisting of three atoms—one oxygen atom flanked by two hydrogen atoms (H_2O) (Chemist's Corner 3-3).

CHEMIST'S CORNER 3-2

Free or Bound Water

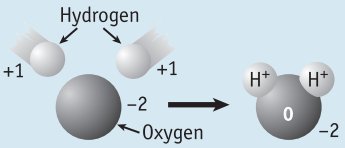
The water in foods may be in either free or bound form. Free water, the largest amount of water present in foods, is easily separated from the food, whereas bound water is incorporated into the chemical structure of other nutrients such as carbohydrates, fats, and proteins. Examples include the free water found in fruit and the bound water found in bread. Bound water is not easily removed and is resistant to freezing or drying. It is also not readily available to act as a medium for dissolving salts, acids, or sugars.

CHEMIST'S CORNER 3-3

The Chemical Structure and Properties of Water

Water has an overall neutral charge. This "neutrality" is derived from the combination of its two hydrogen (H^+) atoms, each with one positive charge, being balanced by the two negative charges of water's one oxygen (O^{-2}) atom. Overall, this gives water a neutral charge. However, the charge is not evenly distributed over the molecule; the electrons are more strongly attracted by the oxygen atom than by the hydrogen atoms. This results in a water molecule with a negative pole and a positive pole, making it dipolar (Figure 3-5). Dipolar molecules have poles with partial charges that oppose each other, and this dynamic contributes to some of water's very unique properties. Hydrogen bonds form between the (slightly positive) hydrogen atom of one water molecule and the electronegative oxygen atom of an adjacent water molecule. One water molecule is able to form up to four hydrogen bonds. Although these bonds are weak and are easily broken and reformed, they are important because there are so many of them. Energy is required to break them when water is converted to steam. In fact, without hydrogen bonds, water would be a gas at room temperature. In foods, water molecules are able to form hydrogen bonds with other polar molecules such as sugars, starches, gums, and proteins, and this has profound effects on the properties of these molecules in solution.

FIGURE 3-5 Two atoms of hydrogen combine with one oxygen atom, creating a dipolar molecule.



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Measuring Heat Energy

It takes heat, or its loss, to move the molecules of water through their different states, and this heat is commonly measured in units called Calories (with an uppercase "C"), also known as kilocalories (kcalories or kcal). A kilocalorie is equal to the amount of energy required to raise 1 kilogram of water 1°C (measured between 14.5°C and 15.5°C at normal atmospheric pressure). A much smaller unit often used by chemists, the calorie (with a lowercase "c"), is equal to 0.001 kilocalorie; therefore, 1 Calorie = 1,000 calories = 1 kilocalorie. The energy values of foods are actually measured in kilocalories (thousands of calories), and when the general public and food package labels use the term *calorie,* they are really referring to kilocalories. Within this textbook, the term *calorie* is used as chemists use it (to mean 0.001 kcal), so *kilocalorie* or *kcalorie* is used when describing energy derived from foods.

Specific Heat

The presence of hydrogen bonding between water molecules (Chemist's Corner 3-3) means that it takes more energy to heat water than it does any other known substance. Water's high **specific heat** makes it unique among the compounds on earth. Given the same amount of heat, a metal pan or the oil in it will become burning hot, whereas water will become only lukewarm. This important characteristic of water enables animals, including people, with a high water content to withstand the very hot and very cold temperatures sometimes found on earth. Water's specific heat of 1.00 (1 calorie will raise 1 gram of water 1°C) is used as the measure against which all other substances are compared. Similarly, water differs from other compounds in the amount of energy it takes to reach its specific freezing, melting, and boiling points.

How & Why?

If the atoms in H_2O do not change, how is water able to exist as a gas (steam or humidity), liquid, or solid (ice)?

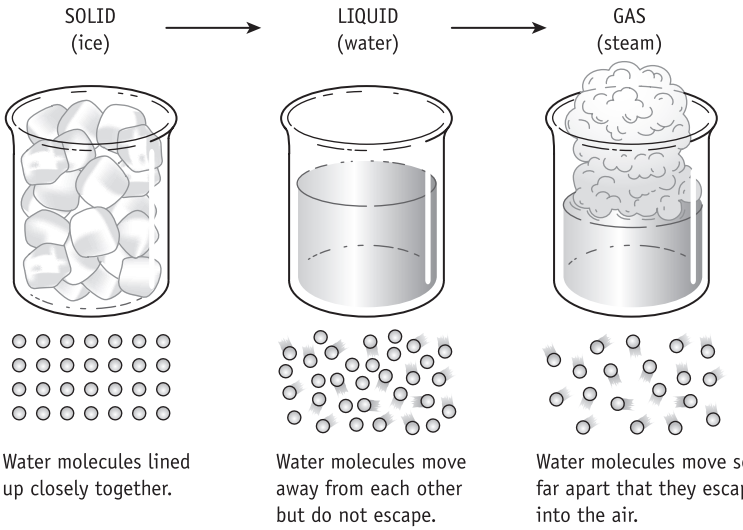
The distance between the molecules determines these differences, and the distances are influenced by temperature. At very low temperatures, ice forms as the water molecules line up very close together. Elevating the temperature increases the movement of the water molecules against each other, pushing them farther away from each other. When enough heat is applied, ice melts into a liquid. Continued heating transforms liquid water into a gas (steam) by giving the molecules freedom to move even farther apart (Figure 3-6). The variations of water from solid to liquid to gas are called changes in state. In spite of the obvious differences in these states, they do not involve any changes in the structure of the water molecule.

Freezing Point

In many parts of the world, winter temperatures can turn water into ice when its **freezing point** is reached. People living in snow country are particularly aware that when the temperature drops to freezing (32°F/0°C at normal atmospheric pressure), ice can form on the roads. The lower temperature decreases water's kinetic energy, that is, the energy associated with motion, which slows the movement of the water molecules until they finally set into a compact configuration. **Heat of solidification** occurs when at least 80 calories (0.08 kcal) of heat are lost per gram of water.

Unlike other substances, water expands and becomes less dense when completely frozen, which is why ice floats. The expansion of frozen water ruptures pipes and containers filled with water. Popsicle molds and other food containers would also break if food companies did not allow for expansion of the contents during the freezing process. It should come as no surprise, then, that ice formation also ruptures the cells in plants and meats, diminishing the potential food's textural quality. Pure water freezes at 32°F (0°C), but adding anything else to the water changes its freezing point. The addition of **solutes**, such as salt or sugar, to water lowers the freezing point (Chemist's Corner 3-4).

FIGURE 3-6 Molecular movement dictates whether a substance is a solid, liquid, or gas.



Specific heat The amount of heat required to raise the temperature of 1 gram of a substance 1°C.

Freezing point The temperature at which a liquid changes to a solid.

Heat of solidification The temperature at which a substance converts from a liquid to a solid state.

Solute Solid, liquid, or gas compound dissolved in another substance.

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CHEMIST'S CORNER 3-4

Calculating Freezing Point Depression and Boiling Point Elevation

The freezing or boiling point of a solution can be calculated using known constants for the solvent and the solute concentration. The freezing point depression phenomenon occurs when a solute (such as salt) is added to water so that it forms ice at a lower temperature:

- Decreased freezing point of a solvent = the freezing point depression constant (K_f) for the solvent multiplied by the molal concentration (m) of the solute in the solution.
- Freezing point of a solution = the freezing point of the pure solvent ($T_{\text{pure solvent}}$) plus the change (depression) in freezing point (ΔT).

Similarly, a liquid's boiling point temperature is elevated by adding a solute:

- Increased boiling point of a solvent = the boiling point elevation constant (K_b) for the solvent multiplied by the molal concentration (m) of the solute in the solution.
- Boiling point of a solution = the boiling point of the pure solvent ($T_{\text{pure solvent}}$) plus the change in the boiling point of the solution (ΔT).

Adding too much, however, slows the freezing process. Thus, frozen desserts made with large quantities of sugar take extra time to freeze.

Melting Point

Just as removing heat from water causes it to turn into ice, returning the same 80 calories (0.08 kcal) of heat to a gram of ice will cause it to reach its **melting point** and turn back into water. While the ice absorbs the 80 calories of heat, there is no rise in temperature. This **latent heat** does not register because it was put to work in breaking hydrogen bonds and moving the molecules of water far enough apart to change the physical structure of the solid ice into liquid water.

Boiling Point

Bubbles start to break the surface of water when it reaches 212°F (100°C) at sea level. This is its **boiling point** (further explained in Chapter 5). The water will not get any hotter, nor will the food cook faster, no matter how much more heat is added, and this is why a slow rolling boil is often recommended. Maintaining a slow rolling boil is also more gentle on the foods and results in less evaporation.

The point at which water boils is reached when the pressure produced by steam, called *vapor pressure,* equals the pressure of the atmosphere pushing down on earth. At this point, the natural pressures of the atmosphere are not strong enough to push back the expanding gases of boiling water. Water requires 540 calories (0.54 kcal) of energy per gram to boil and vaporize. However, when salts or sugars are added, the boiling point of water is increased (Chemist's Corner 3-4). This is due to dilution of the **solvent** (water, in this case); however, the salt or sugar molecules also attract or bind the water molecules. The vapor pressure is therefore decreased (at a particular temperature), so more energy is required to increase that pressure to the point at which the water boils and is converted to steam.

This **heat of vaporization** is quite a bit higher than the 80 calories (0.08 kcal) needed to melt ice. Serious burns can result from human exposure to steam because the amount of heat required to produce it is so high.

Elevation and Boiling Point

Increasing the elevation decreases the boiling point of water. At sea level, water boils at 212°F (100°C), but this drops 1°F for every 500-foot increase in altitude (an increase of 960 feet in elevation decreases water's boiling point by 1°C). Water boils in the mountains at lower temperatures than it does at sea level because there is less air and atmospheric pressure pushing down on the earth's surface. Steam has less resistance to overcome and therefore occurs at lower temperatures. For example, at 7,000 feet, water boils at 198°F (92°C). At even higher elevations, such as on Mount Everest, the boiling point of water drops to 156.2°F (69°C). Recipes are usually modified for elevations above 3,000 feet because the lower boiling temperature might affect ingredient actions and reactions.

Increasing the atmospheric pressure raises water's boiling point. Artificial changes in atmospheric pressure can be achieved by pressure cookers as well as by special equipment used only in the commercial food industry. A pressure cooker speeds up heating time by increasing atmospheric pressure to 15 pounds; thus, water temperatures up to 240°F (116°C) can be achieved.

Hard vs. Soft Water

Most water is not pure water but contains dissolved gases, organic materials, and mineral salts from the air and soil. The minerals in water determine whether it is hard or soft water. Hard water contains a greater concentration of calcium and magnesium compounds, whereas soft water has a higher sodium concentration.

Functions of Water in Food

Water is the most abundant and versatile substance on earth. Among its many uses in food preparation, its two most important functions are as a transfer medium for heat and as a solvent. In addition, it is important as an agent in chemical reactions and is a factor in the perishability and preservation of foods (Table 3-1).

Melting point The temperature at which a solid changes to a liquid state.

Latent heat The amount of energy in calories per gram absorbed or emitted as a substance undergoes a change in state (liquid/solid/gas).

Boiling point The temperature at which a heated liquid begins to boil and changes to a gas.

Solvent A substance (usually a liquid) in which another substance is dissolved.

Heat of vaporization The amount of heat required to convert a liquid to a gas.

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TABLE 3-1 Functional Properties of Water in Food

Heat Transfer	Solvent	Chemical Reactions
Moist Heating of Foods	Dispersion	Ionization
Boiling	Solution	Changes in pH
Simmering	Colloidal dispersion	Salt formation
Steaming	Coarse dispersion (suspension)	Hydrolysis
Stewing		CO_2 release
Braising		Food preservation

How & Why?

How can you tell whether water is hard or soft?

Hard water leaves a ring in the bathtub, a grayish sediment on the bottom of pans, and a grayish cast in washed whites. Although permanently hard water cannot be softened by boiling or distilling, it can be converted by a water softener, which works by exchanging sodium for calcium and magnesium. Another way to determine whether water is hard or soft is to call the local water department and ask how much calcium carbonate (in ppm—parts per million) is in the water. The following breakdown defines whether it is hard or soft:

Water Hardness	Calcium Carbonate (ppm)
Soft	0–50
Medium	50–100
Hard	100–200
Very Hard	200+

Heat Transfer: Moist-Heat Cooking Methods

Water both transfers and moderates the effects of heat. A potato heated by itself in a pan will burn, but surrounding that same potato with water ensures that the heat will be evenly distributed. Water also transfers heat more efficiently than either air or metal, which explains why a potato heats faster in boiling water than in the oven. Because water has a higher specific heat than other substances, it buffers changes in temperature. More energy is needed to increase the temperature of 1 gram of water than 1 gram of fat. For example, the specific heat of oil is 0.5; thus, it heats twice as fast as water when the same amount of heat is applied.

Almost half of the methods used to prepare foods rely on water to transfer heat; these are known collectively as *moist-heat methods*. The major moist-heat methods discussed in this book are boiling, simmering, steaming, stewing, and braising. Dry-heat methods use heat in the form of radiation and include baking, grilling, broiling, and frying. Microwaving uses both dry- and moist-heat methods; microwaves are actually a form of radiation that heats the water molecules in foods, which then heat the food itself. Microwaving techniques are discussed throughout this book under moist-heat preparation methods.

Solvent

The many biochemical interactions occurring in living organisms—human, animal, and plant—could not occur without a solvent environment. Although all liquids can act as solvents, water is considered to be the earth's most important solvent. The fluid substance, mostly water, within and around the cell is a solvent that contains many dissolved solutes.

Dispersions

In order to appreciate the role of water as a solvent, it's important to understand **dispersions**. These are mixtures containing particles (solid, liquid, or gas) that are dispersed within another substance (solid, liquid, or gas) known as the continuous phase (dispersion medium). As shown in Table 3-2, there are three types of dispersions, classed based on particle size—**solutions**, **colloidal dispersions** (sol, gel, emulsion and foams), and **coarse dispersions**.

Dispersion A system (mixture) containing particles (solid, liquid, or gas) dispersed in a continuous phase (solid, liquid, or gas).

Solution A completely homogeneous mixture of a solute (usually a solid) dissolved in a solvent (usually a liquid).

Colloidal dispersion A type of dispersion in which the particles are between 2 nanometers and 1 micrometer in diameter, which is too large to go into solution but not large enough to precipitate out of the continuous phase.

Coarse dispersions (suspension) A type of dispersion in which the particles are larger than 1 micrometer in diameter and remain "suspended" in the continuous phase.

TABLE 3-2 Dispersion Types (Based on Particle Size)

Dispersion Type	Particle (dispersed or dissolved phase)	Dispersion Medium (continuous phase)	Food Example(s)
Solution (<1 nanometer)	Solid	Liquid	Solution: sugar in water
	Liquid	Liquid	Solution: alcoholic beverage
	Gas	Liquid	Solution: carbonated water
Colloidal dispersion (2 nanometers to 1 micrometer)	Solid	Liquid	Sol: gravy, jellies
	Liquid	Solid	Gel: egg custard
	Liquid	Liquid	Emulsion: milk, butter, mayonnaise, vinegar and oil
	Gas	Liquid	Foam: whipped cream, whipped egg whites
Coarse dispersion (>1 micrometer)	Solid	Liquid	Suspension: cornstarch in water

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Solutions

Unlike those in colloidal or coarse dispersions, the molecules of solute in a solution are so small that they are completely dissolved by the solvent. A solution is a homogeneous mixture composed of only one phase; the solute(s) will not **precipitate** from its fluid medium and cannot be separated from it by filtering but can sometimes be removed by **distillation**.

Food Applications

The ability of water to dissolve sugar allows the production of sweetened beverages. Water also forms solutions with minerals and water-soluble vitamins (B complex and C). This increases the likelihood that these minerals and vitamins may leach out of foods into cooking water, which is often discarded, causing nutrients to be lost. Much of what people perceive as the taste of foods depends on the formation of solutions with solutes in foods such as sugars, salts, acids, and other flavor compounds, and their resulting enhanced ability to attach to flavor receptors. To the delight of tea and coffee lovers, water can also dissolve caffeine and other flavorful compounds from tea leaves and coffee beans. In molecular solutions, higher temperatures increase the amount of solute that will dissolve in the solvent, which explains why very hot water is used for making coffee and tea.

Solubility

If a substance is able to enter into a solution by dissolving, it is considered to be soluble or miscible. If not, it is insoluble or immiscible. Not all substances dissolve in the same manner. Compounds such as salt dissolve to form ionic solutions, whereas polar compounds such as sugars dissolve to form molecular solutions.

Saturated Solutions

The **solubility** of a substance is expressed as the amount in grams that will dissolve in 100 mL of solvent (see Chapter 21). A solution containing the maximum amount of solute that will dissolve at a particular temperature is termed a **saturated solution**. In the case of sugars and other polar solutes, raising the temperature allows more solute to dissolve in the solvent (Chemist's Corner 3-5). For example, the solubility of sucrose at 68°F (20°C) is 67 grams of sucrose in 100 grams of solvent (67% solubility), whereas at 212°F (100°C), 83 grams of sucrose can be dissolved (83% solubility).

CHEMIST'S CORNER 3-5

Temperature Increases Solubility

The solubility of polar molecules such as sucrose increases with increasing temperature, whereas the solubility of ionic molecules such as salt is essentially unchanged as temperature increases. This is due to a phenomenon known as *hydrogen bond interchange*. The polar sucrose molecules are attracted to each other via hydrogen bonds between adjacent hydroxyl (–OH) groups. When sucrose is added to water, these hydrogen bonds are disrupted, and new ones form between sucrose and water. In this way, the sucrose crystals become hydrated and dissolve. At higher temperatures, hydrogen bonds are more easily disrupted. This results in decreased attraction between molecules within the sucrose crystals, as well as decreased attraction between water molecules. More hydrogen bonds are then able to form between sucrose and water, so more sucrose dissolves. Hydrogen bond interchange doesn't just occur when sugars dissolve in water. It is important in hydration of proteins and complex carbohydrates as well (39).

Supersaturated Solutions

Creating a saturated sucrose solution at a high temperature and then cooling it down can result in a **supersaturated solution**. This is a very unstable solution that must be cooled very slowly to prevent the solute from precipitating out or crystallizing. Many candies, including rock candy and fudge, rely on the creation of supersaturated solutions.

Colloidal Dispersions

Not all particles readily or homogeneously dissolve. Some particles, called "colloids" (e.g., starches, gums, and some proteins), never truly dissolve in a solvent because of their large size (1 nanometer to 1 micrometer). Instead, they remain in an unstable colloidal dispersion and do not noticeably change the dispersion's freezing or boiling point. Types of colloidal dispersions include the following:

- ***Emulsion***. A liquid-in-liquid mixture. Food examples include water-in-oil (w/o) or oil-in-water (o/w) **emulsions**. Neither water nor fats will dissolve in each other, but they may become dispersed in each other, creating an emulsion. Examples of food emulsions include milk, cream, ice cream, egg yolk, mayonnaise, gravy, sauces, salad dressings, and butter (7). These and other emulsions can be separated by freezing, high temperatures, agitation, and/or exposure to air (10). Emulsions are discussed in more detail in Chapter 22.
- ***Gel***. A liquid-in-solid dispersion (jam, gelatin, cheese, butter).
- ***Foam***. A gas-in-liquid (whipped egg white or whipped cream foams) or gas-in-solid (marshmallow) dispersion.

Precipitate To separate or settle out of a solution.

Distillation A procedure in which pure liquid is obtained from a solution by boiling, condensation of the vapor, and collection of the condensed liquid in a separate container.

Solubility The ability of one substance to blend uniformly with another.

Saturated solution A solution holding the maximum amount of solute that can be dissolved at its current temperature.

Supersaturated solution An unstable solution created by cooling a saturated solution without disturbance; the solution contains more than the maximum amount of solute that can be dissolved at that temperature.

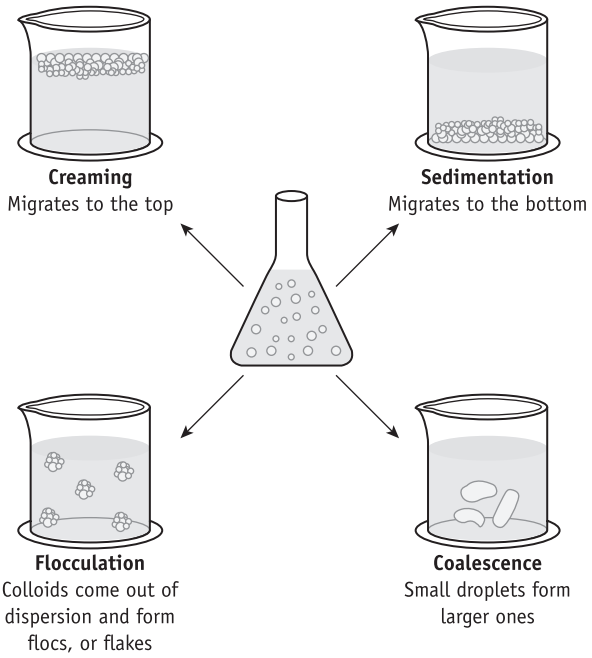
Emulsion A liquid dispersed in another liquid with which it is usually immiscible (incapable of being mixed).

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FIGURE 3-7 Dispersion destabilization.



Coarse Dispersions (Suspensions)

Unlike colloids, coarse dispersions or suspensions will eventually settle out. Generally, mechanical agitation is necessary to create a suspension. For example, when cornstarch is mixed into water, the starch grains float within the liquid rather than dissolve. Cornstarch suspensions are often used in Chinese cooking to give food its particular shiny appearance and smooth mouthfeel.

Dispersion Destabilization

Solutions are stable, but unstable colloidal and coarse dispersions can separate out. Emulsions can either cream or coalesce, and suspensions undergo either sedimentation or **flocculation** (Figure 3-7).

Flocculation A process in which colloid particles come out of suspension and solidify in the form of flocs, or flakes.

Ionize To separate a neutral molecule into electrically charged ions.

Electrolyte An electrically charged ion in a solution.

pH scale A scale used to measure the degree of acidity or alkalinity of a substance, with 1 the most acidic, 14 the most alkaline, and 7 neutral.

Chemical Reactions

Water makes possible a vast number of chemical reactions that are important in foods, including ionization, pH changes, salt formation, hydrolysis, and the release of carbon dioxide.

Ionization

When particles dissolve in a solvent, the solution is either molecular or ionic in nature. Molecular solutions are those in which the dissolved particles remain "as is" in their molecular form. An example would be the dissolving of a flavored sugar mix in water to make a beverage. The sugar molecules participate in hydrogen bond interchange with the water molecules (Chemist's Corner 3-5) but remain unchanged. Ionic solutions occur when the solute molecules **ionize** into electrically charged ions or **electrolytes**. When salt, or sodium chloride (NaCl), is dissolved in water, it ionizes into the individual ions of sodium (Na^+) and chloride (Cl^-). This chemical reaction is written as follows:

$$NaCl \rightarrow Na^+ + Cl^-$$

Changes in pH—Acids and Bases

Acids are substances that donate hydrogen (H^+) ions (protons), and bases provide hydroxyl (OH^-) ions and serve as proton receptors. The **pH scale** (pH stands for *power* and *hydrogen*) is a numerical representation of the hydrogen (H^+) ion concentration in a liquid. A solution with a pH of under 7 is considered acidic, whereas anything over 7 is alkaline or basic. A pH of 7 indicates that the solution is neutral, containing equal concentrations of hydrogen (H^+) ions and hydroxyl (OH^-) ions. Each number on the scale represents a tenfold change in degree of acidity (Chemist's Corner 3-6).

Water is naturally neutral, but tap water is normally adjusted to be slightly alkaline (pH 7.5 to 8.5) because acidic water causes pipe corrosion. Overly alkaline water, however, results in deposits of carbonates that may block water pipes. Many coffee connoisseurs prefer distilled water for making coffee because of its neutral nature.

CHEMIST'S CORNER 3-6

The Logarithmic pH Scale

The concentrations of ions in water are so small that it is awkward to speak or write about these concentrations using ordinary words. For example, water has a hydrogen ion concentration of 0.0000001 mole per liter, which is translated in terms of the negative logarithm of the hydrogen ion concentration (17):

$$pH = -\log(H^+)$$

pH is also understood in a scale of 1 to 7. The expression of 0.0000001 mole per liter using a decimal can also be written in its exponential form of 1×10^{-7} and then placed into the negative logarithm to yield a pH of 7:

$$\begin{aligned} pH &= -\log(1 \times 10^{-7}) \\ &= \log 1/(1 \times 10^{-7}) \\ &= \log(1 \times 10^{7}) = 7 \end{aligned}$$

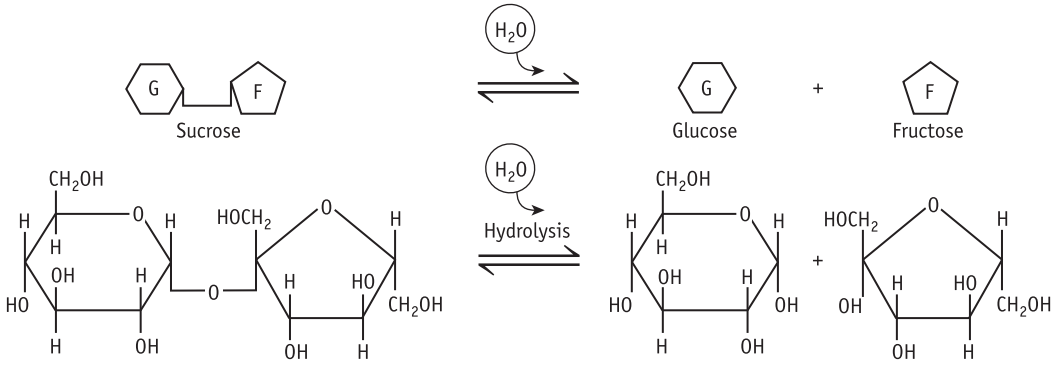
These single-digit numbers are much easier to fathom as long as it is understood that each number in the pH scale represents a tenfold change in the degree of acidity.

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FIGURE 3-8 Hydrolysis of sucrose to glucose and fructose.



Salt Formation

The nature of water as a solvent makes it possible to form salts. This occurs when a positive ion combines with a negative ion, as long as neither is a hydrogen (H^+) nor a hydroxyl (OH^-) ion. The primary example is sodium chloride (Na^+Cl^-), resulting from sodium (Na^+) combining with chloride (Cl^-). Salts can also be formed by combining an acid and a base or a metal and a nonmetal. Metal salts include potassium fluoride (K^+F^-) and lithium bromide (Li^+Br^-).

Hydrolysis

Countless chemical reactions rely on **hydrolysis**. Figure 3-8 shows an example of how a water molecule is used to break a sugar into smaller molecules. Just a few of the hydrolysis applications used in the food industry include breaking down cornstarch to yield corn syrup; dividing table sugar into its smaller components to create another sugar helpful in the manufacture of some candies (see Chapter 21); and splitting protein into hydrolysates, smaller molecules that can be added to foods to improve flavor, texture, foaming abilities, and nutrient content.

Carbon Dioxide Release

Many baked products are allowed to rise before baking. One of the agents making this possible is baking powder, which is a combination of baking soda and acid. It is only when baking powder is combined with water that the gas carbon dioxide is released, which causes baked products to rise. The chemical reaction is a two-step process:

Step 1:

$$NaHCO_3 + HX \xrightarrow{\text{water}} NaX + H_2CO_3$$

baking soda + acid ⟶ salt + carbonic acid

Step 2:

$$H_2CO_3 \longrightarrow H_2O + CO_2$$

carbonic acid ⟶ water + carbon dioxide

Food Preservation

While water is essential to the chemical reactions on which living things and many foods depend, it is also important for the life of **microorganisms** such as bacteria, molds, and yeasts. The actions of these microorganisms on food cause deterioration and decay. Atmospheric humidity alone increases the likelihood of foods degenerating. For example, a relative humidity of 75% or more, especially if combined with warm temperatures, encourages the growth of microorganisms. Thus, removing water from fruits, vegetables, meats, and herbs was among the earliest forms of food preservation. Without water, microorganisms cannot survive, so limiting the amount of water available to them inhibits their growth. Conversely, water in a cool environment helps preserve the freshness of fruits and vegetables by preventing dehydration—hence those artificial "rain" showers we see in supermarket produce displays.

Removing dirt and other debris from fruits and vegetables by rinsing them in water or even washing them with detergent eliminates many microorganisms. Detergents lower the surface tension of water, which improves its ability to act as a cleansing agent.

Water Activity

A food's **water activity (a_w)**, or available water (free vs. bound), determines its perishability. Bacteria need water to grow, and most foods do not support bacterial growth if their aw is below 0.85 (pure water has a water activity of 1.00) (5). Thus, foods high in water content, such as milk, meat, vegetables, and fruits, are much more prone to microbial spoilage than drier foods such as grains, nuts, dried milk, dried beans, or dried fruits (40). After deterioration sets in, the putrefying food itself releases water, which fuels the further growth of microorganisms. Dehydration can preserve a food because it reduces its water activity. The water activity of even pure water is reduced below 1.00 when other substances are added (Chemist's Corner 3-7) (11). Water molecules orient themselves around any added solute, making them unavailable for microbial growth. Thus,

Hydrolysis A chemical reaction in which water (hydro) breaks (lysis) a chemical bond in another substance, splitting it into two or more new substances.

Microorganism Plant or animal organism that can only be observed under the microscope, for example, bacterium, mold, yeast, virus, or animal parasite.

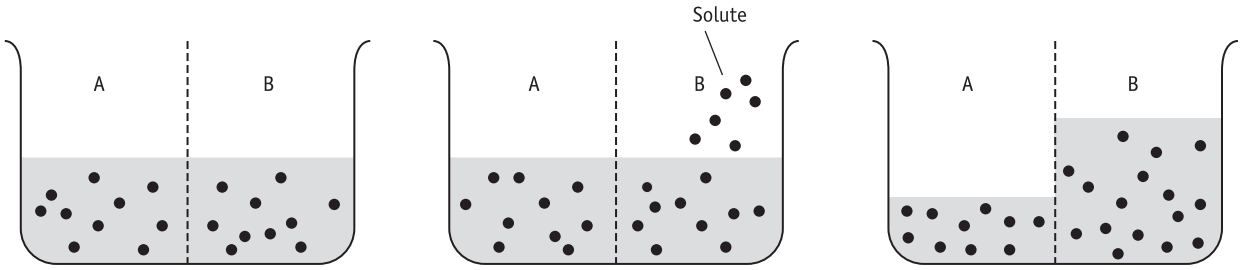
Water activity (aw) A measure of the amount of available (free) water in foods. Water activity ranges from 0 to the highest value of 1.00, which is pure water.

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FIGURE 3-9 Water flows in the direction of the higher concentration of solute.



1. With equal numbers of solute particles on both sides, the concentrations are equal, and the tendency of water to move in either direction is about the same.
2. Now additional solute is added to side B. Solute cannot flow across the divider (in the case of a cell, its membrane).
3. Water can flow both ways across the divider, but has a greater tendency to move from side A to side B, where there is a greater concentration of solute. The volume of water becomes greater on side B, and the concentrations on side A and B become equal.

CHEMIST'S CORNER 3-7

Measuring Water Activity

As free water decreases, so does the water activity. Water activity is measured by dividing the vapor pressure exerted by the water in food (in solution) by the vapor pressure of pure water (P_w), which is equal to 1.00 (3).

solutes such as sugar and salt added to jams and cured meats inhibit microbial growth by lowering water activity. The food industry makes water unavailable to microorganisms by using solutes such as salt, sugars, glycerol, propylene glycol, and modified corn syrups.

Osmosis and Osmotic Pressure

Salting has been used as a method of preserving foods for thousands of years because salt draws water out of foods and to itself. Of course, ancient peoples did not understand the process of **osmosis**, which causes water to be drawn to solutes; all they knew was that salting kept their food edible for long periods of time. Part of this process depends on the fact that water passes through membranes freely, but most solutes do not (Figure 3-9). The side of the membrane with more solute has more **osmotic pressure** and draws the necessary water to that side to dilute its solute concentration. Any bacteria contacting heavily salted food lose their water by the same process and die by dehydration. Beef jerky is the result of the combined processes of salting, smoking, and drying of meats. The high sugar concentration of jams and jellies acts to preserve them in the same way as salt preserves meats.

Osmosis The movement of a solvent through a semipermeable membrane to the side with the higher solute concentration, equalizing the solute concentration on both sides of the membrane.

Osmotic pressure The pressure or pull that develops when two solutions of different solute concentration are on either side of a permeable membrane.

CARBOHYDRATES

Foods High in Carbohydrates

Carbohydrates are the sugars, starches, and fibers found in foods. Plants are the primary source of carbohydrates, with the exception of milk, which contains a sugar called "lactose." The muscles from animals can also contain some carbohydrate in the form of glycogen, but much of this is converted to a substance called "lactic acid" during slaughter. Most carbohydrates are stored in the seeds, roots, stems, and fruits of plants. Common food sources for carbohydrates include grains such as rice, wheat, rye, barley, and corn; legumes such as beans, peas, and lentils; fruits; and some vegetables, such as carrots, potatoes, and beets. Sugar cane and sugar beets provide table sugar, whereas honey is derived from the nectar of flowers.

Composition of Carbohydrates

Carbohydrates have been described in the media as good, bad, simple, complex, and even as net carbs, but regardless of how they are described, the simplest elements making up carbohydrates are carbon (C), hydrogen (H), and oxygen (O). The word *carbohydrate* can be broken down into *carbon* (C) and *hydrate* (H_2O). This leads to the basic chemical formula of carbohydrates, which is $C_n(H_2O)_n$, where n stands for a number ranging from two into the thousands. Carbohydrates are synthesized in green plants through the process of photosynthesis. The chemical reaction of photosynthesis is written as follows:

$$\text{carbon dioxide} + \text{water} + \text{sun energy} \longrightarrow \text{glucose} + \text{oxygen}$$

$$6CO_2 + H_2O + \text{sun energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

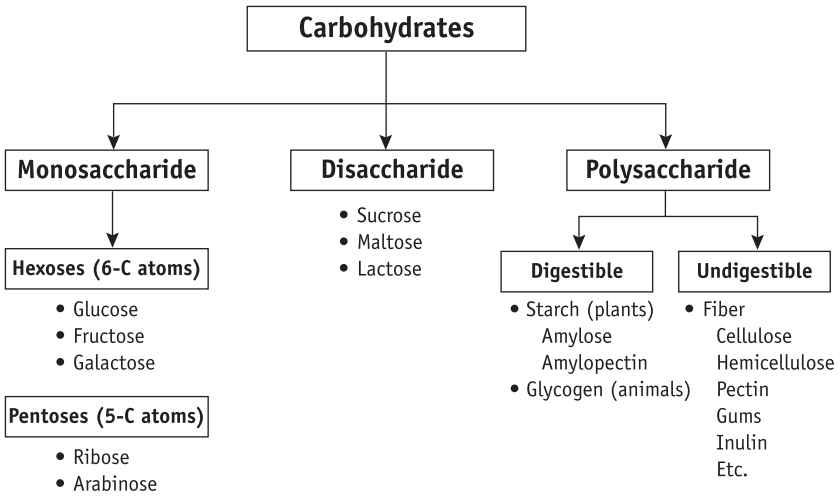
The carbon, hydrogen, and oxygen atoms making up carbohydrates are arranged in a basic unit called a saccharide. Carbohydrates are classified into monosaccharides, disaccharides, oligosaccharides, and polysaccharides, depending on the type and number

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FIGURE 3-10 Classification of carbohydrates.



of saccharide units they contain (Figure 3-10):

- Monosaccharides (one saccharide)
- Disaccharides (two monosaccharides linked together)
- Oligosaccharides (*few*—three to ten—monosaccharides linked together; these are not as common in foods as either monosaccharides or disaccharides)
- Polysaccharides (*many* monosaccharides linked together in long chains; these include starch and fibers)

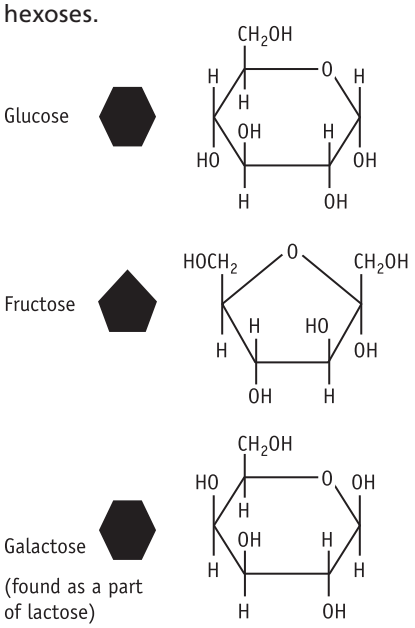
Monosaccharides

The simplest sugars, monosaccharides, are classified by the number of carbons in the saccharide unit—triose (three carbons), tetrose (four carbons), pentose (five carbons), and hexose (six carbons). The chemical names of many of the carbohydrates end in *-ose,* which means *sugar* (Chemist's Corner 3-8). Pentose and hexose sugars are more common in foods; the main pentoses are ribose and arabinose, and the three most predominant hexoses are glucose, fructose, and galactose (Figure 3-11).

Ribose and Arabinose

Ribose is an extremely important component of nucleosides, compounds that are part of the genetic material deoxyribonucleic acid (DNA), ribonucleic acid (RNA), and the energy-yielding adenosine triphosphate (ATP). Ribose also plays an important role as part of vitamin B_2 (riboflavin). Arabinose contributes to the structure of many vegetable gums and fibers.

FIGURE 3-11 Monosaccharides—hexoses.



Glucose

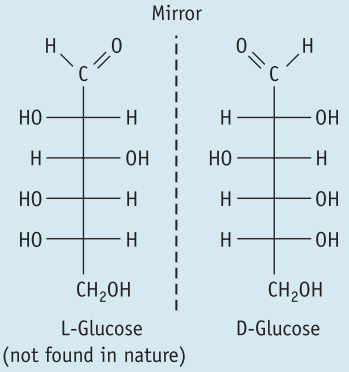
Glucose is the most common hexose found in foods and the major sugar in the blood. It is present in its free form in fruits, honey, corn syrup, and some vegetables. Glucose also exists as the repeating saccharide unit in starch and glycogen, and it is incorporated into many fibers. Refined glucose, called "dextrose" in the food industry, is used in the production of candies, beverages, baked goods, canned fruits, and alcoholic beverages. Glucose is also the major ingredient of corn syrup, which is made commercially by hydrolyzing cornstarch.

CHEMIST'S CORNER 3-8

D and L Sugars

Saccharide nomenclature uses D or L (or alpha or beta) to describe the chemical spatial arrangement of certain saccharides. The designations D and L allude to two series of sugars. Most natural sugars belong to the D series, in which the highest-numbered asymmetric carbon has the hydroxyl group pointed to the right (Figure 3-12). L-series sugars point to the left. The prefix "alpha" or "beta" can also be used to describe whether the hydroxyl group points to the right (alpha) or left (beta) of the saccharide.

FIGURE 3-12 The D or L system of nomenclature describes the right or left chemical configuration of a molecule.



How & Why?

Why is glucose called dextrose?

Glucose molecules occur in two structural forms (stereoisomers) that have the same composition but are mirror images of each other in space. Solutions of the D form of glucose rotate to the right in polarized light, and only this "right-hand" version of glucose is biologically active (in mammals). The Latin word for "right" is *dexter,* and both the term "dextrose" and the "D-" prefix of D-glucose are derived from *dextrorotatory glucose.*

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Fructose
Also called "fruit sugar" or "levulose," fructose is found primarily in fruits and honey. Fructose is the sweetest of all sugars, yet it is seldom used in its pure form in food preparation because it can cause excessive stickiness in candies, overbrowning in baked products, and lower freezing temperatures in ice cream. High-fructose corn syrup, however, is the preferred and predominant sweetening agent used in soft drinks.

Galactose
Seldom found free in nature, galactose is part of lactose, the sugar found in milk. A derivative of galactose, galacturonic acid is a component of pectin, which is very important in the ripening of fruits and the gelling of jams.

Disaccharides
Combining two saccharides results in a disaccharide. The three most common disaccharides are sucrose, lactose, and maltose (Figure 3-13).

Sucrose
Sucrose is table sugar, the product most people think of when they use the word "*sugar*." Chemically, sucrose is one glucose molecule and one fructose molecule linked together. The types of sugars derived from sucrose are explained in Chapter 21.

Lactose
A glucose molecule bound to a galactose molecule forms lactose, one of the few saccharides derived from an animal source. About 5% of fluid milk is lactose, or milk sugar. Some people are unable to digest lactose to its monosaccharides because they lack sufficient lactase, the **enzyme** responsible for breaking down milk sugar into glucose and galactose. The symptoms of lactase deficiency, or lactose intolerance, include gas, bloating, and abdominal pain caused by the disaccharides not being properly digested. In some cheeses, yogurt, and other fermented dairy products, bacteria break down the lactose to lactic acid; therefore, these products can usually be tolerated by lactase-deficient individuals.

Enzyme A protein that catalyzes (causes) a chemical reaction without itself being altered in the process.

Maltose
Two glucose molecules linked together create maltose, or malt sugar. Maltose is primarily used in the production of beer and breakfast cereals and in some infant formulas. This saccharide is produced whenever starch breaks down, for example, in germinating seeds and in human beings during starch digestion.

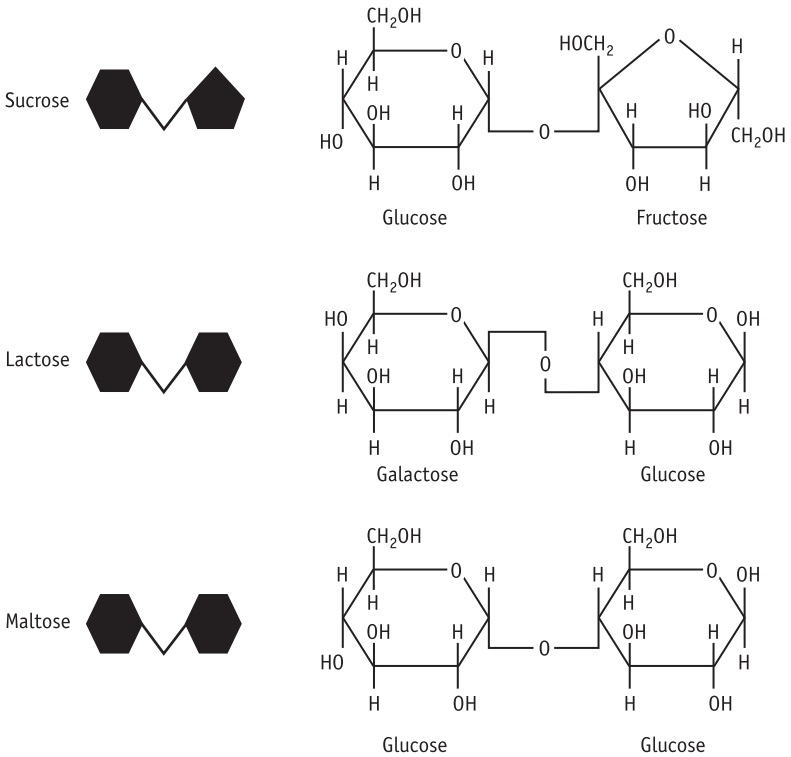
Oligosaccharides
Oligo means "few" in Greek, so compounds made up of three to ten monosaccharides are called oligosaccharides. The two most common are raffinose (three monosaccharides) and stachyose (four monosaccharides). These saccharides, found in dried beans, are not well digested in the human digestive tract, but intestinal bacteria do break them down, forming undesirable gas as a by-product (see "Legumes" in Chapter 13). Fructo-oligosaccharides (FOS) consist of short chains of fructose molecules and are found in certain fruits and vegetables, such as asparagus, bananas, burdock, chicory, garlic, Jerusalem artichoke, leeks, and onions. As prebiotics, they may serve as food for health-promoting colon bacteria (22).

Food Industry Uses
The food industry can use oligosaccharides for bulking agents in low-kcalorie diet foods such as confections, beverages, and yogurt, and as fat replacers in beverages. One benefit of oligosaccharides is that they are not cariogenic, or cavity producing, as are many of the disaccharides. There are twelve classes of food-grade oligosaccharides in commercial production. These are either extracted directly from soybeans or synthesized by building up disaccharides or breaking down starch.

Polysaccharides
Starch, glycogen, and fiber are the polysaccharides most commonly found in foods. Polysaccharides contain many monosaccharides linked together and are divided into two major groups: digestible (starch and glycogen) and indigestible (fiber).

Starch—Digestible Polysaccharide from Plant Sources
The glucose derived from photosynthesis in plants is stored as starch. As a plant matures, it not only provides energy for its immediate needs but also stores energy for future use in starch granules. Microscopic starch granules are found in various foods such as rice, tapioca, wheat, and potato. A cubic inch

FIGURE 3-13 Disaccharides.

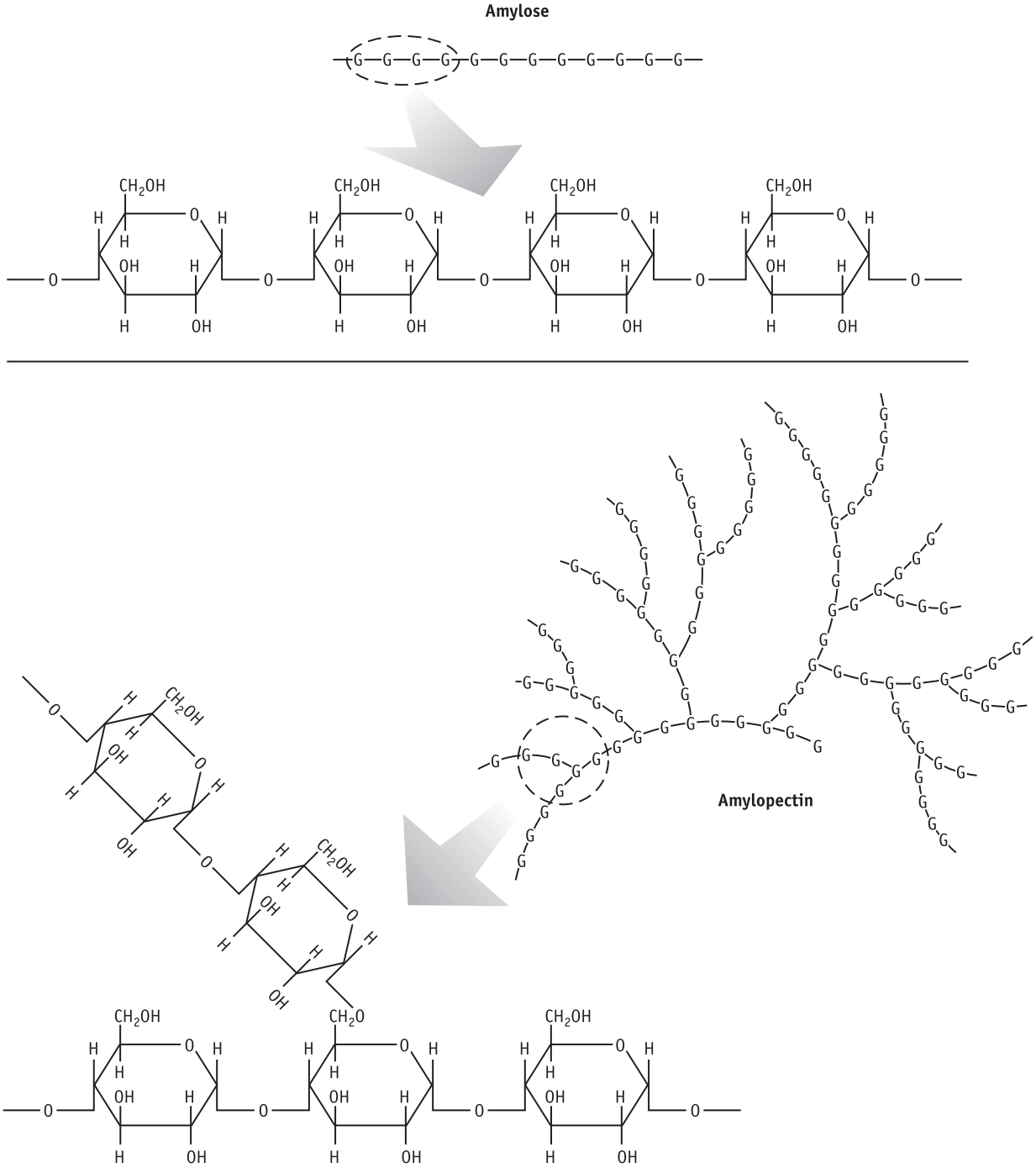


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FIGURE 3-14 Starch consists of a mixture of amylose (straight chain) and amylopectin (branched chain). Each G represents a glucose molecule.



of food may contain as many as a million starch molecules (36). Amylose and amylopectin are the two major forms of starch found in these granules. The glucose units in both of these starch molecules are joined together with a glycosidic bond (alpha-1,4) that is capable of being digested by human enzymes. Amylose is a straight-chain structure of repeating glucose molecules, whereas amylopectin is highly branched with alpha-1,6 bonds (every 15 to 30 glucose units) (Figure 3-14). The majority of starchy foods in their natural state usually contain a mixture of about 75% amylopectin and 25% amylose. These two starches are further explained and illustrated in Chapter 18.

The body can break starch down during digestion into its individual glucose units for absorption. In foods, heat, enzymes, and acid are used to break starches down into smaller, sweeter segments called "dextrins." The sweeter taste of toasted bread, as compared with its untoasted counterpart, comes from the dextrins formed during heating.

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How & Why?

Why do starches from different plant sources differ in their ability to gel?

The concentrations of amylose and amylopectin in a solution determine the starch's ability to hold water. The higher the amylose content, the more likely the starch will gel (form a solid structure) when mixed with water and heated. Cornstarch is high in amylose, whereas potato starch and tapioca are high in amylopectin, so cornstarch will form the gels needed in custards, gravies, and other foods better than tapioca starch.

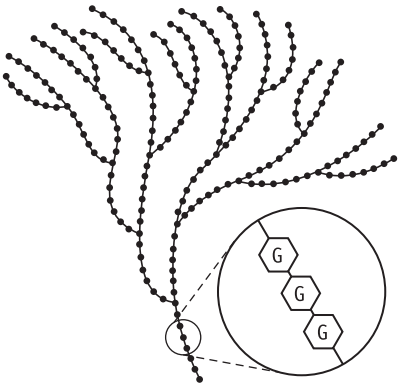
Glycogen—Digestible Polysaccharide from Animal Sources

Glycogen is one of the few digestible carbohydrates found in animals. It is located only in the liver and muscles. Just as glucose is stored by plants as starch, it is stored by animal bodies in long chains of glycogen (Figure 3-15). This highly branched arrangement of glucose molecules serves as a reserve of energy. Glycogen can be quickly hydrolyzed by an animal's enzymes to release the glucose needed to maintain blood glucose levels. The glycogen in meat is converted to lactic acid during slaughtering and so is not present by the time it reaches the table. Shellfish such as scallops and oysters provide a minuscule amount of glycogen, which is why they tend to taste slightly sweet as compared with other fish and plants.

Fiber—Indigestible Polysaccharides

Fiber, also known as roughage or bulk, describes a group of indigestible polysaccharides, oligosaccharides, lignin, and associated plant substances (25). A variety of fiber definitions are accepted by food and nutrition professionals, some based on analytical methods and others on physiological effects (8). According to the AACC (American Association of Cereal Chemists) International, **dietary fiber** is the edible parts of plants that are resistant to digestion and absorption in the human small intestine but undergo fermentation (partial or complete) in the large intestine. Unlike those in starch, the sugar units in fibers are held together by bonds that the human digestive enzymes cannot break. Most fibers, therefore, pass through the human body without providing energy. Fiber is found only in foods of plant origin, especially certain whole-grain cereals, vegetables, and fruits. Plant cells rely on the fiber between their cell walls for structural strength.

FIGURE 3-15 Animals store glucose in the form of glycogen. Each circle represents a glucose molecule.



Measuring Dietary Fiber

Several different laboratory methods are used to measure the amount of fiber in foods. The most reliable is an analytical method approved by the Association of Official Analytical Chemists (AOAC) International. Most recently, the Codex Alimentarius Commission developed a technique that uses an enzymatic-gravimetric method to simulate human digestion and liquid chromatography to determine the amount of water-soluble fiber (25).

Soluble vs. Insoluble Fiber

Chemists classify fibers according to how readily they dissolve in water: soluble fibers dissolve in water, whereas insoluble fibers do not. The insoluble fibers of foods act as a sponge in the intestine by soaking up water. This increases the softness and bulk of the stool and may thereby decrease the risk of constipation, and possibly **diverticulosis** and colon cancer (27). Scientists have also suggested that soluble fibers may benefit health by lowering high blood cholesterol levels and reducing high blood glucose in type 2 diabetes (20). Foods containing fiber usually have a mixture of both soluble and insoluble fiber. Foods high in soluble fiber include dried beans, peas, lentils, oats, rice bran, barley, and oranges. Insoluble fibers are found predominantly in whole wheat (wheat bran) and rye products, as well as bananas.

The Institute of Medicine recommends that the terms "*soluble*" and "*insoluble fibers*" no longer be commonly used to classify dietary fibers even though they may still appear on some food labels. Both are considered *functional fibers*—indigestible carbohydrates that have beneficial physiological effects in humans. The term "*total fiber*" refers to the sum of dietary fiber and functional fiber (19).

Common Fibers and Their Food Industry Uses

The most common fibers are cellulose, hemicelluloses, and pectic substances. A few other types of fiber include vegetable gums, inulin, beta-glucan, oligosaccharides, fructans, some resistant starches, and lignin—one of the few fibers that is not a carbohydrate (19).

Cellulose Cellulose is one of the most abundant compounds on earth. Every plant cell wall is partly composed of cellulose, long chains of repeating glucose molecules similar to starch. Unlike those in starch, however, the chains do not branch, and the bonds holding the glucose molecules together cannot be digested by human enzymes (Figure 3-16). As a result, the cellulose fiber is not absorbed, provides no energy, and simply passes through the digestive tract. The digestive systems of herbivores such as cattle, horses, goats, and sheep have the proper enzymes to digest cellulose, allowing them to use the energy from glucose found in grass and other plants.

Hemicelluloses Hemicelluloses are composed of a mixture of monosaccharides. The most common

Dietary fiber The undigested portion of carbohydrates remaining in a food sample after exposure to human digestive enzymes.

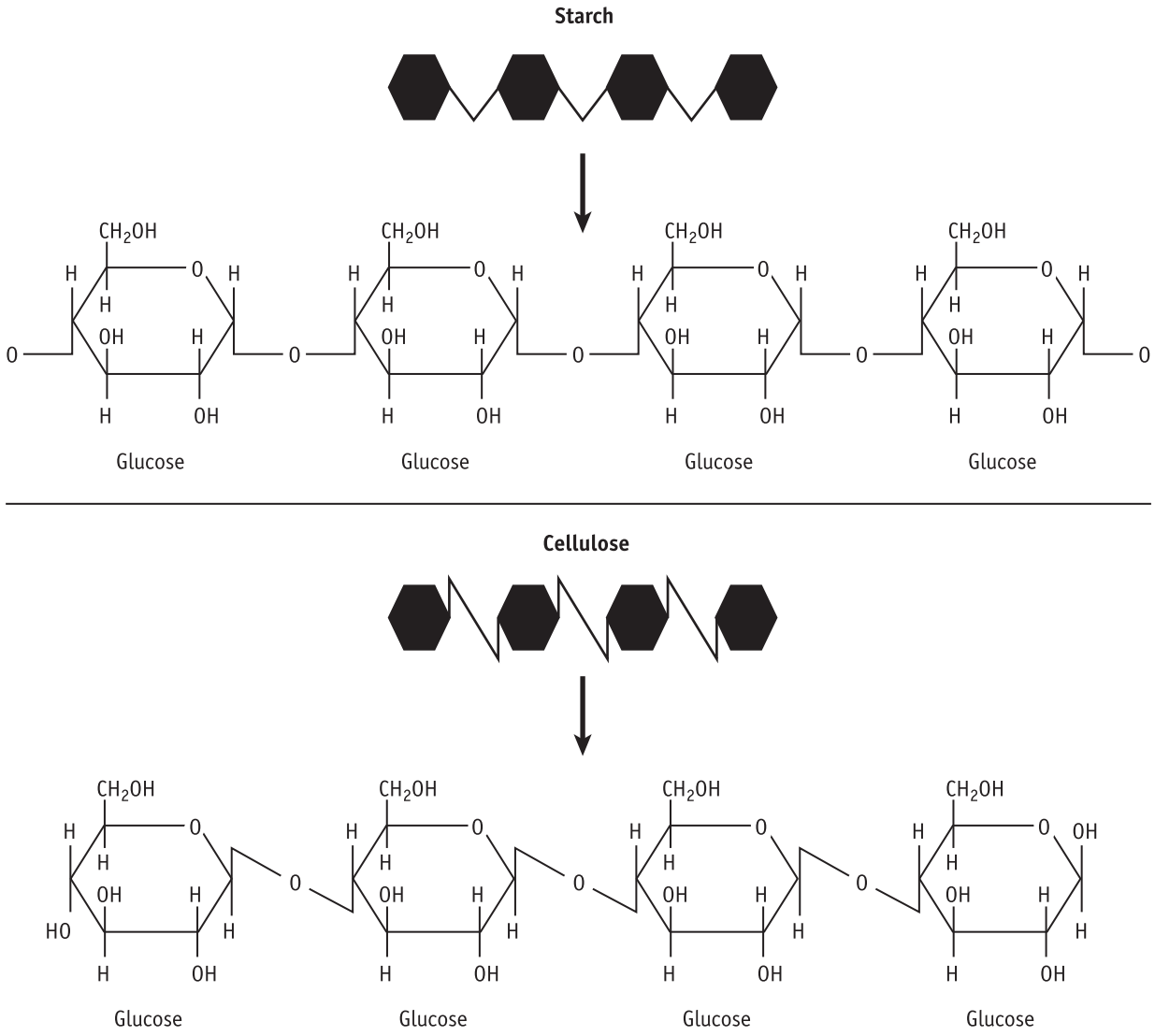
Diverticulosis An intestinal disorder characterized by formation of pockets that bulge out from the digestive tract, especially the colon.

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FIGURE 3-16 The bonds differ between the glucose molecules in starch (alpha-1,4) and cellulose (beta-1,4). The latter is not digestible by humans.



monosaccharides comprising the backbone of hemicelluloses are xylose, mannose, and galactose; the common side chains are arabinose, glucuronic acid, and galactose. Baking soda is sometimes added to the water in which green vegetables are boiled to maintain their color. Unfortunately, it breaks down the hemicelluloses of the vegetables, causing them to become mushy.

Pectic Substances These polysaccharides found between and within the cell walls of fruit and vegetables include protopectin, pectin, and pectic acid. Pectic substances act as natural cementing agents, so they are extracted from their source foods by the food industry for use in thickening jams, jellies, and preserves; keeping salad dressings from separating; and controlling the texture and consistency of a variety of foods. Not all the pectic substances can be used for gelling purposes, however, and the amounts that can be obtained vary depending on the ripeness of the fruit or vegetable. The pectin found in ripe, but not overripe, fruit is responsible for gel formation in jams. Protopectin and pectic acid are prevalent in unripe and overripe fruit, respectively, and are insufficient themselves to cause gel formation. Further details on the use of pectins by the food industry for the formation of jams, jellies, and preservers are covered in Chapter 14.

Vegetable Gums Vegetable gums belong to a group of polysaccharides known as hydrocolloids. Composed of simple sugars, gum fibers are used by the food industry to thicken, increase viscosity of, gel, stabilize, and/or emulsify certain processed foods (33). They impart body, texture, and mouthfeel to foods, while also making it less likely that dispersed ingredients will separate. In addition, the gums' "water-loving" nature combined with their ability to bind as much as one hundred times their weight in water contribute a certain desirable appearance, texture, and stability to food products (26). As shown in Figure 3-17, gums may be derived from plants or from a bacterium (10).

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FIGURE 3-17 Natural and synthetic gums used by the food industry.

Gum Source	Examples	Structure	Selected Function[1]	Selected Foods[1]
Plant exudates[2]	Gum Arabic	Galactose, arabinose, rhamnose, glucuronic acid, arabino-galactan-protein complex (AGP)	Emulsifier, flavor stabilizer, film former, enhances mouthfeel in beverages	Flavor emulsions, candy coating, icing, beverages
	Gum karaya	Galacturonic acid, galactose, rhamnose, glucuronic acid	Gelling	Bakery goods, French dressing, ice pops (prevents ice crystals, bleeding of free water), ground meats, meringues
	Gum tragacanth	Polymer of galacturonic acid, galactose, arabinose, xylose	Emulsifier, thickener	Dressings, sauces, tomato-based products, milkshake
Seeds	Guar gum	Mannose and galactose	Provides mouthfeel to dairy, thickens, stabilizer, moisture retention	Ice cream, breads, dressings, sauces, baked goods
	Locust (carob) bean gum	Galactose, mannose	Provides heat/shock resistance to ice cream, prevents whey off in dairy, texture	Sauces and gravy, ice cream, cottage cheese, frozen foods
Seaweeds	Agar-agar	Alpha-D-galactopyranosyl and 3,6-anhydro-alpha-L-galactopyranosyl	Gelling agent, suspends particulates, melting-point management	Yogurt, bakery glazes, icings, confections
	Alginates	D-mannuronic acids and L-glucuronic acids	Gelling, controls syneresis, improves cooking yield and texture in meat	Frozen desserts, pie filling, meat sauce, dairy, beverages
	Carrageenan	Sulfated linear polysaccharide of D-galactose	Improves mouthfeel, controls syneresis, suspension, binder gelation	Sauces, pudding, whipped toppings, chocolate milk, meat, pie filling, ice cream
	Furcellaran (Danish agar)	Sulfated polysaccharide of D-galactose	Gelling	Jams and jellies
Microbial[3]	Xanthan gum	D-glucose, D-mannose, and D-glucuronic acids	Stabilizes and emulsifies salad dressings and sauces, improves cling, suspends particulates, controls moisture in refrigerated dough	Salad dressings and sauces, refrigerated dough, dry mixes, bakery emulsions
Plant fibers	Cellulose gum	Glucose	Stabilizer, thickener, moisture retention	Egg (frozen/dried), syrup, milk, cakes
	Konjac (elephant yam)	Glucose and mannose (40% glucomannan) with some acetyl substituted groups	Viscosity, forms strong films, gelling agent	Jellies, diet food
Synthesized	Carboxymethyl cellulose (CMC)	Glucose	Provides mouthfeel to beverages, provides structure and freeze/thaw stability, ice crystal growth management, thickener	Dietetic foods, bakery goods, syrups, frozen dairy, puddings, ice cream
	Hydroxypropyl methylcellulose	Glucose	Firm texture, stabilize foam	Soy burgers, whipped cream
	Hydroxypropyl cellulose	Glucose	Thickener, emulsion stabilizer	Dairy, batter and breaded coatings

[1]Only a few examples of the many functions and food uses for gums were selected.
[2]Sap-like oozings from injured plants.
[3]Produced from fermentation by the Xanthomonas campestris bacterium.
Sources: Adapted by Amy Brown from www.ticgums.com, www.gumtech.com, www.foodadditives.org, and www.marcelcarrageenan.com, jorgegonzalez/istockphoto.com.

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Vegetable gums are normally sold as a dry powder and are used extensively as stabilizers in the production of low-kcalorie salad dressings, confections, ice cream, puddings, and whipped cream. Gums are also used in many frozen products because they control crystal growth, yield optimal texture, and make the food more stable in the freezing and thawing process. Typical food industry applications of several gums are listed in Figure 3-17. Agar gum, for instance, can be used for quick-drying frostings and to reduce chipping or cracking in glazed doughnuts (40).

Inulin Inulin consists of repeating units of fructose with an end molecule of glucose. Although this soluble fiber occurs naturally in more than 30,000 plants, it is most commonly found in asparagus, Jerusalem artichoke, and garlic. Commercial processors extract inulin from the chicory root (24), and it is used by the food industry to impart a creamy texture to frozen dairy products such as no-fat or no-sugar ice cream, improve the textures of margarine spreads, and develop no-fat icings, fillings, and whipped toppings.

Lignin Lignin is the one fiber that is not a carbohydrate. Instead of saccharides, it consists of long chains of **phenolic** alcohols linked together into a large, complex molecule. As plants mature, their cell walls increase in lignin concentration, resulting in a tough, stringy texture. This partially explains why celery and carrots get tougher as they age. Boiling water does not dissolve or even soften the lignin.

Functions of Carbohydrates in Foods

Carbohydrates play numerous roles in foods. Saccharides or sugars contribute to sweetness, solubility, crystallization, color (through browning), moisture absorption, texture, fermentation, and even preservation. These functions are described in Chapter 21. Starches also have many roles in food, including as a thickening agent, edible film, and sweetener source (syrups) (see Chapter 18).

LIPIDS (FATS)

The fats and oils in foods belong to a group called *lipids*. Lipids are commonly called "fats" when their content in foods is under discussion; although this terminology is not precisely accurate, this textbook will follow this generally accepted practice. Fats and oils are differentiated in two ways: (1) fats are solid at room temperature, whereas oils are liquid; and (2) fats are usually derived from animal sources, whereas oils are derived predominantly from plants. Three exceptions are coconut and palm oils, which are solid at room temperature, and fish oils, which, at the same temperature, are liquid.

Foods High in Lipids

The foods that are high in fats from animal sources include meats, poultry, and dairy products. Plant food sources high in fat include nuts, seeds, avocado, olives, and coconut. Most fruits, vegetables, and grains, however, contain little, if any, fat. Invisible fats are those not easily observed in foods, such as the marbling in meat. Visible fats, such as the white striations found in bacon and the outside trim on meats, are easily seen. Vegetable oils, butter, margarine, shortening, lard, and tallow are also obvious visible fats.

Composition of Lipids

Lipids, like carbohydrates, are composed of carbon, hydrogen, and oxygen atoms but in differing proportions. One way to determine whether a substance is a lipid is to test whether it will dissolve in water. Lipids are not water soluble but can be dissolved in organic solvents not used in food preparation, such as benzene, chloroform, ether, and acetone. Acetic acid, which is responsible for the sour taste of vinegar, is the one lipid that will dissolve in water because its molecule is so small. Edible lipids are divided into three major groups: triglycerides (fats and oils), phospholipids, and sterols.

Triglycerides

About 95% of all lipids are triglycerides, which consist of three ("tri") fatty acids attached to a glycerol molecule (Figure 3-18; Chemist's Corner 3-9). (Two fatty acids linked to the glycerol molecule form a diglyceride, whereas one fatty acid linked to glycerol is a monoglyceride.) The fatty acids on the glycerol can be identical (simple triglyceride) or different (mixed triglyceride).

CHEMIST'S CORNER 3-9

Chemical Formation of Triglycerides

Few fatty acids occur free in foods, but rather they are incorporated into triglycerides. Each fatty acid has an acid group (–COOH) on one end and a methyl group ($-CH_3$) on the other end. The fatty acids are attached to the glycerol molecule by a condensation reaction: the hydrogen atom (H) from the glycerol and a hydroxyl (–OH) group from a fatty acid form a molecule of water (Figure 3-18). When a fatty acid reacts like this with an alcohol such as glycerol, the resulting compound is called an ester. Because *acyl* refers to the fatty acid part of an ester, the more accurate term for a triglyceride is *triacylglycerol* (18).

Fatty Acids

Fatty Acid Structure

Fatty acids differ from one another in two major ways: (1) their length, which is determined by the number of carbon atoms; and (2) their degree of *saturation,* which is determined by the number of double bonds between carbon atoms. The number of carbons can range from two to twenty-two, with the number usually being even. A fatty acid is said to be saturated if there are no double bonds between carbons—every carbon on the chain is bonded to two

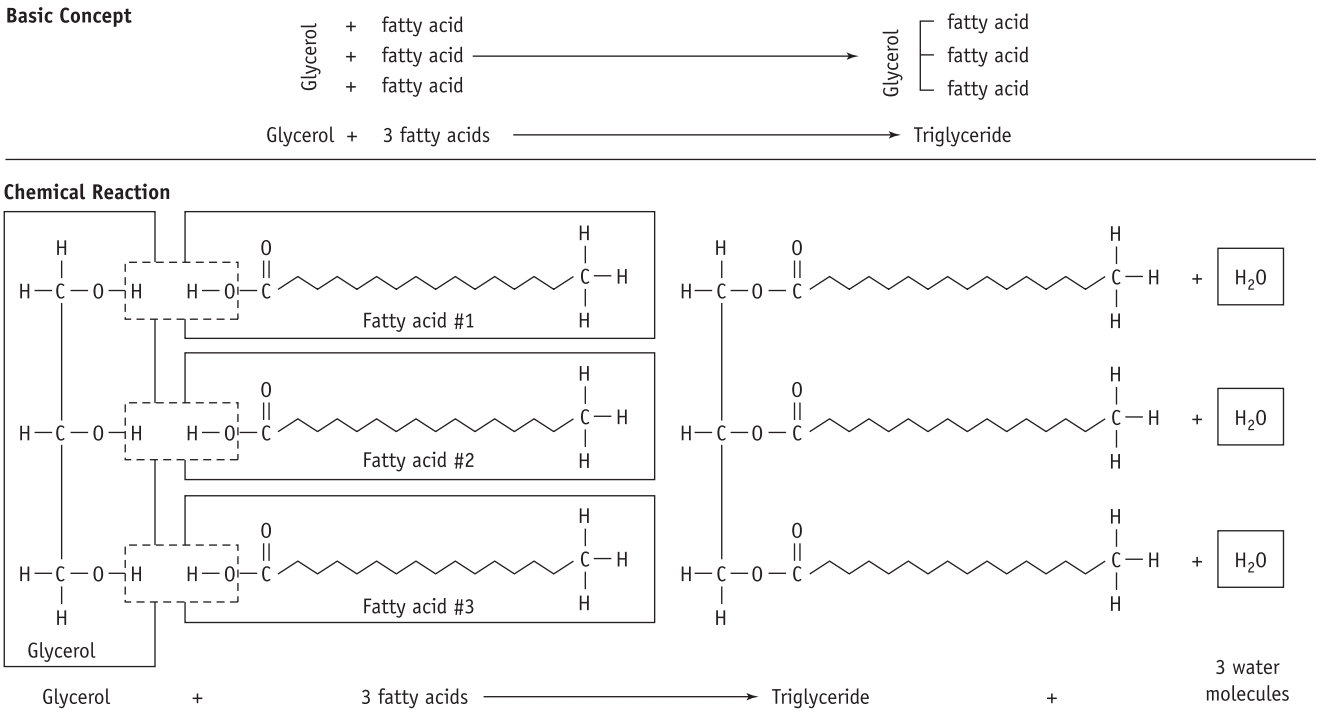
Phenolic A chemical term to describe an aromatic (circular) ring attached to one or more hydroxyl (–OH) groups.

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FIGURE 3-18 A triglyceride (fat) is made by combining three fatty acids with a glycerol molecule. Water is released as a by-product.



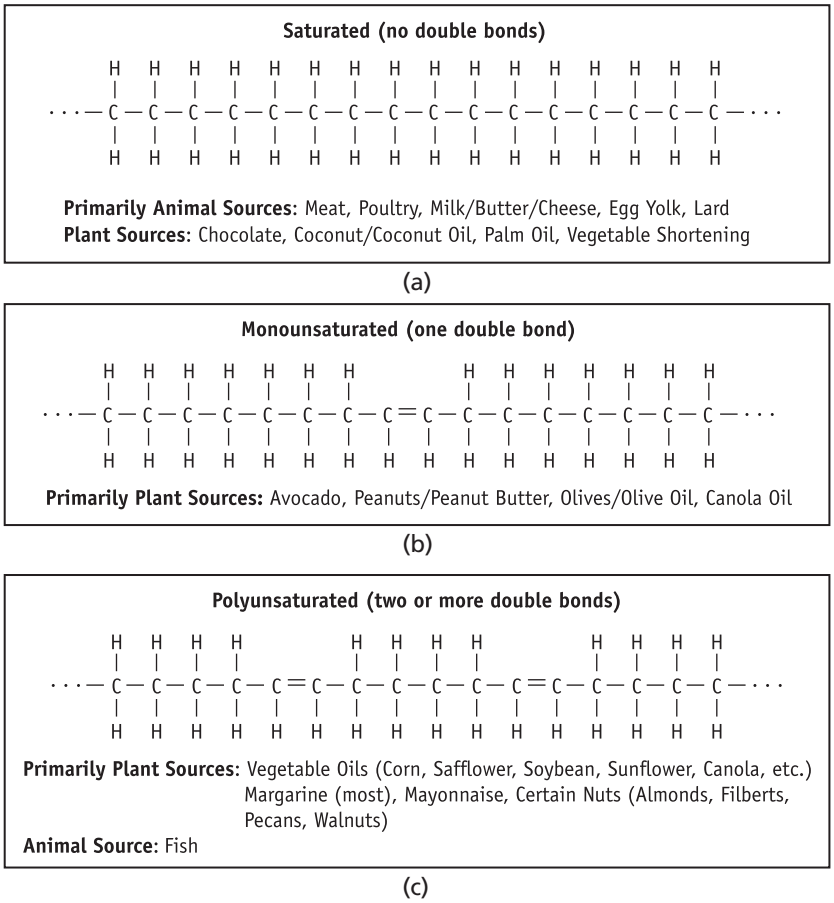
hydrogens and therefore fully loaded. If one hydrogen from each of two adjacent carbons is missing, the carbons form a double bond with one another (a point of unsaturation). A fatty acid with one double bond present is called a monounsaturated fatty acid. If there are two or more double bonds in the carbon chain of a fatty acid, the fatty acid is polyunsaturated (Figure 3-19).

The degree of unsaturation of the fatty acids in a fat affects the temperature at which it melts. Generally, the more unsaturated a fat, the more liquid it remains at room temperature. In contrast, the more saturated a fat, the firmer its consistency. Thus, vegetable oils containing mostly monounsaturated or polyunsaturated fatty acids are generally liquid at room temperature, whereas largely saturated animal fats are solid.

Fatty Acids in Foods

Most foods contain all three types of fatty acids—saturated, monounsaturated, and polyunsaturated—but one type usually predominates. Generally speaking, most vegetable and fish oils are high in polyunsaturates, whereas olive and canola oils are rich in monounsaturates. The animal fats, as well as

FIGURE 3-19 Fatty acids differ in their degree of saturation.



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CHEMIST'S CORNER 3-10

Naming Chemical Compounds

Billions of compounds exist in nature. This vast number does not even include the compounds that are synthesized in a laboratory. At first, people named compounds after people, places, and things, but that proved too cumbersome. Scientists then developed a system to name chemical substances, known as *chemical nomenclature*, and this is defined as the systematic naming of chemical compounds. In chemistry, the systematic name literally describes the chemical construction of the compound. The International Union of Pure and Applied Chemistry (IUPAC) is the official organization responsible for mandating the nomenclature of all chemical compounds. Learn more about the IUPAC through their website at www.iupac.org.

TABLE 3-3 Nomenclature Methods for Selected Fatty Acids

Common Name	Systematic Name	Numerical Ratio No. of C Atoms: No. of Double Bonds
Butyric	Butanoic	4:0
Linoleic	9, 12-octadecadienoic	18:2
Linolenic	9, 12, 15-octadecatrienoic	18:3

coconut and palm oils, are more saturated. Overall, foods of animal origin usually contain approximately a 50:50 **P/S ratio** of polyunsaturated and saturated fats, whereas for plant foods, the ratio is usually 85:15. The higher the P/S ratio, the more polyunsaturated fats the food contains.

Fatty Acid Nomenclature

Each fatty acid is identified by a common name, systematic name (Chemist's Corner 3-10), chemical configuration (Chemist's Corner 3-11), or numerical ratio (Table 3-3). Usually a fatty acid is referred to by its common name, whereas the systematic name is used when a more precise chemical nomenclature is required. The numerical ratio is a type of chemical shorthand that conveys the carbon chain length and degree of saturation of a fatty acid. For example, palmitic acid is a saturated fatty acid that is represented by 16:0, meaning that it is sixteen carbons long with zero double bonds. Approximately forty fatty acids are found in nature. Some of the more common fatty acids are butyric acid, found in butter, and the two fatty acids that are **essential nutrients**—linoleic and linolenic.

Phospholipids

Phospholipids are similar to triglycerides in structure, in that fatty acids are attached to the glycerol molecule. The difference is that one of the fatty acids is replaced by a compound containing phosphorus, which makes the phospholipid soluble in water, whereas its fatty acid components are soluble in fat (Figure 3-22). Phospholipids are very important in the body as a component of cell membranes, where they assist in moving fat-soluble vitamins and hormones in and out of the cells. Foods that naturally contain phospholipids include egg yolks, liver, soybeans, wheat germ, and peanuts.

Food Industry Uses

The dual nature of phospholipids makes them ideal **emulsifiers**. The best-known phospholipid is lecithin, which is found in egg yolks. Lecithin acts as an emulsifying agent that allows **hydrophobic** and **hydrophilic** compounds to mix. This natural function of phospholipids results in their wide use by the food industry as emulsifiers in such products as beverages, baked goods, mayonnaise, and candy bars.

Sterols

Sterols are large, intricate molecules consisting of interconnected rings of carbon atoms with a variety of side chains attached. Many compounds important in maintaining the human body are sterols, including cholesterol, **bile**, both sex (testosterone, estrogen) and adrenal (cortisol) hormones, and vitamin D. The sterol of most significance in foods is cholesterol (Figure 3-23). Although both animal and plant foods contain sterols, cholesterol is found only in foods of animal origin, such as meat, poultry, fish, fish roe (caviar), organ meats (liver, brains, kidneys), dairy products, and egg yolks. Plants do not contain cholesterol, but they may contain other types of sterols.

Plant Sterols

Sterols are found in small amounts in many fruits; vegetables; nuts; seeds; cereals; legumes (beans, peas, and lentils), including soybeans; and other plant sources (41). The Food and Drug Administration (FDA) allows the use of health claims regarding foods containing these substances with regard to the role of plant sterols or plant sterol esters in reducing the risk for coronary heart

P/S ratio The ratio of polyunsaturated fats to saturated fats. The higher the P/S ratio, the more polyunsaturated fats the food contains.

Essential nutrients Nutrients that the body cannot synthesize at all or in amounts sufficient to meet the body's needs.

Emulsifier A compound that possesses both water-loving (hydrophilic) and water-fearing (hydrophobic) properties so that it disperses in either water or oil.

Hydrophobic A term describing "water-fearing" or substances that are not water soluble.

Hydrophilic A term describing "water-loving" or water-soluble substances.

Bile A digestive juice made by the liver from cholesterol and stored in the gallbladder.

Plant stanol esters Naturally occurring substances in plants that help block absorption of cholesterol from the digestive tract.

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CHEMIST'S CORNER 3-11

Cis, *Trans*, and Omega Fatty Acids

Other notations that are frequently encountered when discussing fatty acids are cis, or trans, and omega-3 or omega-6. *Cis* and *trans* describe the geometric shape of the fatty acid. A cis fatty acid has the hydrogens on the same side as the double bond, causing it to fold into a U-like formation. A trans fatty acid has the hydrogens on either side of the double bond, creating a linear configuration (Figure 3-20). Most of the fatty acids in nature are in the cis or slightly V-shaped configuration, whereas trans fatty acids often result from hydrogenation. The difference between the omega-3 and omega-6 fatty acids is the location of the double bond between the third and fourth, or the sixth and seventh, carbon from the methyl group end of the fatty acid molecule (to the left in Figure 3-21), respectively.

FIGURE 3-20 *Cis* or *trans* fatty acids are defined by their chemical configuration at the double bonds.

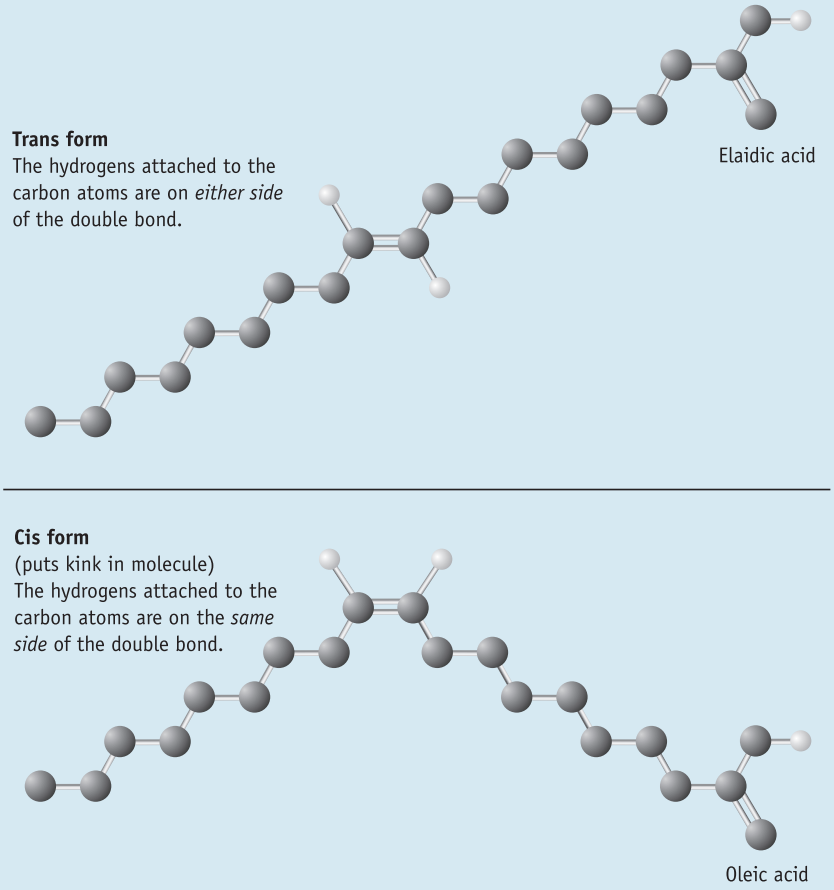
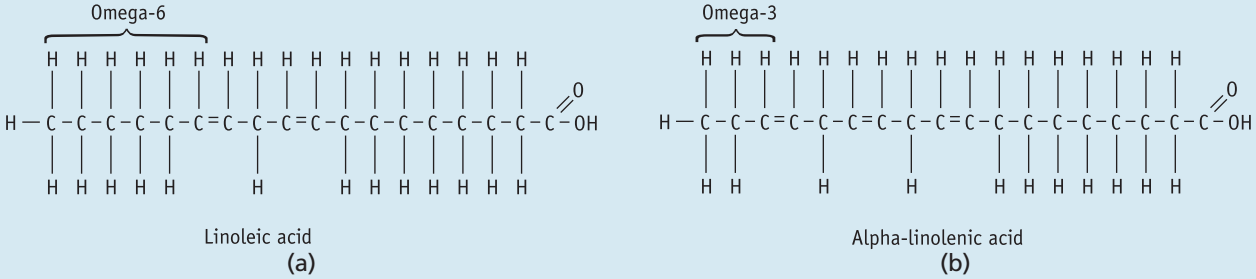


FIGURE 3-21 Omega-3 or omega-6 fatty acids are defined by the location of the first double bond.



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FIGURE 3-22 Phospholipids, such as this lecithin molecule, have a phosphorous-containing compound that replaces one of the fatty acids on a triglyceride. Each compound in the lecithin molecule is derived from simpler molecules (see arrows).

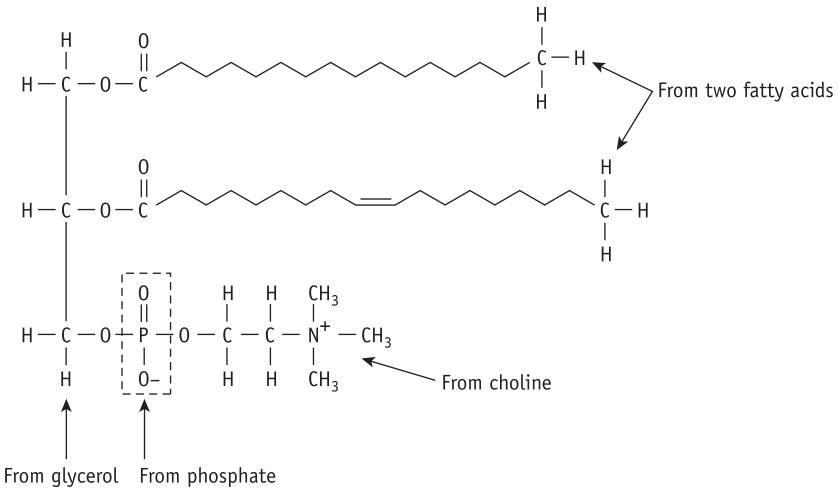
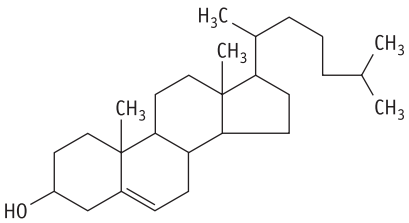


FIGURE 3-23 Cholesterol is a lipid found in foods of animal origin.



Cholesterol

disease. To qualify for a claim, the food must contain at least 0.65 gram of plant sterol esters or 1.7 grams of **plant stanol esters** per serving. It also must not contain more than 13 grams of total fat per serving and per 50 grams. Spreads and salad dressings are exempted if the label refers the consumer to the product's Nutrition Facts panel (12).

Functions of Lipids in Foods

Chapter 22 discusses the roles of lipids in foods, which include heat transfer during food preparation; contributing to the tenderness, mixing (emulsifying), texture (melting, plasticity, solubility), and flavor of foods; and increasing one's feeling of fullness after eating (satiety).

PROTEINS

Proteins derive their name from the Greek word *proteos,* of "prime importance." The body can manufacture most of the necessary carbohydrates (except fiber) and lipids (except a few essential fatty acids) it needs, but when it comes to protein, the body can synthesize only about half of the compounds it requires in order to manufacture the proteins needed for the body. These substances needed for protein manufacture are called amino acids. Of the twenty-two amino acids, nine are essential nutrients and thus must be obtained daily from the diet (Table 3-4).

Protein Quality in Foods

Foods vary in their protein quantity and quality. Most protein from animal sources—meat, poultry, fish and shellfish, milk (cheese, yogurt, etc.), and eggs—is **complete protein**. Gelatin is one of the few animal proteins that is not complete. Plant protein, with the exception of that from soybeans and certain grains (quinoa and amaranth), is **incomplete protein** and will support maintenance but not growth. To obtain complete protein primarily from plant sources, it is necessary to practice the strategy of **protein complementation**. The best sources of protein from plants are the legumes—beans, peas, and lentils—which are often combined with grains.

TABLE 3-4 Essential and Nonessential Amino Acids

Classification	Amino Acid
Essential for all humans	Histidine
	Isoleucine
	Leucine
	Lysine
	Methionine
	Phenylalanine
	Threonine
	Tryptophan
	Valine
Nonessential	Alanine
	Arginine
	Asparagine
	Aspartic acid
	Cysteine
	Glutamic acid
	Glutamine
	Glycine
	Proline
	Serine
	Tyrosine
Related compounds sometimes classified as amino acids	Carnitine
	Cystine
	Hydroxyglutamic acid
	Hydroxylysine
	Hydroxyproline
	Norleucine
	Taurine
	Thyroxine

Composition of Proteins

One key way in which proteins differ from carbohydrates and lipids is that proteins contain nitrogen atoms,

Complete protein A protein, usually from animal sources, that contains all the essential amino acids in sufficient amounts for the body's maintenance and growth.

Incomplete protein A protein, usually from plant sources, that does not provide all the essential amino acids.

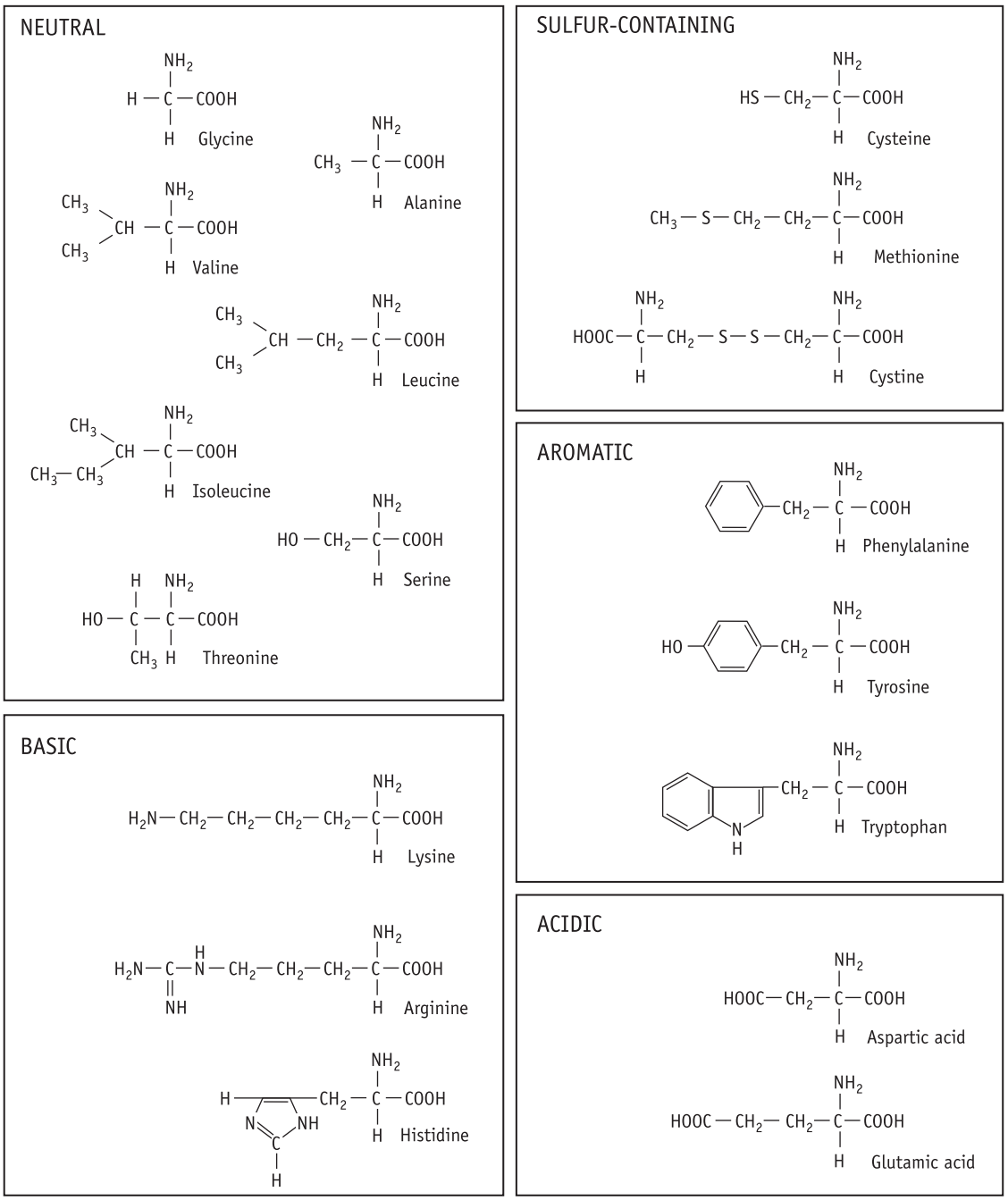
Protein complementation Two incomplete-protein foods, each of which supplies the amino acids missing in the other, combined to yield a complete protein profile.

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FIGURE 3-24 An amino acid's chemical nature is determined by its side group.



whereas carbohydrates and lipids contain only carbon, hydrogen, and oxygen atoms. These nitrogen atoms give the name "amino," meaning "nitrogen-containing," to the amino acids of which protein is made. Protein molecules resemble linked chains, with the links being amino acids joined by **peptide bonds**. A protein strand does not remain in a straight chain, however. The amino acids at different points along the strand are attracted to each other, and this pull causes some segments of the strand to coil, somewhat like a metal spring. In addition, each spot along the coiled strand is attracted to, or repelled from, other spots along its length. This causes the entire coil to fold this way and that, forming a globular or fibrous structure.

Peptide bond The chemical bond between two amino acids.

Amino Acids

Each protein has its own specific sequence of amino acids. The twenty-two amino acids that exist in nature are like an alphabet, forming the "letters" of the "words"—proteins—that make up the language of life itself. All amino acids have the same basic structure—a carbon with three groups attached to it: an amine group ($-NH_2$), an acid group ($-COOH$), and a hydrogen atom (H) (Figure 3-24). Attached to the carbon

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at the fourth bond is a side chain called an R group. This fourth attachment, the side chain, is different for each amino acid and gives the amino acid its unique identity and chemical nature. The simplest amino acid is glycine, with only a hydrogen for the R group. In other amino acids, the R group may consist of carbon chains or cyclic structures. Amino acids that are acidic contain more acid groups (–COOH) than amine groups ($–NH_2$), whereas alkaline amino acids contain more amine than acid groups.

Functions of Proteins in Food

The proteins in foods allow several important reactions to occur during food preparation:

- Hydration
- Denaturation/coagulation
- Enzymatic reactions
- Buffering
- Browning

Hydration

The ability of proteins to dissolve in and attract water, a process called "hydration," allows them to play several important roles in foods. One of these is the capability to form a gel, an intricate network of protein strands that trap water, resulting in a firm structure. Another is to aid in dough formation to produce numerous bread products.

Food Industry Uses

Proteins from milk, meat, egg, and soy are used in a variety of gels (Chemist's Corner 3-12). The gelling ability of proteins allows them to be used as binders, stabilizers, and thickeners in a variety of foods such as preserves, confectioneries (gums, marshmallows), and desserts (ice cream, puddings, custards, pie fillings, mousses, and gelatins). Sausages and gelled fish products also rely on the ability of proteins to gel. See Chapter 15 for the use of animal protein in the formation of gelatin products.

Another example of protein's hydrating ability in food preparation is in bread making. Water or milk is combined with yeast and the two major proteins of wheat—gliadin and glutenin—through the process of kneading to yield the protein gluten, whose elastic qualities allow it to stretch with the carbon dioxide gas produced by the yeast during fermentation. This is how bread rises, and without protein's ability to hydrate, rising would not take place.

CHEMIST'S CORNER 3-12

Protein Gels

The different types, concentrations, and interactions of proteins in any given food determine the overall resulting gel strength. Myosin has the highest gel-forming ability of all the muscle proteins, but the whole myofibrillar protein fraction, sarcoplasmic proteins, and connective-tissue proteins can also gel (37).

Denaturation/Coagulation

Large protein molecules are sensitive to their surroundings. When subjected to heat, pH extremes, alcohol, and physical or chemical disturbances, proteins undergo **denaturation**. Denaturation can result in **coagulation**, which is described as a curdling or congealing of the proteins. Both denaturation and coagulation are irreversible in most proteins. Examples include the hardening of egg whites with heating, the formation of yogurt as bacteria convert lactose to lactic acid and lower the pH, and the stiffening of egg whites when they are whipped (21).

Food Industry Uses

Foam formation depends on denaturing the protein found in eggs through mechanical disruption. After the foam forms, adding sugar to beaten egg whites helps to stabilize the delicate denatured proteins; therefore, sugar is often added near the end of whipping, just before the egg whites have reached their optimal consistency. Foams produced by milk and eggs are discussed in Chapter 10 and Chapter 12, respectively.

Cheese production (discussed in Chapter 11) also relies on the coagulation of proteins, which is speeded up by adding salt. Cheese is made by creating a curd (hard mass) composed of denatured milk proteins that collapse together. The enzymes that break down milk proteins are enhanced by adding salt, which is why salt is frequently used by cheese makers to help produce a firm curd.

CHEMIST'S CORNER 3-13

Enzyme Classification

Most enzymes are grouped into one of six different classes according to the type of reaction they catalyze (42). Hydrolases are the most common enzymes used by the food industry; they catalyze hydrolytic reactions. These hydrolytic enzymes break, or cleave, a chemical bond within a molecule by adding a molecule of water. Water is, in fact, broken apart as its two hydrogens and oxygen become part of the two new molecules formed. Examples of hydrolases include lipases that hydrolyze lipids, proteases that hydrolyze protein, and amylases that hydrolyze starch.

Another type of enzyme, the oxidoreductase, catalyzes oxidation-reduction reactions. This type includes dehydrogenases, which act by removing hydrogen, and oxidases, which add oxygen.

Lyases assist in breaking away a smaller molecule, such as water, from a larger substrate. Transferases, as their name implies, transfer a group from one substrate to another. Ligases catalyze the bonding of two molecules. The last type, isomerases, transfer groups within molecules to yield isomeric forms.

Enzymatic Reactions

Enzymes (or biocatalysts) are one of the most important proteins formed within living cells because they act as biologic catalysts to speed up chemical reactions (Chemist's Corner 3-13). Thousands of enzymes reside in a single cell, each one a catalyst that facilitates a specific chemical reaction. Without enzymes, reactions would occur in a random and

Denaturation The irreversible process in which the structure of a protein is disrupted, resulting in partial or complete loss of function.

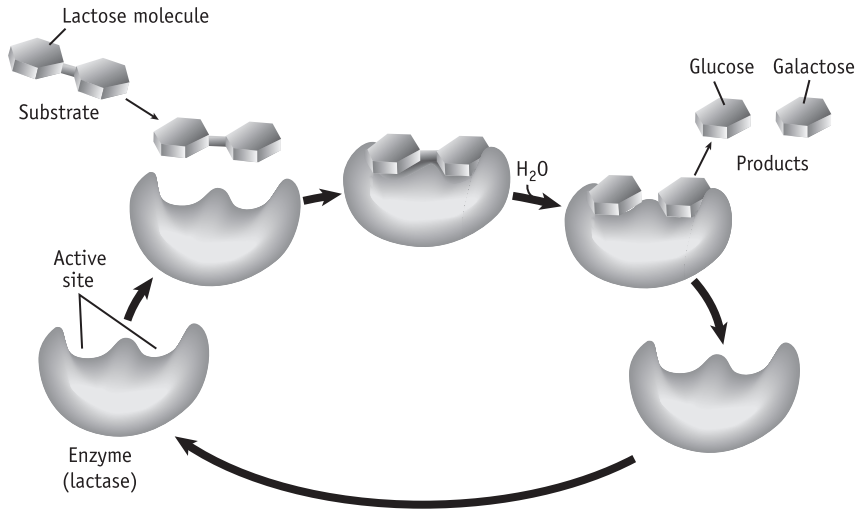
Coagulation The clotting or precipitation of protein in a liquid into a semisolid compound.

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FIGURE 3-25 Lactase enzyme hydrolyzing lactose to glucose and galactose.



Enzymes are like three-dimensional puzzle pieces that fit alone or with the help of a coenzyme (usually a vitamin) or a cofactor (usually a mineral).

Enzymes catalyze thousands of reactions per second without being changed themselves.

indiscriminate manner. The lock-and-key concept describes enzyme action (Figure 3-25). An enzyme combines with a substance, called a **substrate**, catalyzing or speeding up a reaction, which releases a product. The enzyme is freed unchanged after the reaction and is able to react with another substrate, yielding another product.

Enzyme Nomenclature

The names of most enzymes end in *-ase*. Enzymes are usually named after the substrate they act upon or the resulting type of chemical reaction. For example, sucrase is the enzyme that acts on sucrose, and lactase breaks down lactose to glucose and galactose. This general nomenclature rule does not always apply; for example, the enzyme papain is named after papaya, from which it is derived, and ficin gets its name from figs. These enzymes, obtained from fruits, are used in meat tenderizers to break down meat's surface proteins.

Structure of Enzymes

The overall structure of an enzyme, called the holoenzyme, contains both a protein and a nonprotein portion. Most of the enzyme is protein, but the nonprotein portion, which is necessary for activity, is either a coenzyme (usually a vitamin) or a cofactor (usually a mineral).

Substrate A substance that is acted upon, such as by an enzyme.

Factors Influencing Enzyme Activity

Enzymes are readily inactivated and will operate only under mild conditions of pH and temperature. Because enzymes are primarily protein, they are subject to denaturation caused by extremes in temperature or pH or even by physical and/or chemical influences. Every enzyme has an optimal temperature and pH for its operation, but most do best in the 95 to 104°F (35 to 40°C) range and with a pH near neutral.

Food Industry Uses

Many foods would not be on the market if it were not for certain enzymes. Foods that can be manufactured with the aid of enzymes include wines, cheeses, corn syrups, yogurt, cottage cheese, baked goods, sausages, juices, egg white replacers, the artificial sweetener aspartame, and various Asian foods that rely on molds (33). Examples include the following:

- Rennin, also known as chymosin, aids in cheese production by converting milk to a curd.
- Meats can be tenderized with the enzymes of papain, bromelain, and/or ficin.
- Polyphenol oxidase imparts the characteristic dark hue to tea, cocoa, coffee, and raisins.
- Glucose oxidase has been used for decades in the desugaring of eggs, flour, and potatoes, as well as in the preparation of salad dressings.
- Manufacturers of baked products use enzymes to retard staling, improve flour and dough quality, bleach flour, and enhance crust color.
- Enzymes can also be used in improving the filtration of beer.

Fruit juice processors use enzymes to increase juice yields, enhance juice clarity, improve filtration, reduce bitterness, and speed fruit dehydration. The enzymes most commonly used by fruit juice processors are pectinase, cellulase, hemicellulase, amylase, and arabinase. The bitter compounds in grapefruit juice—naringin and limonin—can be hydrolyzed with naringinase and limonase, respectively (20).

Sometimes the food industry is more interested in inhibiting the action of enzymes. This is the case for lipoxygenase activity in milk, which produces off-flavors (31). The vulnerability of enzymes to high temperatures makes it easy to destroy enzymes that cause the spoilage of fruits and vegetables. Briefly submerging foods (usually vegetables) in boiling water denatures the enzymes that contribute to deterioration. Pasteurization of milk, which is intended to kill harmful bacteria, also halts enzyme activity.

Another major use of enzymes by the food industry is in quality testing of a variety of food products (Table 3-5). A test for ensuring that adequate pasteurization temperatures have been reached is to measure the activity of the phosphatase enzyme that naturally exists in milk. Lack of phosphatase activity indicates that sufficient heat was applied to destroy harmful microorganisms. Fish quality can be measured by using xanthine oxidase, which acts on hypoxanthine, a compound that increases as the fish spoils (20). A strip of absorbent paper soaked partially in xanthine oxidase can be used aboard ships, dockside, or in a food processing plant. The strip of paper is moistened

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TABLE 3-5 Use of Enzymes by the Food Industry to Test for Food Quality

For This Food	Use This Enzyme	To Test for
Fruits and vegetables Milk, dairy products Eggs	Peroxidase Alkaline phosphatase β-acetylglucosaminidase	Proper heat treatment
Oysters Meat	Malic enzyme Glutamate oxaloacetate	Freezing and thawing
Meat, eggs Beans	Acid phosphatase Catalase	Bacterial contamination
Potatoes Pears	Sucrose synthetase Pectinase	Maturity
Fish	Lysolecithinase Xanthine oxidase	Freshness Hypoxanthine content
Flour Wheat	Amylase Peroxidase	Sprouting
Coffee, wheat Meat	Polyphenol oxidase Succinic dehydrogenase	Color

in fish extracts and then observed for color intensity, which is correlated to freshness. Enzymes can also be used to detect bacterial contamination in meat, poultry, fish, and dairy products.

CHEMIST'S CORNER 3-14

Proteins and Buffering

Proteins act as buffers to prevent extreme swings in acidity or alkalinity. This is due to their unique ability to accept or donate H^+. Specifically, amino groups on the amino acids act as bases (accept H^+ to yield $-NH^{3+}$), while the carboxyl groups act as acids (donate H^+ to yield $-COO^-$). When the amino and carboxyl groups are equally ionized (neutralized), the protein reaches its isoelectric point—the point at which its charges become neutral. Most proteins have isoelectric points ranging between pH 4.5 and 7.0. These different isoelectric points make proteins structurally unique and allow them to be separated by electrophoresis, a process in which an electrical field automatically causes the proteins to move on a plate toward each of their own neutral isoelectric points. Proteins do not all have the same isoelectric points, so they stop at different points on the electrified plate and are "separated."

Buffering

Proteins have the unique ability to behave as buffers, compounds that resist extreme shifts in pH (Chemist's Corner 3-14). The buffering capacity of proteins is facilitated by their **amphoteric** nature.

Browning

Proteins play a very important role in the browning of foods through two chemical reactions: the Maillard reaction and enzymatic browning.

Maillard Reaction

The brown color produced during the heating of many different foods comes, in part, from the **Maillard reaction** (Chemist's Corner 3-15). For example, this reaction contributes to the flavors and golden crust of baked products (pretzels, bread, cakes, cookies), the browning of meats, and the dark color of roasted coffees. Temperatures most conducive to the Maillard reaction are those reaching at least 194°F (90°C), but browning can occur at lower temperatures, as seen in dried milk that has been stored too long. The following factors speed up the Maillard reaction:

- Reducing sugars (glucose, fructose, lactose, maltose)
- Proteins (milk or egg)
- High temperatures
- High-pH (alkaline/basic) ingredients (baking soda, sodium bicarbonate)
- Water loss through evaporation and/or high temperatures

Powdered egg whites are prone to browning if stored for long periods of time, so before drying, the eggs are enzymatically treated to remove glucose and thus prevent browning.

CHEMIST'S CORNER 3-15

The Maillard Reaction

In 1912, chemist Louis Camille Maillard discovered that when he heated sugars and amino acids together, the mixture slowly turned brown. It was not until later that the Maillard reaction was also associated with flavor changes. The Maillard reaction occurs in five steps: (1) condensation (amine/carbonyl), (2) rearrangement, (3) fragmentation, (4) Strecker degradation, and (5) polymerization. In step 1, the sugar (free carbonyl group on reducing sugars) reacts with the amino acid (amino group) when heated. Only amino acids with free amino groups—arginine, histidine, lysine, and tryptophan—can participate, and the specific amino acid involved determines the resulting flavor. An alkaline environment stimulates the reaction because it deprotonates the amino groups. The next steps vary. A rearrangement of the resulting compound can serve as the starting point for the main browning reactions. Alternatively, if the amino acid is removed instead, then reactive compounds result that degrade to important flavor and color compounds.

Amphoteric Capable of acting chemically as either an acid or a base.

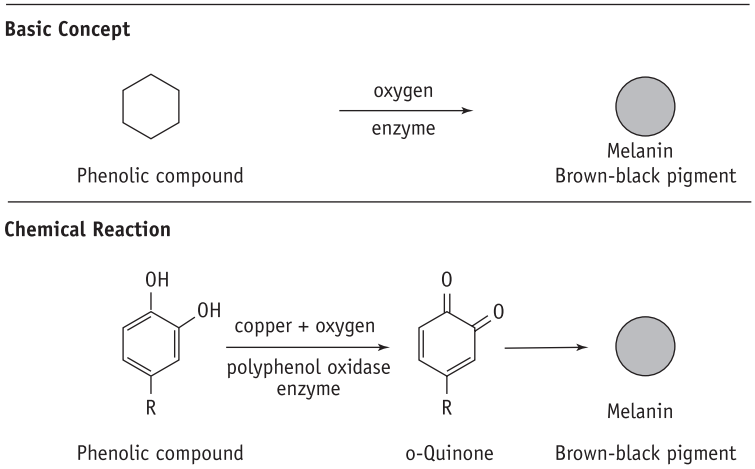
Maillard reaction The reaction between a sugar (typically reducing sugars such as glucose/dextrose, fructose, lactose, or maltose) and a protein (specifically the nitrogen in an amino acid), resulting in the formation of brown complexes.

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FIGURE 3-26 Enzymatic browning.



How & Why?

Why does an apple turn brown when you take a bite out of it and then let it sit?

Enzymatic browning is responsible for the discoloration seen on the cut surface of certain fruits and vegetables. Normally, the cell structure separates the enzymes from the phenolic compounds in the fruit. When the vegetable or fruit is cut or bruised, however, the phenols and enzymes, thus exposed to oxygen, react in its presence to produce brown-colored products. Not all fruits and vegetables contain phenolic compounds, but sliced apples, pears, bananas, and eggplants turn brown rather rapidly after cutting. Potatoes turn slightly pink or gray.

Enzymatic Browning

Enzymatic browning is the result of an entirely different mechanism than the Maillard reaction. It requires the presence of three substances: oxygen, an enzyme (polyphenolase), and a phenolic compound (Figure 3-26).

Enzymatic browning occurs when the enzyme tyrosinase oxidizes the amino acid tyrosine to result in dark-colored melanin compounds such as those observed in dark teas and certain vegetables (lettuce, avocados, and mushrooms) and fruits (see How & Why box) (20). Although the browning from either phenolase or tyrosinase is unappealing in itself, it is harmless. A spritz of lemon juice or another acidic component helps keep certain freshly cut produce from turning brown. Certain vegetables such as potatoes can be blanched (briefly heated) to inactivate the phenolase.

Enzymatic browning A reaction in which an enzyme acts on a phenolic compound in the presence of oxygen to produce brown-colored products.

VITAMINS AND MINERALS

Foods High in Vitamins and Minerals

Most foods contain some vitamins and minerals. Vitamins can be categorized into two major groups: fat-soluble (A, D, E, and K) or water-soluble (B complex and vitamin C). Minerals may be termed either macro or micro (Table 3-6). Meats are good sources of B vitamins, iron (Fe), and zinc (Zn). Dairy foods provide about 80% of the average American's dietary calcium (Ca). Vitamin C (ascorbic acid) is found only in plants. All the fat-soluble vitamins (A, D, E, and K) are found in an egg yolk. Vitamin B_{12} is found naturally only in foods of animal origin or fermented foods such as tempeh, tofu, and miso, which contain bacteria that produce vitamin B_{12} as a by-product. The two major sources of sodium (Na) in the diet are processed foods and the saltshaker.

TABLE 3-6 Major Vitamins and Minerals in Foods

Vitamins	
Water Soluble	**Fat Soluble**
B complex:	Vitamin A
Thiamin (B_1)	Vitamin D
Riboflavin (B_2)	Vitamin E
Vitamin B_6 (pyridoxine)	Vitamin K
Vitamin B_{12} (cobalamin)	
Niacin	
Folate	
Pantothenic acid	
Biotin	
Ascorbic acid (vitamin C)	

Minerals	
Macrominerals (minerals present in the body in relatively large amounts)	**Microminerals (minerals present in the body in relatively small amounts)**
Calcium (Ca)	Iron (Fe)
Phosphorous (P)	Zinc (Zn)
Potassium (P)	Selenium (Se)
Sulfur (S)	Manganese (Mn)
Sodium (Na)	Copper (Cu)
Chlorine (Cl)	Iodine (I)
Magnesium (Mg)	Molybdenum (Mo)
	Chromium (Cr)
	Fluorine (F)

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Composition of Vitamins and Minerals

Vitamins are organic (carbon-containing) compounds, each with a unique chemical composition. Minerals are inorganic elements and are depicted in the periodic table. Unlike vitamins, minerals cannot be destroyed by heat, light, or oxygen. Vitamins and minerals do not provide energy (kcalories).

Functions of Vitamins and Minerals in Food

Enrichment and Fortification

Because of the vital role vitamins and minerals play in the body's processes, many foods are **enriched** or **fortified** with additional vitamins and minerals. During processing and preparation, foods such as wheat and rice may lose some of their vitamin or mineral content. Some of the nutrients, such as vitamin B_1 (thiamin), vitamin B_2 (riboflavin), niacin, and iron (calcium optional), may be added back to the processed food (enrichment). Fortification is intended to deliver nutrients to the general public in an effort to deter certain nutrient deficiencies. In 1922, salt became the first food ever to be fortified, with the addition of iodine. Iodine deficiencies were resulting in goiter (enlarged thyroid gland) and cretinism (dwarfism, mental retardation) in children born of mothers who had not ingested sufficient iodine. Other nutrients that are used to fortify foods include vitamins A and D (milk), calcium (orange juice), and/or folate, a B vitamin (cereal products) (4).

The decision to fortify with a particular nutrient is a complex one. It starts with the realization that a significant number of people are not obtaining desirable levels of a specific nutrient and the determination that the food to be fortified makes an appreciable contribution to the diet. It must be further ascertained that the fortification will not result in an essential nutrient imbalance, that the nutrient is stable under storage and capable of being absorbed from the food, and that toxicity from excessive intakes will generally not occur (35).

Antioxidants and Their Food Industry Uses

Certain nutrients, especially vitamins A, C, and E and the mineral selenium, may also be added to foods to act as **antioxidants**. These compounds neutralize **free radicals** (Figure 3-27), increasing shelf life (28). Foods to which antioxidants are commonly added include dry cereals, crackers, nuts, chips, and flour mixes. Consumer interest in antioxidants and health has also caused manufacturers to add additional amounts of these nutrients to other food products.

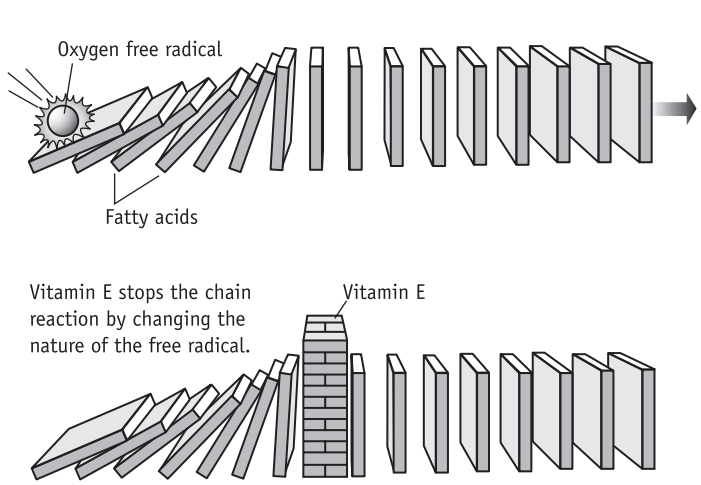
Sodium and Its Food Industry Uses

Another compound in the vitamin/mineral category that is used to preserve foods is salt, the only mineral directly consumed by people. Salt is used for more than preservation of certain foods. It provides flavor to so many processed foods that it is now the second-most common food additive by weight, after sugar, in the United States. Salt in a variety of forms can be purchased and added to products by the food industry: topping salt for saltine crackers, breadsticks, and snack crackers; surface-salting for pretzels, soft pretzels, and bagels; fine crystalline salt for potato chips, corn chips, and similar snacks; blending/dough salts for flour and cake mixes; light salt (potassium chloride) for reducing sodium levels; and encapsulated salt for frozen doughs (29). See Chapter 5 for more on salt and salt substitutes.

NONNUTRITIVE FOOD COMPONENTS

Not everything found in food can be classified within the six basic nutrient groups. All sorts of substances may be present—naturally, intentionally, and/or unintentionally. Natural compounds, whether beneficial or harmful, are discussed in this chapter. Intentional and unintentional food additives are discussed here and in Chapter 29. Among the beneficial compounds naturally found in foods are those that provide color and flavor.

FIGURE 3-27 Antioxidant action of vitamin E.



Enriched Modified by the addition of certain nutrients at levels established by federal standards in order to replace those lost during processing (refers to refined grain products).

Fortified Modified by the addition of nutrients that were not present in the original food.

Antioxidant A compound that inhibits oxidation, which can cause deterioration and rancidity.

Free radicals An unstable molecule that is extremely reactive and that can damage cells.

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FIGURE 3-28 Food additives are available in powder, granule, liquid, or other forms.



istock.com/jorgegonzalez

Food Additives

According to the FDA, a food additive is any substance added to food (Figure 3-28). The more precise legal definition is "any substance the intended use of which results or may reasonably be expected to result—directly or indirectly—in its becoming a component or otherwise affecting the characteristics of any food" (14). More than 3,000 food additives exist, but the 3 most common, by weight, are sugar, salt, and corn syrup. Others that are commonly used include citric acid (from oranges and lemons), baking soda, vegetable colors, mustard, and pepper. These food additives account for 98%, by weight, of all food additives listed on packaged food labels in the United States (1).

The FDA maintains an online list of food additives used in U.S. foods called EAFUS (Everything Added to Foods in the United States). It contains information on more than 3,000 substances added directly to food that are approved by the FDA or listed or affirmed as Generally Recognized As Safe (GRAS) (13). Food additives are referenced by their E number or International Numbering System. The presence of an E number means that it passed safety tests and was approved by the European Union. Other countries may drop the E and just use the number.

Purposes of Food Additives

The purposes of food additives, according to FDA regulations, are to meet one or more of the following four objectives:

1. Improve the appeal of foods by improving their flavor, smell, texture, or color.
2. Extend storage life.
3. Maximize performance.
4. Protect nutrient value.

Many types of ingredients are used to meet these objectives, and a few examples are listed in Table 3-7. The purposes of food additives are now addressed in more detail.

Additives that Improve Appeal

Food appeal can be improved by the addition of coloring, flavoring, and texture-enhancing agents.

Color Compounds

Food additives in this category can be any dye, pigment, or substance that imparts color. Color additives are used to offset color loss due to exposure to air, moisture, temperature changes, light, or storage conditions; enhance the food's natural colors; keep colors that may naturally vary consistent; and provide color to colorless or "fun" foods (15). Foods would be dramatically different without added colors: imagine clear colas, white margarines, and non-green mint ice cream. Colors added to foods may be synthetic (certified) or natural.

Certified Colors

Certified color additives are also known as artificial or synthetic colors (14). They are synthetically produced (manufactured) to create colors that are uniform in hue and blend more easily than natural colors. Examples of certified colors include nine Food, Drug, and Cosmetic (FD&C) colors: Blue No. 1 and 2, Green No. 3, Yellow No. 5 and 6, Red No. 3 and 40, Orange B, and Citrus Red No. 2. FD&C Yellow No. 5 might cause hives in a few people (less than 1 out of 10,000), so the law requires that it be listed as an ingredient.

How & Why?

What is the difference between dyes and lake color additives?

Dyes and lakes are both certified colors, but dyes dissolve in water, whereas lakes do not. As a result, dyes are less stable than the lakes that are often used in fat-based products (14).

Natural Colors

Colors exempt from certification include natural colors that are obtained from vegetable, animal, or mineral sources (or synthetic replicas of them) (14). Examples of natural colors include annatto extract (yellow), dehydrated beets (bluish-red to brown), caramel (yellow to tan), beta-carotene (yellow to orange), and grape skin extract (red, green).

Use of Colors in Foods

Food is made more appetizing and interesting to behold by the wide spectrum of colors made possible through pigments. One way these pigments are classified by food scientists is according to the following four categories: (1) shiny (diffuse reflection), (2) glossy (specular or mirror-like reflection), (3) opaque or cloudy (diffuse transmission), or (4) translucent (specular transmission) (16). Most of the natural pigments contributing to color are

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TABLE 3-7 Purpose, Use, and Names of Types of Food Additives

Types of Ingredients	What They Do	Examples of Uses	Names on Labels
Improve Appeal			
Sweeteners	Add sweetness with or without adding kcalories	Beverages, baked goods, confections, table-top sugar, substitutes, many processed foods	Sucrose (sugar), glucose, fructose, sorbitol, mannitol, corn syrup, high-fructose corn syrup, saccharine, aspartame, sucralose, acesulfame potassium (acesulfame-K), neotame
Color additives	Offset color loss due to exposure to light, air, temperature extremes, moisture, and storage conditions; correct natural color variations; enhance natural colors; provide color to colorless and "fun" foods	Many processed foods (candies, snack foods, margarine, cheese, soft drinks, jams/jellies, gelatins, pudding and pie fillings)	FD&C Blue Nos. 1 and 2, FD&C Green No. 3, FD&C Red Nos. 3 and 40, FD&C Yellow Nos. 5 and 6, Orange B, Citrus Red No. 2, annatto extract, beta-carotene, grape-skin extract, cochineal extract or carmine, paprika oleoresin, caramel color, fruit and vegetable juices, saffron (exempt color additives are not required to be declared by name on labels but may be declared simply as colorings or color added)
Flavors and spices	Add specific flavors (natural and synthetic)	Pudding and pie fillings, gelatin dessert mixes, cake mixes, salad dressings, candies, soft drinks, ice cream, barbecue sauce	Natural flavoring, artificial flavor, and spices
Flavor enhancers	Enhance flavors already present in foods	Many processed foods	Monosodium glutamate (MSG), hydrolyzed soy protein, autolyzed yeast extract, disodium guanylate or inosinate
Fat replacers (and components of formulations used to replace fats)	Provide creamy mouthfeel in reduced-fat foods	Baked goods, dressings, frozen desserts, confections, cake and dessert mixes, dairy products	Olestra, cellulose gel, carrageenan, polydextrose, modified food starch, microparticulated egg white protein, guar gum, xanthan gum, whey protein concentrate
Humectants	Retain moisture	Shredded coconut, marshmallows, soft candies, confections	Glycerin, sorbitol
Firming agents	Maintain crispness and firmness	Processed fruits and vegetables	Calcium chloride, calcium lactate
Gases	Serve as propellant, aerate, or create carbonation	Oil cooking spray, whipped cream, carbonated beverages	Carbon dioxide, nitrous oxide
Extend Storage Life			
Preservatives	Prevent food spoilage from bacteria, molds, fungi, or yeast (antimicrobials); slow or prevent changes in color, flavor, or texture; maintain freshness	Fruit sauces and jellies, beverages, baked goods, cured meats, oils and margarines, cereals, dressings, snack foods, fruits, and vegetables	Ascorbic acid, citric acid, sodium benzoate, calcium propionate, sodium erythorbate, sodium nitrite, calcium sorbate, potassium sorbate, BHA, BHT, EDTA, tocopherols (vitamin E)
pH control agents and acidulants	Control acidity and alkalinity, prevent spoilage	Beverages, frozen desserts, chocolate, low-acid canned foods, baking powder	Lactic acid, citric acid, ammonium hydroxide, sodium carbonate
Maximize Performance			
Emulsifiers	Allow smooth mixing of ingredients, prevent separation Keep mixed products stable, reduce stickiness, control crystallization, keep ingredients dispersed, and help products dissolve more easily	Salad dressings, peanut butter, chocolate, margarine, frozen desserts	Soy lecithin, monoglycerides, diglycerides, egg yolks, polysorbates, sorbitan monostearate

(*continued*)

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TABLE 3-7 Purpose, Use, and Names of Types of Food Additives (*continued*)

Types of Ingredients	What They Do	Examples of Uses	Names on Labels
Stabilizers and thickeners, binders, texturizers	Produce uniform texture, improve mouthfeel	Frozen desserts, dairy products, cakes, pudding and gelatin mixes, dressings, jams and jellies, sauces	Gelatin, pectin, guar gum, carrageenan, xanthan gum, whey
Leavening agents	Promote rising of baked goods	Breads and other baked goods	Baking soda, monocalcium phosphate, calcium carbonate
Anticaking agents	Keep powdered foods free-flowing, prevent moisture absorption	Salt, baking powder, confectioner's sugar	Calcium silicate, iron ammonium citrate, silicon dioxide
Yeast nutrients	Promote growth of yeast	Breads and other baked goods	Calcium sulfate, ammonium phosphate
Dough strengtheners and conditioners	Produce more stable dough	Breads and other baked goods	Ammonium sulfate, azodicarbonamide, L-cysteine
Enzyme preparations	Modify proteins, polysaccharides, and fats	Cheese, dairy products, meat	Enzymes, lactase, papain, rennet, chymosin
Protect Nutrient Value			
Nutrients	Replace vitamins and minerals lost in processing (enrichment), add nutrients that may be lacking in the diet (fortification)	Flour, breads, cereals, rice, macaroni, margarine, salt, milk, fruit beverages, energy bars, instant breakfast drinks	Thiamin hydrochloride, riboflavin (vitamin B2), niacin, niacinamide, folate or folic acid, beta-carotene, potassium iodide, iron or ferrous sulfate, alpha-tocopherols, ascorbic acid, vitamin D, amino acids (L-tryptophan, L-lysine, L-leucine, L-methionine)

Source: Adapted by Amy Brown from International Food Information Council (IFIC) and U.S. Food and Drug Administration. *Food ingredients and colors.* www.fda.gov/Food/FoodIngredientsPackaging/ucm094211.htm. Accessed 5/27/12.

found in fruits and vegetables. The colors of foods from animal products and grains are less varied and bright. The three dominant color pigments found in most plants are carotenoids (orange-yellow), chlorophyll, and flavonoids (blue, cream, red). These plant pigments, their colors, and food examples are explained in more detail in Chapter 13 on vegetables.

Although foods of animal origin are less colorful, even meat varies in color depending on its stage of maturity (see Chapter 7). When first sliced with a knife, a cut of beef is purplish red from the presence of a pigment called myoglobin. As it is exposed to air, the myoglobin combines with oxygen to turn the meat a bright red color. The meat then turns grayish brown during cooking when the protein holding the pigment becomes denatured. Cured meats present an altogether different scenario, as added nitrites, compounds that are used as a preservative, react with the myoglobin to cause the meat to be a red color, which converts to pink (denatured protein) when cooked. Meat pigments are covered in more detail in Chapter 7.

Milk appears white as light reflects off the colloidal dispersion of milk protein. The yellowish hue of cream comes from carotene and riboflavin (vitamin B_2). Carotene, a fat-soluble pigment, is also the substance that gives butter its yellow color.

Flavor Compounds

The flavors in foods are usually mixtures of substances derived from both nutrient and nonnutrient compounds (41). These are sometimes too numerous to track as the source of a specific flavor. Like colors, flavoring agents can be synthetic, such as saccharine, or natural, such as fruit extracts, juice concentrates, processed fruits, fruit purees, spice resins, and monosodium glutamate (MSG) (30).

Organic acids found naturally in foods, or sometimes added, determine whether the food is acidic or basic. An acidic pH in foods not only contributes to a sour taste but also to the color of fruit juices, the hue of chocolate in baked products, and the release of carbon dioxide in a flour mixture. An alkaline pH contributes a bitter taste and soapy mouthfeel to foods.

Texture Compounds

Food additives are also used to add body and texture to foods. For example, thickeners generate a smooth texture in ice cream by preventing ice crystals from forming.

Additives that Extend Storage Life

Food storage life can be extended using additives that reduce the rancidity of fats such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT), which slow or prevent food deterioration.

Additives that Maximize Performance

Emulsifiers, stabilizers, and other additives maximize the performance of foods. Emulsifiers make it possible to distribute tiny particles of one liquid into another, thereby preventing immiscible liquids from separating. For example, emulsifiers prevent the oil from separating out of peanut butter. Stabilizers and thickeners give milkshakes body and a smoother feel in the mouth. If necessary, certain compounds can be added to alter the pH of a food

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to achieve the desired acidity or alkalinity. Some additives retain moisture, whereas anticaking agents prevent moisture from lumping up powdered sugar or other finely ground powdered substances.

Additives that Protect Nutrient Value

Food additives that protect nutrient value include vitamins and minerals that are added to enrich or fortify foods (15). Enriched foods have the vitamins thiamin (B_1), riboflavin (B_2), folate, and niacin, and the minerals iron and sometimes calcium added back to levels established by federal standards for breads and cereals. Most table salt is fortified with iodine to help prevent goiter. Milk is fortified with vitamin D to help prevent rickets. Many fruit drinks are fortified with vitamin C, which tends to be missing in the diets of people who do not consume sufficient amounts of fruits and vegetables.

Plant Compounds

In addition to color and flavor compounds, some plants contain other nonnutritive substances that, when ingested, may have either beneficial or harmful effects.

Beneficial

Many of the possible anticarcinogens, or compounds that inhibit cancer, come from plants. In particular, **phytochemicals**, a special group of substances found in plants, appear to have a protective effect against cancer (32). One class of these phytochemicals, called indoles, is found in vegetables such as cabbage, cauliflower, kale, kohlrabi, mustard greens, Swiss chard, and collards. Laboratory animals given indoles and then exposed to carcinogens developed fewer tumors than animals exposed to the same carcinogens but not given indoles. A few of the plant substances that appear to protect against cancer are listed in Table 3-8.

Harmful

There are several potentially harmful substances in plants (34). The U.S. Department of Health and Human Services has gone so far as to say that natural toxins are so widespread that the only way to avoid them completely is to stop eating. Other substances, although not strictly toxins, can cause problems for certain people if ingested in excess. One such substance is caffeine (38).

Caffeine

Caffeine is a natural stimulant that belongs to a group of compounds called methylxanthines. The most widely used sources of caffeine include coffee beans, tea leaves, cocoa beans, and cola nuts. The high concentrations of caffeine found in the leaves of some plants provide protection from insects.

Caffeine ingested at high concentrations may temporarily increase heart rate, basal metabolic rate, secretion of stomach acid, and urination. Though the increased secretion of stomach acids may cause problems for people with ulcers, a moderate intake of caffeine does not appear to cause health problems in healthy adults. Individuals who habitually drink a lot of caffeine-containing beverages may, however, experience withdrawal headaches and irritability if they reduce consumption (9). Another possible side effect in sensitive individuals is fibrocystic conditions in the breast, which are painful but usually harmless lumps within the breasts and under the arms (6).

Excessive caffeine intake, defined as more than five 5-ounce cups of strong, brewed coffee daily, can also cause "coffee nerves." *The Diagnostic and Statistical Manual of Mental Disorders* published by the American Psychiatric Association defines caffeine intoxication as exhibiting at least five of the following symptoms: nervousness, agitation, restlessness, insomnia, frequent urination, gastrointestinal disturbance, muscle twitching, rambling thought and speech, periods of exhaustion, irregular or rapid heartbeat, and psychomotor agitation. Infants who ingest caffeine through their mother's milk may also get the "jitters." Because infants are unable to metabolize caffeine efficiently, the compound may stay in their system up to a week, as compared with about 12 hours in a healthy adult.

Phytochemical A nonnutritive "chemical" in plants (phyto) that is considered beneficial to health.

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TABLE 3-8 Some Nonnutritive Substances in Foods

	Phytochemicals Chemicals in Plants (Food)				
	Alkaloids	**Phenolics****			**Terpinoids**
		Lignans	**Polyphenols**	**Tannins**	
Description	Over 12,000 plant chemicals. Many drugs and poisons are derived from plant alkaloids	Polyphenolic substances from phenylalanine	Flavonoids (5 classes) 1) Flavones & Flavonols Blueberries Celery Parsley 2) Flavanones Grapes Orange juice 3) Isoflavones Legumes (includes phytoestrogens such as daidzein, genistein, & glycitein) 4) Pro-anthocyanidins Apple Almond Blueberry Cocoa beans 5) Anthocyanidins - red, blue, purple food: Blueberries Cranberries Eggplant Raspberries Red cabbage Red onions	Derivatives of gallic acid that give food a bitter, astringent (puckering) taste and mouthfeel	Over 25,000 including the carotenoids (gives carrots their orange color), astaxanthin, lutein, lycopene, zeaxanthin
Food Examples	Caffeine (cocoa, coffee, etc.) Theobromine (chocolate)	Apricots Broccoli Cabbage Cereals (wheat, oat, barley, rye) Flax seed Sesame seed Soybeans Strawberries		Apple Blackberries Chocolate Coffee / tea Cranberry juice Red wine	Beet greens Broccoli Corn Kale Carrots Greens Mustard greens Red algae Spinach Swiss chard

* Alkaloids contain at least one nitrogen atom

** Phenolics are defined by the presence of one or more aromatic rings bearing a hydroxyl group

*** Terpinoids are modified terpenes (combined isoprene units) with the general formula of $(C_5H_8)n$

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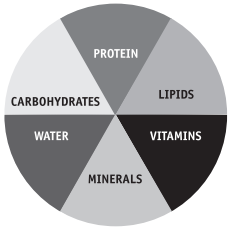
PICTORIAL SUMMARY / 3: Chemistry of Food Composition

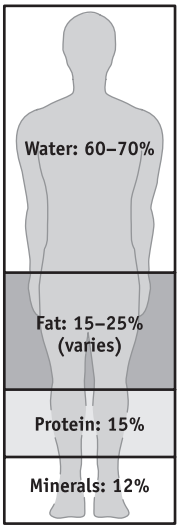
Truly, we are what we eat. Food provides energy (kcalories) and nutrients, which are needed for the maintenance, repair, and growth of cells. Understanding food chemistry is important in planning good nutrition.

BASIC FOOD CHEMISTRY

The six major nutrient groups are as follows:

- Water
- Carbohydrates
- Proteins
- Lipids
- Vitamins
- Minerals





Proportion of nutrients in the human body

- Most foods contain a combination of these six groups. The main purpose of eating and drinking is to provide energy and to replace those nutrients used up in the body's maintenance, repair, and growth.

WATER

Water (H_2O) is the simplest but most important of all nutrients. The human body contains about 60 to 70% water, and water concentrations in foods range from 70 to 95% in fruits, vegetables, and meats to less than 15% in grains, dried beans, and fats. In food preparation, water acts as a heat-transferring agent and a solvent, plays a crucial role in preservation, and is involved in the formation of numerous solutions, colloidal dispersions (including emulsions), and suspensions.

CARBOHYDRATES

Carbohydrates are the sugars, starches, and fibers found primarily in plants. The basic building block of carbohydrates is the saccharide, which is composed of carbon, hydrogen, and oxygen. Starches consist of amylose and amylopectin. Fiber can be characterized in several ways, including crude or dietary, soluble or insoluble, functional, or total.



LIPIDS OR FATS

Lipids, which are derived from both plant and animal sources, include fats and oils. Foods that are high in fat include the following:

Animal sources

- Meats
- Poultry
- Dairy products



Plant sources

- Seeds and nuts
- Vegetable oils
- Avocados, olives, coconut





Three major lipid groups:

- Triglycerides
- Phospholipids
- Sterols

PROTEINS



Proteins are essential to proper growth and maintenance. They differ from carbohydrates and lipids in that they contain nitrogen. Proteins consist of amino acids linked together by peptide bonds. Plant proteins, with the exception of the protein in legumes (beans, peas, and lentils), lack all the essential amino acids and are therefore "incomplete."

VITAMINS AND MINERALS



Both vitamins and minerals function at the cellular level. Neither provides energy, and both are found to some degree in most foods. Some foods are enriched (nutrients that were lost in processing are added) or fortified (nutrients that were not originally in the food are added) with vitamins and/or minerals. Salt is one of the few minerals used in foods for a functional purpose, specifically its ability to act as a preservative.

NONNUTRITIVE FOOD COMPONENTS

Nonnutritive components in foods include food additives and beneficial or harmful plant compounds. Food additives are used to (1) improve appeal, (2) extend storage life, (3) maximize performance, and (4) protect nutrient value. Both natural and synthetic food additives are available; two examples are color compounds (carotenoids, chlorophylls, flavonoids) and flavor compounds.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. What is the process by which water splits a larger molecule into two smaller molecules?
   a. Hydrolysis
   b. Fission
   c. Hydration
   d. Fusion

2. Sucrose is an example of a(n)_____.
   a. monosaccharide
   b. disaccharide
   c. oligosaccharide
   d. polysaccharide

3. Which of the following foods is a good source of polyunsaturated fatty acids?
   a. Meats
   b. Fruits
   c. Dairy products
   d. Most vegetable oils

4. Orange juice that has had calcium added during processing is considered to be _____.
   a. hydrolyzed
   b. fortified
   c. enriched
   d. purified

5. Nonnutritive substances that may have protective effects against certain cancers are called _____.
   a. triglycerides
   b. vitamins
   c. minerals
   d. phytochemicals

6. Which of the following foods is an example of a complete protein source?
   a. Egg
   b. Spinach
   c. Gelatin
   d. Carrot

7. Which food is an example of a monounsaturated fat source?
   a. Butter
   b. Steak
   c. Fish
   d. Olive

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

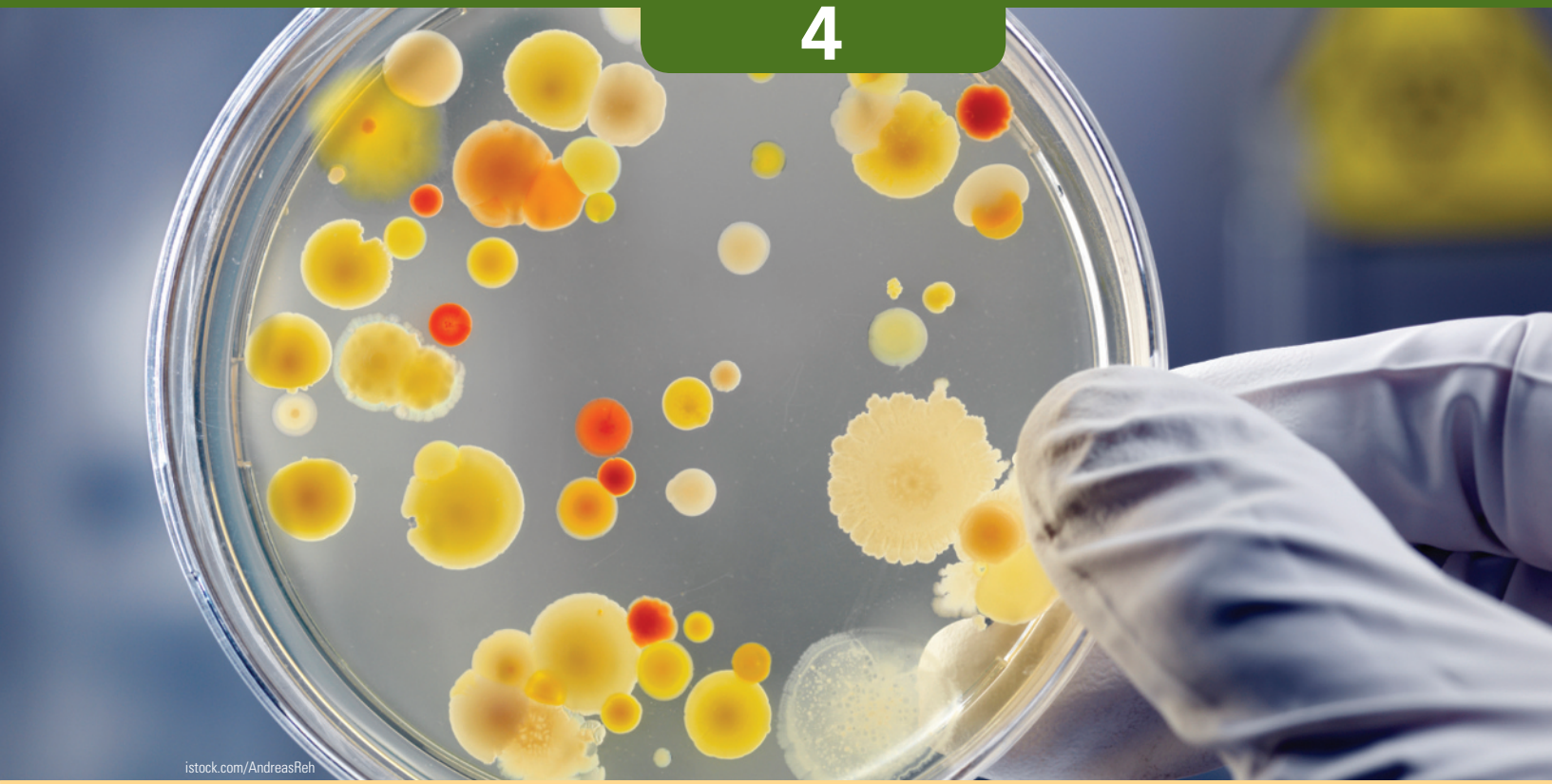
1. List the six basic nutrient groups and describe the basic composition of each group. What is the caloric contribution (kcal) of each group to the diet?
2. Does the addition of solutes to water increase or decrease its freezing point?
3. Define *solute, solvent,* and *solution,* and explain how solutions differ from colloidal dispersions.
4. Define *precipitate, electrolyte, emulsion, hydrolysis,* and *water activity*.
5. List and describe the most common monosaccharides, disaccharides, oligosaccharides, and polysaccharides.
6. Describe the basic structure of a triglyceride, and explain the two primary ways in which fatty acids differ.
7. Describe the basic structure of an amino acid. What is the difference between complete and incomplete protein?
8. Discuss the various functions of protein in foods.
9. What is the difference between food enrichment and fortification?
10. List and describe three nonnutritive compounds found in food.

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4



Food Safety

What Is a Foodborne Illness? 62
Biological Hazards—Living Culprits 62
Bacterial Food Infections 65
Bacterial Food Intoxications 66
Bacterial Toxin-Mediated Infections 66
Chemical Hazards—Harmful Chemicals in Food 71
Physical Hazards—Objects in Food 73
Food Allergy, Intolerance, and Sensitivity 73
Preventing Foodborne Illness 74
Proper Use of Thermometers 82

The U.S. food supply is probably the safest in the world (17). Why is this so? Food safety is achieved primarily by controlling contamination at the food source. Federal and state regulations, along with local inspections, require vigilance at all levels of food production and distribution. (Chapter 29 covers government regulations in detail.) In addition, the Centers for Disease Control and Prevention (CDC) agency tracks down causal factors when even as few as one or two **outbreaks** of **foodborne illness** occur. The U.S. Food and Drug Administration (FDA) maintains the following public website with yearly updates on multistate outbreaks: www.cdc.gov/foodsafety/outbreaks/multistate-outbreaks/outbreaks-list.html. Finally, food manufacturers and distributors are motivated to avoid lawsuits brought against them as a result of negligence. Therefore, many follow food safety practices and programs to ensure that their food products are safe.

In spite of all these preventive measures, people still get sick from food and beverages. Although it is difficult to assess the total number of people afflicted with foodborne illness each year, the CDC estimates that as many as 48 million illnesses, 128,000 hospitalizations, and 3,000 deaths can be traced to contaminated foods (9). The majority of these foodborne illnesses—approximately 66%—originate at restaurants and other food-service establishments (39), and most of the rest are traced to errors at home.

Control and prevention of restaurant-related contamination is inconsistent due to complicated regulatory jurisdiction and a fragmented food safety

Outbreak As defined by the CDC, the occurrence of two or more cases of a similar illness resulting from the ingestion of a common food.

Foodborne illness An illness transmitted to humans by food.

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system with uneven enforcement on the part of various agencies (20). Regulating food manufacturers is similarly problematic. Politicians have pointed out that "many of the laws and regulations governing food safety in America have not been updated since they were written in the time of Teddy Roosevelt (89)." A major change occurred in 2011 when President Obama signed into law the FDA Food Safety Modernization Act (FSMA), which shifted the focus from simply responding to foodborne outbreaks to preventing them (88). Major components of this act include establishing a tracking system to pinpoint contaminated products quickly as they move through the food chain, developing regulations against intentional food contamination, creating standards for the safe growing and harvesting of produce, requiring each food facility to have written plans for food safety, allowing third parties to certify foreign food facilities, and empowering the FDA to refuse any imported food from a facility that denies access for FDA inspection (40). Although only 15% of the overall U.S. food supply is imported, this includes 20% of fresh vegetables, 50% of fresh fruit, and 80% of seafood (32).

Ultimately, two federal agencies—the FDA and the U.S. Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS)—share the primary responsibility for monitoring the U.S. food supply. The FDA's task is difficult because they have the staffing capability to inspect "just 7,000 of our 150,000 food processing plants and warehouses each year. That means roughly 95% of them go uninspected" (79). In some instances of food safety violations, criminal charges have been brought against negligent food manufacturers. For example, a former peanut butter company owner was sentenced to 28 years in 2015 after knowingly shipping *Salmonella*-contaminated product that sickened thousands and killed nine (25). Civil suits, such as the case in which egg company executives were sued after 1,900 people who had consumed eggs contaminated with *Salmonella* became ill, are more common (26).

Concern about the perceived threat of intentional *food supply terrorism* arose after September 11, 2001. The attention to *food defense,* protecting against intentional food contamination, has grown in recent years (93). Food biosecurity aims to keep the food supply free from planned contamination with biological, chemical, radiological, or physical hazards due to malicious and/or criminal intent. The Bioterrorism Act of 2002 expanded government authority to prevent, detect, and respond to potential threats.

Before developing an irrational fear of foodborne illnesses, whatever their cause, it is necessary to consider the relative risk. More than 273 billion meals and an inestimable number of snacks are consumed each year in the United States. When compared with these numbers, the number of illnesses resulting from food contamination in this country is minimal. This chapter defines foodborne illness and discusses its causes and methods of prevention. All three topics serve as the foundation of food safety certification courses that a certain percentage of food-service workers and their managers are often required to pass.

WHAT IS A FOODBORNE ILLNESS?

Many people have experienced the unpleasant effects of a foodborne illness. Symptoms include inflammation of the gastrointestinal tract lining (gastroenteritis), nausea, abdominal cramps, diarrhea, and vomiting. The severity of diarrhea or any of the other symptoms varies depending on the type of causative agent, the amount of the agent consumed, and the age and susceptibility of the immune system of the affected individual. Those most seriously affected by foodborne illness are the very young, the old, and those with immune systems compromised by diseases such as the acquired immunodeficiency syndrome (AIDS) or cancer (94). Mild cases of foodborne illness usually subside with time. Dehydration resulting from diarrhea and vomiting can be treated by the consumption of electrolyte-rich liquids. Still, severe cases may result in hospitalization or even death. Globally, about 1.5 million children under five die from a diarrheal illness each year, and up to 70% of these deaths are associated with foodborne pathogens (18).

TABLE 4-1 Types of Foodborne Hazards

Biological	Chemical	Physical
Bacteria	Plant toxins	Glass
Molds	Animal toxins	Bone
Viruses Parasites	Agricultural chemicals	Metal
Prions	Industrial chemicals	Plastic

What Causes Foodborne Illness?

People get sick from food that has been contaminated by one of three types of food hazards: (1) biological, (2) chemical, (3) radiological, and (4) physical (Table 4-1). Biological hazards are organic materials or living organisms such as bacteria, molds, viruses, and parasites. Some are so small that they cannot be seen except with the aid of a microscope. These kinds of microorganisms (*micro* means small) are the topics of introductory microbiology classes. Chemical hazards are chemical substances that can harm living systems. These range from agricultural and industrial contaminants (including cleaners and sanitizers) to plant and animal toxins. Radiological hazards are due to radioactive foods from nuclear power plants or weapons. Physical hazards include materials such as glass, metal, stones, and wood that could cause harm if ingested. Other common physical hazards include jewelry, insects, insulation, bone, and plastic (62).

BIOLOGICAL HAZARDS—LIVING CULPRITS

Foodborne biological hazards are organisms such as bacteria, molds, viruses, and parasites. Which of these hazards are responsible for the highest number of illnesses? The answer varies based on country and what year is being surveyed, but in the United States, the top three are *Campylobacter, Norovirus*, and *Salmonella* (43). The seriousness of these biological hazards varies greatly (Table 4-2). It is difficult to avoid microorganisms because they

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TABLE 4-2 Biological Hazards Grouped According to Severity of Risk

Severe Hazards	Moderate Hazards: Potentially Extensive Spread*	Moderate Hazards: Limited Spread
Clostridium botulinum	*Listeria monocytogenes*	*Bacillus cereus*
Shigella dysenteriae	*Salmonella*	*Campylobacter jejuni*
Salmonella typhi	*Shigella*	*Clostridium perfringens*
Hepatitis A and E	Enterovirulent *Escherichia coli* (EEC)	*Staphylococcus aureus*
Brucella abortus	*Streptococcus pyogenes*	*Vibrio cholerae (non-01)*
Vibrio cholerae (01)	*Rotavirus*	*Vibrio parahaemolyticus*
Vibrio vulnificus	*Norovirus* group	*Yersinia enterocolitica* *Giardia lamblia*

*Although classified as moderate hazards, complications, and aftereffects may be severe in certain susceptible populations.

Source: Adapted from International Commission on Microbiological Specifications for Food (ICMSF) (1986); and Pierson, M (Ed). *HACCP Principles and Applications.* Chapman & Hall, New York, 1992.

TABLE 4-3 Bacterial Food Infections

Causative Agent	Latency Period (Duration)	Principal Symptoms	Typical Foods	Mode of Contamination	Prevention of Disease
Listeria monocytogenes	3–70 days (up to 1 month)	Meningoencephalitis; stillbirths; septicemia or meningitis in newborns	Raw milk, soft cheeses, and vegetables, deli meats	Soil or infected animals, directly or via manure	Pasteurization of milk; cooking
Salmonella species	12–36 hours (2–7 days)	Diarrhea, abdominal pain, chills, fever, vomiting, dehydration	Raw, undercooked eggs; raw milk, meat, poultry; fresh produce	Infected food-source animals; human feces	Cook eggs, meat, and poultry thoroughly; pasteurize milk; irradiate chickens; thoroughly wash produce
Shigella species	12–48 hours (4–7 days)	Diarrhea (bloody), fever, nausea; sometimes vomiting, cramps	Raw foods, contaminated water	Human fecal contamination, direct or via water	General sanitation; cook foods thoroughly
Streptococcus pyogenes	1–3 days (varies)	Various, including sore throat, erysipelas, scarlet fever	Raw milk, deviled eggs	Handlers with sore throats, other "strep" infections	General sanitation; pasteurize milk
Yersinia enterocolitica	3–7 days (2–3 weeks)	Diarrhea, pains mimicking appendicitis, fever, vomiting, etc.	Raw or undercooked pork and beef; tofu packed in spring water	Infected animals, especially swine; contaminated water	Cook meats thoroughly; chlorinate water

are everywhere. However, most biological hazards are inactivated or killed by adequate cooking (heating). Sufficient cooling keeps their numbers to a minimum. In the following, which is really a mini food safety course review, these biological hazards, along with chemical, radiological, and physical hazards, are briefly discussed followed by methods of preventing foodborne illnesses.

Bacteria: Number-One Cause of Foodborne Illness

More than 90% of foodborne illnesses are caused by **bacteria,** but only about 4% of identified bacteria are **pathogenic,** that is, able to cause illnesses. The remaining 96% are benign (harmless). Some are actually helpful when used to produce foods such as cheese, yogurt, soy sauce, butter, sour cream, buttermilk, cured meats, and sourdough bread, as well as fermented foods such as pickles, beer, and sauerkraut. Beneficial and pathogenic bacteria are everywhere. Pathogenic bacteria cause three types of foodborne illnesses: (1) infection, (2) intoxication or poisoning, and (3) toxin-mediated infection. These are summarized in the following subsections and explained in detail in the shaded section.

Food Infections

About 80% of bacterial foodborne illnesses are due to **food infections.** These foodborne illnesses are caused by ingesting bacteria that grow in the host's intestine, replicate, and create an infection through their colonization. Table 4-3 lists the bacteria primarily responsible for food infections.

Bacteria One-celled microorganisms abundant in the air, soil, water, and/or organic matter (i.e., the bodies of plants and animals).

Pathogenic Causing or capable of causing disease.

Food infection An illness resulting from ingestion of food containing large numbers of living bacteria or other microorganisms.

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TABLE 4-4 Bacterial Food Intoxications

Causative Agent	Latency Period (Duration)	Principal Symptoms	Typical Foods	Mode of Contamination	Prevention of Disease
Bacillus cereus (diarrheal)	6–15 hours (12–24 hours)	Diarrhea, cramps, occasional vomiting	Meat products, soups, sauces, vegetables	From soil or dust	Thorough heating and rapid cooling of foods
Bacillus cereus (emetic)	½–6 hours (5–24 hours)	Nausea, vomiting, sometimes diarrhea and cramps	Cooked rice and pasta	From soil or dust	Thorough heating and rapid cooling of foods
Clostridium botulinum (botulism)	12–36 hours (months)	Fatigue, weakness, double vision, slurred speech, respiratory failure, sometimes death	Types A & B: vegetables, fruits; meat, fish, and poultry products; condiments; Type E: fish and fish products	Types A & B: soil or dust; Type E: water and sediments, puncture of aluminum-covered baked potatoes	Thorough heating and rapid cooling of foods, especially homemade canned foods
Clostridium botulinum (infant botulism)	Unknown	Constipation, weakness, respiratory failure, sometimes death	Honey, soil	Ingested spores from soil or dust or honey colonize intestine	Do not feed honey to infants
Clostridium perfringens	8–24 hours (12–24 hours)	Diarrhea, cramps, rarely nausea and vomiting	Cooked meat and poultry	Soil, raw foods	Thorough heating and rapid cooling of foods
Staphylococcus aureus	½–8 hours (6–48 hours)	Nausea, vomiting, diarrhea, cramps	Ham, meat, poultry products, cream-filled pastries, whipped butter, cheese	Handlers with colds, sore throats, or infected cuts; food slicers	Thorough heating and rapid cooling of foods

TABLE 4-5 Bacterial Toxin-Mediated Infections

Causative Agent	Latency Period (Duration)	Principal Symptoms	Typical Foods	Mode of Contamination	Prevention of Disease
Campylobacter jejuni	2–5 days (2–10 days)	Diarrhea, abdominal pain, fever, nausea, vomiting	Infected food-source animals	Chicken, raw milk	Cook chicken thoroughly; avoid cross-contamination; irradiate chickens; pasteurize milk
Escherichia coli (enterohemorrhagic)	12–60 hours (2–9 days)	Watery, bloody diarrhea	Raw or undercooked beef, raw milk	Infected cattle	Cook beef thoroughly
Escherichia coli (enteroinvasive)	At least 18 hours (uncertain)	Cramps, diarrhea, fever, dysentery	Raw foods	Human fecal contamination, direct or via water	Cook foods thoroughly; general sanitation
Escherichia coli (enterotoxigenic)	10–72 hours (3–5 days)	Profuse watery diarrhea; sometimes cramps, vomiting	Raw foods	Human fecal contamination, direct or via water	Cook foods thoroughly; general sanitation
Vibrio cholerae (cholera)	2–3 days (up to 7 days)	Profuse, watery stools; sometimes vomiting; dehydration; often rapidly fatal if untreated	Raw or undercooked seafood	Human feces in marine environment	Cook seafood thoroughly; general sanitation
Vibrio parahaemolyticus	12–24 hours (4–7 days)	Diarrhea, cramps; sometimes nausea, vomiting, fever; headache	Fish and seafood	Marine coastal environment	Cook fish and seafood thoroughly
Vibrio vulnificus	In persons with high serum iron (1 day)	Chills, fever, prostration, often death	Raw oysters and clams	Marine coastal environment	Cook shellfish thoroughly

Food Intoxication

Foodborne illnesses can also be the result of **food intoxication** or poisoning. Bacteria grow on the food and release toxins; these bacterial products, rather than the organisms themselves, cause illness in the person consuming the now toxin-laden food or beverage. Certain plants and animals produce toxins, but the most common food intoxicants originate from bacteria. Table 4-4 identifies bacteria most often associated with food intoxication.

Food intoxication An illness resulting from ingestion of food containing a toxin.

Toxin-Mediated Infection

This type of foodborne illness occurs when bacteria enter the intestinal tract and *then* start to produce the toxin while inside the intestine (Table 4-5).

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BACTERIAL FOOD INFECTIONS

The main bacteria that cause food infections via colonization in the intestinal tract are *Salmonella, Listeria monocytogenes, Yersinia enterocolitica*, and *Shigella* (refer to Table 4-3).

Salmonella

Salmonella is the second most common cause of illnesses in the United States traced to contaminated foods and water (Figure 4-1). Foods most susceptible to *Salmonella* contamination are meat, fish, poultry, eggs (especially eggnog or Caesar salad made with raw egg), and dairy products (especially custard fillings, cream, ice cream, sauces, dressings, and raw or unpasteurized milk).

Poultry is particularly vulnerable to *Salmonella* contamination (66). If birds are to be stuffed, this should be done just prior to cooking, and the stuffing should be removed from the cavity immediately after cooking and refrigerated as soon as possible. If reheated, it should be brought to a temperature of at least 165°F (74°C) prior to consumption. Current recommendations suggest that large birds should not be stuffed at all.

Eggs are also at risk for *Salmonella (S. enteritidis)*. Any crack or hole in an egg allows bacterial contamination to occur, so any damaged eggs in a carton should be discarded. Research suggests that *Salmonella enteritidis* can even be transmitted from infected hens to the eggs they lay (94). Consequently, some states have laws prohibiting the use of raw eggs in institutional settings. An FDA regulation now requires a printed warning on egg cartons for consumers regarding the risk of undercooked eggs: "To prevent illness from bacteria: Keep eggs refrigerated, cook eggs until yolks are firm, and cook foods containing eggs thoroughly."

In 2008, a peanut plant was the source of a *Salmonella* outbreak that sickened more than 400 people and was suspected in six deaths (13). The plant manufactured peanut products that were used in the production of crackers, cookies, and a variety of other foods. During this outbreak, the FDA reported that although *Salmonella* is a heat-sensitive bacteria, it could become heat-resistant in low-water activity conditions such as in the production of peanut products. Failing to monitor foods for bacterial counts and/or allowing contaminated products to be sold is a potential cause of outbreaks for all products (Chemist's Corner 4-1) (31).

Yet another source of *Salmonella* contamination is pet turtles, iguanas, and other reptiles, so handwashing is essential after handling such pets.

Listeria monocytogenes

Listeriosis can have serious consequences. The fatality rates are as high as 20 to 35% of those infected. The CDC records about 255 U.S. deaths annually from *Listeria* (9). *Listeria* infection may also cause pneumonia, septicemia (bacterial infection of the blood), urethritis (inflammation of the urethra), meningitis (inflammation of the spinal cord or brain membranes), and spontaneous abortion (1). *Listeria monocytogenes* is unique for several reasons. It is a facultative bacterium (capable of growing with or without oxygen); it can survive in a wide pH range (from 4.8 to 9.0); and it grows in a wide temperature range (39° to 113°F [4° to 45°C]). It is one of the few bacteria that can thrive at refrigerator temperatures (81), and frozen dairy desserts have been implicated in some cases of *Listeria monocytogenes* contamination (67). Other foods associated with *Listeria* outbreaks are contaminated produce (cabbage, cantaloupes, celery), pasteurized milk, luncheon meats, and Mexican-style soft cheese (see Chemist's Corner 4-2) (12). The principle source of *Listeria* in ready-to-eat foods is recontamination from the processing environment (51).

Yersinia enterocolitica

Yersinia enterocolitica is destroyed by heat, but, like *Listeria*, it can grow in a wide temperature range (32 to 106°F [0 to 41°C]). The ability of this bacterium to grow at refrigerator temperatures makes it all the more hazardous. Yersiniosis infection

FIGURE 4-1 *Salmonella.*



Centers for Disease Control

CHEMIST'S CORNER 4-1

Testing for Contamination

Traditional testing procedures used by the USDA to check for the presence of contamination are tedious and time-consuming. A much faster testing method now available to the USDA is DNA analysis (called *genotyping*) (4). After cutting an isolated bacterial colony's DNA with a specific enzyme, analysts can use ribotyping to identify the bacterial strains by the resulting RNA fragments.

CHEMIST'S CORNER 4-2

Bacteria-Killing Viruses

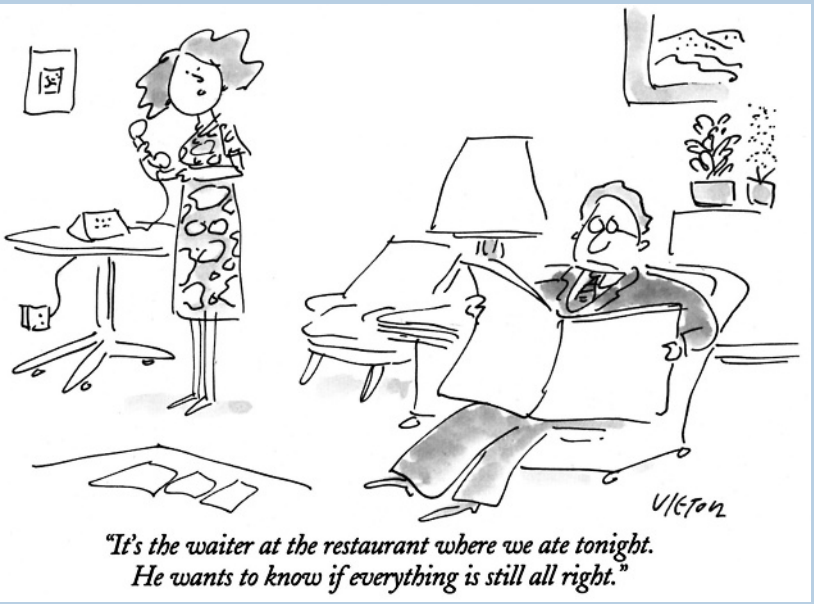
In 2006, the FDA approved the use of a virus to prevent bacterial contamination of luncheon meats (22). The product is a combination of six bacteriophages, a special type of virus, that infect and kill strains of *Listeria* monocytogenes when sprayed on foods. This is the first viral food additive approved for use in the United States.

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FIGURE 4-2



"It's the waiter at the restaurant where we ate tonight. He wants to know if everything is still all right."

Dean Vietor/Cartoonbank.com

commonly occurs in children, resulting in gastrointestinal upset, fever, and appendicitis-like symptoms. In one outbreak, thirty-six children were hospitalized with apparent acute appendicitis and several underwent appendectomies before health officials determined that they had been infected with *Yersinia enterocolitica* by drinking contaminated chocolate milk (6). Yersiniosis infection can occasionally also cause septicemia, meningitis, and arthritis-like symptoms.

Shigella

Poor personal hygiene by food handlers is the number-one cause of *Shigella* infection. *Shigella* is carried in the intestinal tract and transferred to the hands of food-service personnel who visit the restroom and do not wash their hands (Figure 4-2).

BACTERIAL FOOD INTOXICATIONS

Food intoxication or poisoning occurs when a food that contains a toxin produced by bacteria, such as *Clostridium perfringens, Staphylococcus aureus*, or *Clostridium botulinum,* is consumed (refer to Table 4-4).

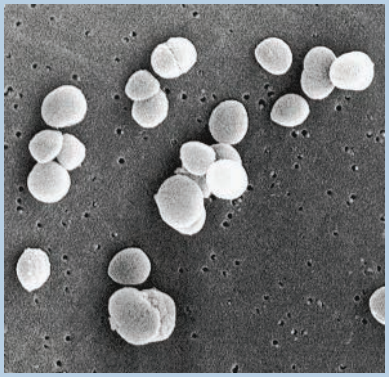
Clostridium perfringens

One of the top five pathogens contributing to foodborne illness in the United States, *Clostridium perfringens* is most commonly transmitted through meat or poultry that was not adequately heated and/or refrigerated before serving. Other foods commonly associated with this bacterium are raw vegetables, dehydrated soups and sauces, and spices.

Staphylococcus aureus

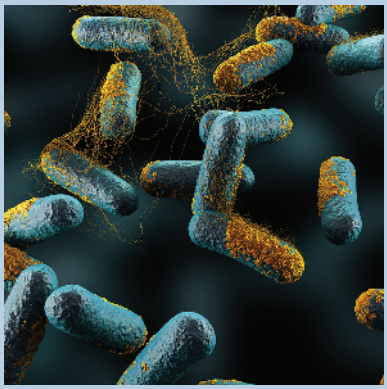
Another top five cause of foodborne illness, *Staphylococcus aureus* is ubiquitous (found everywhere) (Figure 4-3).

FIGURE 4-3 *Staphylococcus aureus.*



Centers for Disease Control

FIGURE 4-4 *Clostridium botulinum.*



decade3d - anatomy online/Shutterstock.com

Up to half of all healthy humans carry it, and it is a common cause of sinus infections and infected pimples and boils. It lives in the throat and nasal passages and in small cuts, so it is easily transmitted to foods through sneezing, coughing, and hand contact (77).

Clostridium botulinum

The *Clostridium botulinum* toxin causes botulism, one of the deadliest, but fortunately rarest, forms of foodborne illness (Figure 4-4). Medical advances, including the development of an antitoxin, have contributed to reducing the death rate from botulism to only 5 to 10% (81).

The most common cause of botulism is improperly home-canned food. For example, an outbreak once occurred at a church potluck involving potato salad made from home-canned potatoes (see Chapter 28) (54). A single botulism case is a public health emergency because it can signal an outbreak. Cans that are dented, have leaky seals, or bulge (indicating the presence of the gas produced by the bacterium) should be discarded. A foul odor or milky liquid in any can is also a sign of contamination.

BACTERIAL TOXIN-MEDIATED INFECTIONS

Common examples of bacteria causing toxin-mediated infections include *Escherichia coli, Campylobacter jejuni*, and *Vibrio* (refer to Table 4-5).

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Escherichia coli

Escherichia coli (E. coli) is a normal inhabitant of the digestive tract in both humans and animals; in its normal environment, it prevents the growth of more dangerous bacteria. However, when it contaminates food sources, it can produce serious illness. In 2006, raw spinach was contaminated with *E. coli*, resulting in 200 cases of infection (90). In this outbreak, more than half of the infected individuals were hospitalized, and three deaths occurred. Eleven percent of the infections occurred in children under the age of five. The source of the contaminant was found to be animals, including cattle and a wild boar, located near the spinach fields.

E. coli is particularly dangerous in children. The main concern for children is that certain strains of *E. coli* cause infant diarrhea, traveler's diarrhea, and bloody diarrhea. *E. coli* may also cause hemorrhagic colitis—severe abdominal cramps, vomiting, diarrhea, and a short-lived fever followed by watery, bloody diarrhea (2). A potentially deadly condition caused by *E. coli* is hemolytic-uremic syndrome (HUS), which is the leading cause of acute renal (kidney) failure in children (52). Up to 10% of children in whom HUS develops may die.

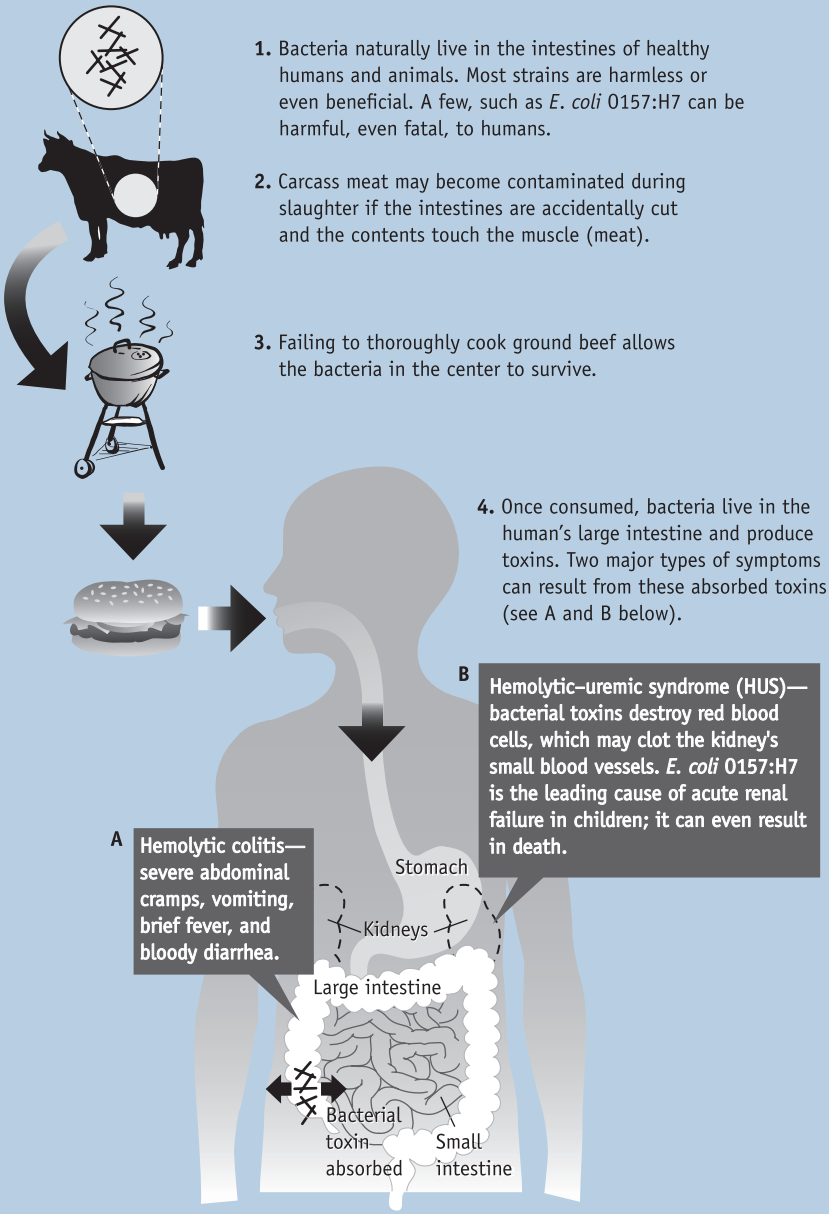
E. coli is naturally found in the intestinal tract and causes problems only when fecal matter gets into the food or water supply. Most infections have been linked to undercooked meat because contamination often occurs during the butchering of a carcass when the meat comes into contact with the animal's intestinal tract (Figure 4-5) (69). Undercooked hamburger is the most common meat source of *E. coli* contamination.

Scientists began identifying *E. coli* O157:H7 (*E. coli* O157 or just O157) in the early 1980s, but it was not until an outbreak in 1993 in the Pacific Northwest that national attention and preventive efforts were focused on the problem. The outbreak, which was caused by the consumption of undercooked ground beef in a fast-food restaurant, brought about a prompt response from the U.S. government. A new safety program was instituted, featuring more rapid testing of ground beef, tighter controls at slaughterhouses and processing plants, and the labeling of fresh meat products with instructions for safe handling and preparation, including increasing final cooking temperature of ground meats from 140 to 160°F (60 to 71°C) (4). Health officials now recommend that ground beef be thoroughly cooked so that no pink remains.

Undercooked hamburgers are not the only sources of *E. coli* infection. Other foods implicated in *E. coli* O157:H7 outbreaks include unpasteurized (raw) milk, unpasteurized apple juice or cider, raw sprouts, dry cured salami, fresh produce (especially manure-fertilized) (Chemist's Corner 4-3), yogurt, sandwiches, and water (44).

E. coli may also be transmitted to children in childcare centers because of poor handwashing after changing diapers. Ideally, those who change diapers should not be the same people who prepare food (77). Other reported outbreaks have been caused by an improperly chlorinated swimming pool and contaminated water systems.

FIGURE 4-5 How *E. coli* can cause serious health problems.



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CHEMIST'S CORNER 4-3

Biofilms

A biofilm is a microscopic layer of bacteria or other microorganisms surrounded by a slimy, glue-like matrix of proteins and sugars (polysaccharides). Biofilms are capable of strong attachment to moist surfaces and can grow on rocks surrounding ponds and streams, medical equipment, drinking water facilities, and even human teeth. Recently, biofilms have been detected on food items. *E. coli* O157:H1, a highly pathogenic strain, can colonize lettuce leaves and stay attached even when the leaves are submerged in water and refrigerated for a week (74).

Campylobacter jejuni

One of the top five bacteria responsible for foodborne illness, if not number one, is *Campylobacter jejuni* (9). *Campylobacter* species are estimated to be responsible for more than 9% of the food-related illnesses and 6% of the deaths attributed to foodborne pathogens annually. Although the largest foodborne disease outbreak was traced to a municipal water supply, most other cases are linked to raw meat (especially hamburger), undercooked poultry, unpasteurized milk, and untreated water (27).

Vibrio

Seafood, primarily shellfish, is the major carrier of *Vibrio* infection. *V. parahaemolyticus* is a leading cause of foodborne illness in Japan and Taiwan, and it's the most common cause of foodborne *Vibrio* infection in the United States (48). Cholera (*V. cholerae*) is responsible for thousands of deaths each year in Asia. Poor sanitary conditions contaminate water supplies and usually account for the deaths reported in other countries (85). In the United States, very few cases are reported, and they are usually associated with the consumption of raw oysters (21). The bacteria can also be transmitted through skin wounds during the cleaning or harvesting of shellfish or if seawater washes over a preexisting wound. The FDA estimates that about 5 to 10% of raw shellfish on the market are contaminated.

Molds

Molds produce **mycotoxins,** which can cause food intoxication. More than 300 mycotoxins, most of which do not present a significant food safety risk, have been identified (60). However, some are carcinogenic (cancer-causing) (58). Aflatoxin, a carcinogenic toxin made by the mold *Aspergillus flavus,* is the most potent liver carcinogen known. The foods most likely to be infected with *Aspergillus flavus* are peanuts and grains; it has also been identified in corn, cottonseed, Brazil nuts, pistachios, spices, figs, and dried coconut.

Patulin is a toxin produced by both *Aspergillus* and *Penicillium* that can contaminate fruits and cereals (60). Fumonisins are produced by *Fusarium verticillioides* and *F. proliferatum* and are associated with corn.

Unlike bacteria, molds are visible, exhibiting **bloom** on affected foods. They also thrive at room temperature and need less moisture than bacteria do. Foods susceptible to molds are breads, jams and jellies, and salty meats such as ham, bacon, and salami.

Black spots in the refrigerator, often called mildew, are actually molds that can be cleaned by washing the surface with a solution of 1 tablespoon of baking soda dissolved in 1 quart of water. Musty-smelling dishcloths, sponges, and mops should be thoroughly cleaned or replaced because such odors indicate that mold has taken root.

Mold A fungus (a plant that lacks chlorophyll) that produces a furry growth on organic matter.

Mycotoxin A toxin produced by a mold.

Bloom Cottony, fuzzy growth of molds.

Virus An infectious microorganism consisting of RNA or DNA that reproduces only in living cells.

How & Why?

Why are some molds all right on foods whereas others are not?

As a rule, foods that show signs of mold should not be eaten. The exceptions are cheeses (e.g., Roquefort, bleu, Brie, and Camembert), whose flavor, texture, and color depend on specific safe molds. Other foods relying on molds during processing include soy sauce, tempeh, and certain types of Italian-style salami that are coated in a thin, white mold. Cheeses such as cheddars and Swiss that become moldy can safely be trimmed 1 inch away from the mold. Soft cheeses such as cottage cheese and cream cheese that have become moldy, however, should be thrown out because the mold may penetrate through the cheese.

Viruses

Viruses are one of nature's simplest organisms. Unlike bacteria, which can exist independently, a virus needs a living cell in order to multiply. These microorganisms have been identified as causal agents in about 3 to 10% of foodborne illnesses (Table 4-6) (41). All foodborne viruses are transmitted via the oral–fecal route, that is, from contaminated feces to the mouth. They may be passed from person to person or through carriers such as flies, soiled diapers, water, and food. Two of the most common viruses known to cause foodborne illnesses are the hepatitis A virus and the *Norovirus.*

Hepatitis A Virus

Hepatitis A infection occurs most frequently after food is contaminated with fecal matter. (This differs from the hepatitis B virus, which is transmitted through body fluids and not through food.) Another common source of hepatitis A is polluted shellfish beds and vegetable fields (70). Shellfish are a

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TABLE 4-6 Viruses Causing Foodborne Illness

Causative Agent	Onset (Duration)	Principal Symptoms	Typical Foods	Mode of Contamination	Prevention of Disease
Hepatitis A virus	10–50 days (2 weeks to 6 months)	Fever, weakness, discomfort, nausea; often jaundice	Raw or undercooked shellfish; sandwiches, salads, etc.	Human fecal contamination via water or directly	Cook shellfish thoroughly; general sanitation
Noroviruses	1–2 hours (1–2 days)	Nausea, vomiting, diarrhea, pains, headache, mild fever	Raw or undercooked shellfish; sandwiches, salads, etc.	Human fecal contamination via water or directly	Cook shellfish thoroughly; general sanitation
Rotaviruses	1–3 days (4–6 days)	Diarrhea, especially in infants and young children	Raw or mishandled foods	Probably human fecal contamination	General sanitation

source of hepatitis A infection because they are eaten with their digestive tracts intact. Another possible source of hepatitis A contamination is childcare centers, where diaper changing occurs. A vaccine is available that is 95% effective against the virus and provides protection for about 15 years (63).

Norovirus

Norovirus, also known as Norwalk virus, was named after the town in Ohio where the first identified outbreak occurred (90). This virus is the most common cause of gastroenteritis and responsible for up to 58% of all foodborne illnesses in the United States (42). It is the second most common viral infection after the common cold, more common in the summer months, and often referred to as the "stomach flu." The *Norovirus* is spread via contaminated food handlers (fecal–oral route), shellfish (especially mollusks and oysters), and water containing raw sewage. Heating will destroy this virus, but freezing will not. *Norovirus* infection outbreaks can be large, as in the case of a Minnesota restaurant in which two salad makers contaminated the food and infected more than 2,000 people (77).

Parasites

Parasites need a host to survive. They infect people in many parts of the world, but in the United States, fewer than 500 cases of parasitic infection are reported each year. Two of the more common foodborne parasites are roundworms and protozoa (Table 4-7).

Roundworms

Roundworm infections can result from eating undercooked pork or uncooked or undercooked fish.

Trichinella spiralis

The *Trichinella spiralis* roundworm, which causes trichinosis, is probably the most common parasite carried in food. Pork products are the primary source of infection, with 1 of every 100 swine in the United States infected. There are now relatively few cases of trichinosis each year, and most infections are thought to be contracted through the consumption of raw or improperly cooked wild game (especially bear meat) or pork (91). Heating pork to an internal temperature of 137°F (58°C) will kill the *T. spiralis* larvae, but the National Livestock and Meat Board recommends a final internal temperature of 160°F (71°C) as a safety margin. Microwave cooking of pork is not recommended because of its uneven heating.

Herring worms (Anisakis simplex) and Cod Worms (Pseudoterranova decipiens)

Japanese cooks preparing sushi (a Japanese dish of thin raw fish slices or seaweed over a cake of cooked rice) inspect fish for these tiny white worms. Because the worms are no wider than a thread, some may be missed; therefore, not all raw fish dishes are guaranteed to be worm free. There is no commercial method to detect all parasites. Even candling, which involves placing a fillet over a lighted translucent surface, finds only 60 to 70% of the worms (49). However, freezing kills the worms so all sushi-grade fish are required to undergo deep freezing.

People who consume raw or undercooked fish containing the live worms may experience a tingling throat sensation caused by the worm wriggling as it is swallowed. Other symptoms usually appear within an hour after ingestion but may show up as much as 2 weeks later. In serious cases, the worm penetrates through the stomach or intestinal wall, causing severe abdominal pain, nausea, vomiting, or diarrhea. Symptoms often continue for several days and have been misdiagnosed as appendicitis, gastric ulcer, Crohn's disease, and gastrointestinal cancer (81). After several weeks, the worm dies, or it may be coughed or vomited up by the host. It also may be removed by a physician using a fiber-optic device equipped with mechanical forceps. Despite these dramatic problems arising from worm infection from contaminated fish, only about ten cases are reported every year. The number of actual cases, however, may be significantly higher because of underreporting.

Protozoa

Protozoa are single-celled animals that most frequently infect humans through contaminated water. Only about four of about thirty types of protozoa are related to food safety: *Giardia, Toxoplasma gondii, Cryptosporidium,* and *Cyclospora*. The most common of these is *Giardia,* but the most serious infection is due to *Toxoplasma gondii*.

Giardia lamblia

Giardia lamblia, which is responsible for the most common parasitic infection in the world, is transmitted primarily through surface streams and lakes that have been contaminated with the feces of infected livestock and other animals. Childcare centers are another common source of infection. Approximately 2% of the population in the United States is

Parasite An organism that lives on or within another organism at the host's expense without any useful return.

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TABLE 4-7 Parasites Causing Foodborne Illness

Causative Agent	Onset (Duration)	Principal Symptoms	Typical Foods	Mode of Contamination	Prevention of Disease
Roundworms (Nematodes)					
Trichinella spiralis	8–15 days (weeks, months)	Muscle pain, swollen eyelids, fever; sometimes death	Raw or undercooked pork or meat of carnivorous animals (e.g., bears)	Larvae encysted in animal's muscles	Thorough cooking of meat; freezing pork at 5°F for 30 days; irradiation
Ascaris lumbricoides	10 days–8 weeks (1–2 years)	Sometimes pneumonitis, bowel obstructions	Raw fruits or vegetables that grow in or near soil	Eggs in soil from human feces	Sanitary disposal of feces; cooking food
Anisakis simplex, Pseudoterranova decipiens	Hours to weeks (varies)	Abdominal cramps, nausea, vomiting	Raw or undercooked marine fish, squid, or octopus	Larvae occur naturally in edible parts of seafood	Cook fish thoroughly or freeze at −4°F for 30 days
Protozoa					
Giardia lamblia	5–25 days (varies)	Diarrhea with greasy stools, cramps, bloating	Mishandled foods	Cysts in human and animal feces, directly or via water	General sanitation; thorough cooking
Cryptosporidium parvum	2–3 days (2–3 weeks)	Diarrhea; sometimes fever, nausea, and vomiting	Mishandled foods	Oocysts in human feces	General sanitation; thorough cooking
Entamoeba histolytica (amebic dysentery)	2–4 weeks (varies)	Dysentery, fever, chills, sometimes liver abscess	Raw or mishandled foods	Cysts in human feces	General sanitation; thorough cooking
Toxoplasma gondii	10–23 days (varies)	Resembles mononucleosis; fetal abnormality or death	Raw or undercooked meats; raw milk; mishandled foods	Cysts in pork or mutton, rarely beef; oocysts in cat feces	Cook meat thoroughly; pasteurize milk; general sanitation
Tapeworms (cestodes)					
Taenia saginata (beef tapeworm)	10–14 weeks (20–30 years)	Worm segments in stool; sometimes digestive disturbances	Raw or undercooked beef	Larvae in beef muscle	Cook beef thoroughly or freeze below 23°F
Diphyllobothrium latum (fish tapeworm)	3–5 weeks (up to 20 years)	Limited; sometimes vitamin B_{12} deficiency	Raw or undercooked freshwater fish	Plerocercoids in fish muscle	Heat fish 5 minutes at 133°F or freeze 24 hours at 0°F
Taenia solium (pork tapeworm)	8 weeks–10 years (20–30 years)	Worm segments in stool, sometimes cysticercosis of muscles, organs, heart, or brain	Raw or undercooked pork; any food mishandled by a *T. solium* serum carrier	Larvae in pork muscle; any food—human feces with *T. solium* serum eggs	Cook pork thoroughly or freeze below 23°F; general sanitation

infected (78). Infection with this organism causes recurring attacks of diarrhea and the passage of stools containing large amounts of unabsorbed fats and yellow mucus. When a *Giardia* infection is contracted, medications can be taken for the symptoms.

Toxoplasma gondii

One of the leading causes of death due to foodborne illness is infection with *Toxoplasma gondii* (9). Up to half the world's population is estimated to carry this parasite, but the majority have very few symptoms. Problems may occur in people with compromised immune systems, such as those with cancer or AIDS, or pregnant women. Two major sources of this dangerous parasite are raw meat and feces from infected cats.

Prion An infectious protein material, called PrP (prion protein) that does not contain DNA or RNA but can lead to disease by misfolding other proteins.

Prions—Mad Cow Disease

Prions are related to mad cow disease, or bovine spongiform encephalopathy (BSE) (87). It is a type of transmissible spongiform encephalopathy (TSE) that riddles the brain with holes, making it look like a sponge. TSE is a group of diseases that affect the brain, resulting in symptoms that range from loss of coordination to convulsions and ultimately death. BSE is a disease affecting cattle. When humans ingest beef from cattle with BSE, they may develop what is called variant Creutzfeldt–Jakob disease (vCJD) (16). TSEs other than mad cow disease include Creutzfeldt–Jakob disease (CJD; a disease causing dementia and not related to BSE), kuru ("the laughing death," a disease formerly found in New Guinea when cannibalism was practiced there), and scrapie (a disease causing loss of coordination and itching/scraping in goats and sheep).

In mad cow disease, prions, or viruses producing prions (identity remains controversial), travel up the spinal cord to the brain. This virus-related protein material incorporates itself into the brain, causing chain reactions that create holes in the brain. The incubation period between infection and manifestation can be months, years, or decades.

Controversy persists concerning how prions are transmitted from food to

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humans. The foods most often believed to be linked to these prions have been cattle and sheep in Great Britain. Prior to the understanding of prions, the practice for some livestock growers was to kill sickly animals and feed the remains to other cattle. It is speculated that healthy cattle being fed rendered livestock would then become infected and, when slaughtered for their meat, would potentially spread this disease to the consumer.

Over 97% of all BSE cases have occurred in Great Britain (92). In 2003, the first case of BSE in a native-born North American cow was identified in Canada (69). This prompted fear that BSE could be spread to the United States because of the frequent trade of cattle and cattle products across the Canadian–U.S. border. Less than a year after the initial case of BSE in Canada was reported, a cow in the United States, which was born in Canada, was found to have BSE. In response to this occurrence, the USDA implemented tighter regulations to prevent the ingestion of contaminated beef products. These included complete removal of high-risk material (central nervous tissue and small intestines) from all cattle products and the introduction of a national identification system to track animals throughout the food supply chain. The USDA also banned the use of rendered carcasses as feed for other livestock (7), and the livestock industry, interested in keeping its food products safe, has exhibited strong compliance with this ban. Previous measures to keep livestock safe in the United States included a 1989 USDA ban on importation of livestock from Great Britain, which was extended to Europe in 1997. Although BSE prevalence in the United States remains extremely low, some countries have banned beef imports from the United States (bans are sometimes temporarily lifted).

Additional attempts to prevent the contamination of the food supply with infectious forms of BSE include the development of rapid bioassays to detect and remove prions and new methods to screen the meat supply for the presence of nervous tissue or prions (23).

New Virulent Biological Hazards

It is not unusual for microorganisms that were relatively unheard of to emerge with a new virulence (become actively harmful), making them a public threat (61). Examples of pathogens that were at one time not recognized as a serious cause of foodborne illness include the *Campylobacter jejuni, Norovirus*, *Listeria monocytogenes, Vibrio vulnificus, Vibrio cholerae,* and *Yersinia enterocolitica* (75).

Pathogens are living organisms that rapidly evolve (14). Bacteria with potential to become public health hazards are constantly appearing, so health departments and government agencies must be vigilant. Several serious outbreaks resulting from "new" microorganisms led the CDC to implement Emerging Infections Programs (EIPs) in state health departments in 1994 (35).

Advanced Techniques for Detecting Contamination

The conventional method of confirming food contamination by microorganisms is culture, growing the organism in the lab (in a Petri dish) until it can be identified visually or by additional tests. Culture is a highly accurate method for identification of pathogens, but it can take a long time—up to several months for some species of mold—and is labor intensive. Culture and other "gold standard" methods for microbe identification are published in the FDA's *Bacteriological Analytical Manual* (available at www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm2006949.htm). Newer techniques are utilized by commercially available assay kits that detect one pathogen or multiple pathogens at one time. These analyses can be performed in a much shorter time, are very reliable, and can make an accurate identification in 90 to 95% of cases (4).

In 1996, the CDC created PulseNet, a national network of food safety testing and regulatory agencies. Participants perform DNA fingerprinting of food contaminants to identify specific bacterial strains (15). They upload these data to the CDC PulseNet database, where participants all over the nation can view outbreaks and determine whether the same bacterial strain is responsible for multiple occurrences in different locations. PulseNet can be accessed online at www.cdc.gov/pulsenet.

CHEMICAL HAZARDS—HARMFUL CHEMICALS IN FOOD

Chemical hazards include any chemical substance hazardous to health. Harmful chemicals can come from additives (unintentional), plant toxins, animal toxins, or certain metals (Table 4-8). Human error is usually responsible for these hazards, especially when they involve kitchen cleaning supplies such as bleach, soaps, and solvents. Contamination can also be deliberate, as was the case in 2007, when pet foods manufactured in China were intentionally spiked with melamine, an industrial chemical, to artificially increase their protein content (see Chemist's Corner 4-4 and 4-5). This resulted in

TABLE 4-8 Potential Chemical Contaminants

Food Additives (Unintentional)	Plant Toxins	Animal Toxins	Toxic Metals
• Pesticides • Herbicides • Fertilizers • Pharmaceuticals in water supply (toilet disposal) • Industrial chemicals: acrylamide, benzene, perchlorate • Pollutants: ethers, dioxins, polybrominated diphenyl, polycyclic aromatic hydrocarbons • Cleaning products	• Raw or undercooked red kidney beans or fava beans • Certain mushrooms • Certain herbs • Fruit pits • Mold toxins (mycotoxins, aflatoxin)	• Certain seafood toxins	• Heavy metals: arsenic, lead, cadmium, mercury • Other metals: antimony, brass, copper, zinc

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CHEMIST'S CORNER 4-4

How Melamine Falsely Elevates Protein Content

The industrial chemical melamine is used in fabric, glues, resins, and fertilizers but is very harmful when ingested. Dog food manufacturers in China added it to their products in 2006 in order to falsely increase the nitrogen content, so the food would appear to have the necessary amount of protein, which is a costly ingredient. Protein contains many nitrogen molecules, so the two standard methods used to evaluate protein content are based on measuring nitrogen concentrations. Because these tests actually measure nitrogen, melamine—protein-free but high in nitrogen—can to be used as a substitute to "fool" the tests. The dog food appeared to be high in protein when evaluated for nitrogen content, and the adulteration was not discovered until animals became sick and, in some cases, died, after ingesting the food (5).

CHEMIST'S CORNER 4-5

How Is the Protein in Foods Measured?

Protein content can be determined two ways: (1) directly, by testing for specific chemical or physical properties unique to proteins; or (2) indirectly, by measuring nitrogen content. The latter relies on one of two standard chemical laboratory methods: Kjeldahl or Dumas. Both measure the amount of nitrogen, which is then multiplied by 6.25 to yield grams of protein. This nitrogen-to-protein conversion factor is derived from the fact that, on average, protein is 16% nitrogen (0.16 g of nitrogen per gram of protein)—100 divided by 16 equals 6.25 (56). The more common Kjeldahl method involves adding sulfuric acid, potassium sulfate, and a metal catalyst to a food sample. This mixture is heated to boiling, and sodium hydroxide is added to liberate the ammonia, which is distilled and titrated with hydrochloric acid to measure the amount of nitrogen (56).

CHEMIST'S CORNER 4-6

Acrylamide

Acrylamide is a chemical that in high doses can cause cancer in laboratory animals but has unknown effects in humans. Acrylamide is not naturally found in food, but it is formed by a chemical reaction when certain foods such as French fries are exposed to high temperatures. The reaction requires sugar, the amino acid asparagine, and high heat (57).

the death of several animals and highlighted the possibility of a similar adulteration in the human food market (5).

Experts from the World Health Organization (WHO) called for food safety reform in China, and, in 2008, the FDA announced the establishment of eight full-time FDA positions at the U.S. diplomatic posts in China (30).

Unlike melamine, most chemical toxins negatively affecting health are introduced accidentally or occur naturally (Chemist's Corner 4-6). The U.S. Pharmacopeia publishes the *Food Chemicals Codex* (FCC) to help differentiate safe additives from harmful ones (84). Technically, additives are considered "safe" when there is "reasonable certainty in the minds of competent scientists that a substance is not harmful under the intended conditions of use" (73). Monographs profiling specific food additives can be found at the Joint Food and Agriculture Organization (FAO)/WHO Expert Committee on Food Additives (JECFA) website (www.who.int/foodsafety/publications/monographs/en/). It is beyond the scope of this book to provide a complete list of harmful additives, but selected chemical toxins are presented in Table 4-8, and those from seafood are now discussed further.

Seafood Toxins: Chemicals from Fish/Shellfish

Both fish and shellfish may harbor toxins, unaffected by the heat from cooking, that can cause foodborne illness (Figure 4-6).

Ciguatera Fish Poisoning

Ciguatera fish poisoning is a common form of toxin-related food poisoning. It is caused by eating fish, usually from tropical waters, that contain a ciguatoxin that is not destroyed by heating (68). Although less than 1% of fish found in tropical areas with coral reefs are actually contaminated, more than one-third of Florida barracuda were found to contain ciguatera toxin, resulting in a ban on the sale of barracuda for human consumption.

FIGURE 4-6 Sign warning that it is unsafe to eat seafood collected from shore.



Chris Howes/Wild Places Photography/Alamy Stock Photo

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How & Why?

How does histamine accumulate?

When fish die, their immune systems no longer inhibit the bacteria naturally found on their bodies. Certain gram-negative bacteria multiply and produce enzymes that in turn produce histamine on the flesh of fish (55).

Histamine Food Poisoning

Excessive histamine accumulation in fish (especially tuna) is often detected by a slight tingling sensation in the mouth when the fish is eaten and may result in histamine food poisoning (scombrotoxism). Other popular fish affected include mackerel, sardines, herrings, and mahi mahi (55). This is one of the most common forms of fish poisoning in the United States and occurs when the fish have not been chilled immediately after being caught. The fish become toxic when bacteria (such as *Morganella morganii*) produce histamine while the fish are stored at incorrect temperatures.

Puffer Fish Poisoning

One of the most violent forms of seafood poisoning occurs when the liver, gonads, intestines, and/or skin of the puffer fish are consumed. These organs contain tetrodotoxin, which, if ingested, results in a mortality rate of 50%. Only a few cases have been reported in the United States, but in Japan, where puffer fish, or *fugu,* is a traditional delicacy, an average of 45 cases are reported each year (81). Most of these cases in Japan originate from people preparing the dish at home, rather than eating it at special restaurants, where licensed chefs are specially trained in how to remove the poisonous viscera from the puffer fish.

Red Tide

Red tide is the result of the rapid growth of a reddish marine alga, usually occurring during the summer or in tropical waters. Shellfish, such as mollusks, oysters, and clams, and certain fish that consume red tide algae become poisonous and should not be eaten until the red tide has disappeared.

PHYSICAL HAZARDS—OBJECTS IN FOOD

Physical hazards that can harm the consumer's health when found in food and beverages include hair (number-one hazard), glass, bone, metal (especially from opening cans), wood, stones, false fingernails, toothpicks, watches, jewelry, insects, staples from food boxes, and many other foreign items that have been known to find their way into the food supply. People have needed emergency surgery after accidently ingesting food containing a hidden single bristle from a wire brush (often used for cleaning grills).

FOOD ALLERGY, INTOLERANCE, AND SENSITIVITY

Individuals who are allergic or sensitive to a food component can develop a food-related illness unrelated to a biological, chemical, radiological, or physical hazard. A *food allergy* is an immune response to a specific protein within a food. The allergic reaction may result in a variety of symptoms, including a skin rash, swelling of the mouth or lips, nausea, abdominal pain, vomiting, diarrhea, runny nose (rhinitis), and difficulty breathing, which can be life threatening. Food allergy is distinct from *food intolerance,* which does not involve an immune response, but rather an inability to absorb or process a certain food because of an enzyme deficiency. The most common food intolerance is to lactose, found in dairy products. *Food sensitivity* is a general term encompassing food allergies, food intolerances, and any other adverse reactions to components found in foods. For example, a reaction to monosodium glutamate (MSG) is considered a food sensitivity but not technically a food allergy or intolerance.

Allergic Reaction Prevention

Complete avoidance of the allergen is the best method of preventing an allergic reaction, although other options, such as desensitization through gradual exposure to small amounts, are being investigated. Foods containing allergens are not always easy to recognize. For instance, peanuts may show up in chili, egg rolls, candies, and ice cream, and wheat is present in soy sauce. Milk is commonly present in deli meats, canned tuna, seafood, and frozen French fries.

Labeling of Common Food Allergens

Although there are more than 160 known food allergens, the vast majority of allergies (90%) are triggered by the top eight: wheat, eggs, peanuts, tree nuts, fish, shellfish, soy, and milk. The Food Allergen Labeling and Consumer Protection Act (FALCPA) requires food manufacturers to appropriately label any product that contains a potential allergen. Products must be labeled with the statement "Contains" followed by a list of all allergens present, or with a parenthetical statement within the ingredient list (3).

Manufacturers are not required to include a FALCPA statement if they can prove their product does not contain any allergens. Allergen test kits that can detect 0.1 to 5 parts per million (ppm) of an antigen are available for milk, eggs, almonds, peanuts, hazelnuts, and soy flour.

Internationally, regulations vary from country to country. Table 4-9 lists labeling requirements in the United States and several other countries.

Cross-Contamination

Prevention of **cross-contamination** with food allergens is a critical step in preventing unwanted reactions in consumers. Because they are under the regulation of the USDA, meat, poultry, and egg products are not subject to FALCPA rules; however, the USDA requires producers to include allergen information in their Hazard Analysis and Risk-Based Preventative Controls (HARPC) plan. Avoidance of cross-contamination must be addressed during storage, production,

Cross-contamination The transfer of bacteria, other microorganisms, or food allergens from one food or surface to another.

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TABLE 4-9 Allergen Labeling Requirements in the United States (U.S.), European Union (EU), Japan, Australia, and New Zealand (NZ)

U.S.	EU	Japan		Australia/NZ
Mandated:	***Mandated:***	***Mandated:***		Voluntary incidental trace allergen labeling (VITAL) system with three action levels:
Tree nuts	Nuts	Peanuts	Kiwifruit	Level 1 (Green): Allergen does not need label.
Peanuts	Peanuts	Eggs	Beef	Level 2 (Yellow): Allergen advisory label stating that allergen may be present.
Soy	Soy	Milk	Tree nuts	Level 3 (Red): Significant levels of allergen are likely, labeling advised.
Eggs	Eggs	Wheat	Salmon	
Milk	Milk/dairy products	Buckwheat	Mackerel	
Fish	Fish	*Labeled when possible:*	Soybeans	
Wheat	Cereals containing gluten	Abalone	Chicken	
Shellfish	Crustaceans	Squid	Pork	
	Celery	Salmon roe	Mushrooms	
	Mustard	Shrimp/prawn	Peaches	
	Sesame seeds	Oranges	Yams	
	Sulfites	Crab	Apples	
			Gelatin	

Source: Adapted from Baldus K, K Werronen, and V Deibel. Adverse reactions to allergens: The importance of labeling and cross-contamination control. *Food Safety Magazine* 14(6):16–22, 2009.

and cleaning. Control of allergens must be documented in the standard operating procedures of the manufacturer and must include a label-development procedure.

PREVENTING FOODBORNE ILLNESS

Biological hazards (especially bacteria) are everywhere, and many other chemical, radiological, and physical food hazards can potentially enter the food supply. It is important to pursue foodborne illness prevention through food safety programs. In order for prevention to be successful, it's important to ask, "Where do most foodborne illnesses occur?"

Prevention Factors Overview

The majority of foodborne illnesses originate at restaurants; a smaller percentage can be traced to food processing plants (47). Most outbreaks in food processing plants are caused by contamination of incoming foods, failure of pathogen-killing processes, or contamination of foods after sanitization. The low percentage of foodborne illnesses originating from food manufacturers is due in part to the implementation of the FDA's **Current Good Manufacturing Practices (cGMPs),** which provide guidelines to minimize the risk of contamination (see www.fda.gov/food/guidanceregulation/cgmp/default.htm). The use of cGMPs allows any product to be traced back to where it was manufactured in case of a recall.

Because most outbreaks occur in restaurants, the second half of this chapter discusses preventing foodborne illness in this environment. According to an FDA report, the top five factors associated with foodborne illness are food from unsafe sources, poor personal hygiene, inadequate cooking, improper holding time and temperature, and contaminated equipment and protection from contamination. To avoid these and other potential problems, this discussion will focus on the following:

- Food-service personnel
- Food flow, which is purchasing, inspection, storage, vulnerable foods, preparation (pre-preparation, cooking, holding, cooling, reheating, serving)
- Sanitation
- Food safety monitoring programs (FDA Food Code, health department inspections, HACCP and/or HARPC, and national surveillance).
- Food Safety Certification Courses

Current Good Manufacturing Practices (cGMPs) A set of regulations, codes, and guidelines for the manufacture of food products, drugs, medical devices, diagnostic products, and active pharmaceutical ingredients (APIs).

These topics are covered in required food safety courses for food-service employees who complete the course, take a test, and receive a certificate. A food safety manager's course is also available.

Personnel

Food-service personnel are critical to food safety. In the early 20th century, a cook in New York named Mary Mallon appeared perfectly healthy but infected about 50 people with typhoid fever. Not surprisingly, she came to be known as "Typhoid Mary." She believed that because she could not see germs, she did not have to wash her hands before cooking. As this story illustrates, a top priority for any food-serving establishment is that food workers be healthy and know how to handle food safely (Figure 4-7). Typhoid is far from the only illness that can be transferred through carelessness and poor hygiene. The common cold, mumps, measles, pneumonia, scarlet fever, tuberculosis, trench mouth, diphtheria, influenza, and whooping cough may also be spread this way. Only people who are free of colds, diarrhea, wounds, and illnesses should work with food.

Training

A Food Management Certificate obtained through a health department education class, commercial in-person or online class, or the National Restaurant Association Educational Foundation (www.chooserestaurants.org) ensures that a food handler has learned safe food-handling techniques, which are often a job requirement for food-service employees. Periodic retraining on sanitation techniques is available from local health departments, the National Restaurant Association, corporations offering food safety courses, or the CDC.

Personal Hygiene Habits

Numerous health habits help keep contamination under control, including the following:

- **Avoid hand-to-mouth.** Any hand-to-mouth movements should be discouraged, including even simple habits such as smoking, gum chewing, and eating, in the food-handling areas. Sampling foods with fingers should not be permitted, as this

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FIGURE 4-7 Food-service personnel checklist.

Self

- ❑ Stay healthy. Maintain daily sleep, well-balanced diet, and relaxation.
- ❑ Report to supervisor if you are sick. Food workers with either vomiting, diarrhea or jaundice (yellow skin or eyes) are excluded from work unless they have:
  1. No symptoms for 24 hours, or
  2. A written release from a physician. Jaundice cases must be reported to regulatory authorities.
- ❑ Stay clean. Practice daily bathing, shampoo hair regularly, use deodorant, and take care of fingernails—they should be cleaned, trimmed, and free of polish and decorations.
- ❑ Wear only clothes that are new or have been washed. Shoes should cover the foot (no sandals, open toe) and have nonskid soles.
- ❑ Wear caps, hairnets, or beard restraints.
- ❑ Avoid items that may fall into food/beverages: hairpins, jewelry, false nails, nail polish, false eyelashes, nail decorations, bandages on hand (cover with plastic gloves), handkerchiefs.
- ❑ Never wipe your hands on your apron.

Food Handling

- ❑ Avoid handling food; use serving spoons, scoopers, dippers, tongs, and ladles.
- ❑ Cover all exposed food with lids, plastic wrap, or aluminum wrap.
- ❑ Taste food with clean spoon and do not reuse.
- ❑ If gloves are used, change them between food and nonfood handling.

Kitchen

- ❑ Wash hands in the hand-washing sink before starting and after breaks/meals.
- ❑ Cough/sneeze into a tissue, an upper sleeve, or your elbow, but not your hands. Discard tissue, and wash hands often with soap and warm water for 20 seconds.
- ❑ No smoking, gum chewing, eating, or drinking.
- ❑ Keep all surfaces clean.
- ❑ Use potholders for pots and dish towels for dishes.
- ❑ Keep cleaning items away from foods/beverages.

Serving

- ❑ Hold plates without touching the surface.
- ❑ Carry silverware only by the handles.
- ❑ Handle glassware without touching the rim or the inside.

transfers bacteria. Sipping from bottles to taste test and double dipping with utensils are both not allowed. *Staphylococcus* can be transferred by workers who touch their mouth, nose, a pimple, or infected cut, and then handle food. Sneezing or coughing sends millions of microorganisms into the surrounding air to settle on food.

- **Handwashing.** Hands should be washed frequently, but especially as soon as the employee enters the kitchen, before handling food, and after touching raw meat or eggs, using the restroom, sneezing, touching any part of the body (i.e., hair or face), touching nonfood items (phone, dirty utensils, pesticides, etc.), and handling garbage. Hot, soapy water should be used for at least 20 seconds to scrub wrists, hands, in between fingers, and especially the fingertips and under the fingernails where higher bacteria numbers are found. To ensure maximum effect from handwashing, the routine should consist of washing up to the elbow for at least 20 seconds, using a nailbrush, and then drying with disposable towels or an air dryer (not a cloth towel). Disposable paper towels or air drying is preferred over cloth, which can harbor bacteria if used repeatedly. When food handlers touch a doorknob, handrail, telephone, counter, or any other surface that is frequently contacted by others, their hands should be washed again before food is touched. One of the most common causes of foodborne illness is failure of employees to wash their hands after using the restroom, particularly if they have diarrhea or are changing an infant's diaper. Hand sanitizers assist in reducing bacterial numbers but should never substitute for handwashing. Food establishments are often required to have a separate sink strictly for handwashing (Figure 4-8). It should never be used for washing foods or utensils.

FIGURE 4-8 Handwashing sinks are separated from food preparation sink(s).



Guy Croft Industrial/Alamy Stock Photo

- **Proper gloving.** Unlike skin that can be washed, gloves should be changed whenever they are contaminated or torn.
- **Uniforms.** Food-service workers should clean their uniforms frequently, wear caps or hairnets, and avoid jewelry such as rings and bracelets that can collect minute particles of food and dust.

Food Flow

The flow of food in terms of maintaining food safety starts with purchasing and is followed by inspection, storage, recognizing vulnerable foods, prepreparation, cooking (heating), holding, cooling, reheating, and serving.

Purchasing: Written Specifications

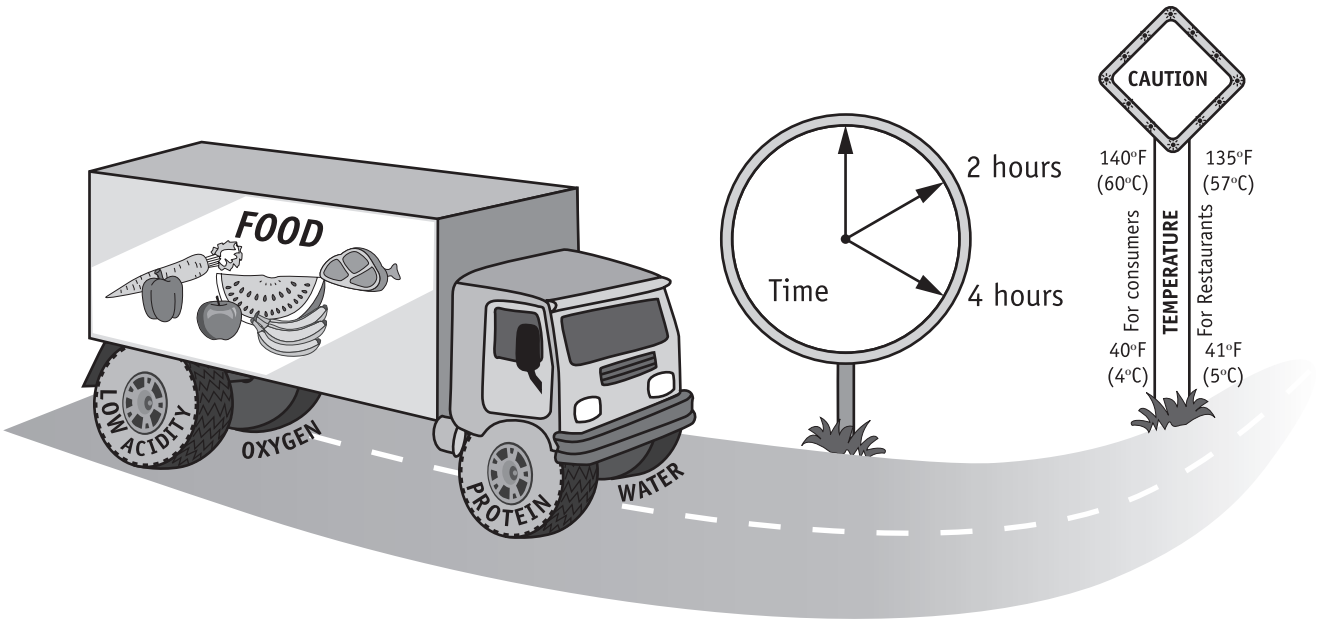
Food should be purchased from safe sources. A quality-control program in a food establishment often ensures that only foods meeting written specifications are purchased. Foods should be purchased from reputable vendors (suppliers), meet temperature and humidity requirements, show no evidence of being refrozen (such as frozen fluid lining the bottom of the food container or large ice crystals on the food's surface), be received in undamaged containers, and meet specifications, such as USDA

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FIGURE 4-9 Food Risk Road. Risk factors on the road to foodborne illness.



grade, weight, size, and form (e.g., fresh or frozen; see Chapter 6). Suspect cans (dented, bloated, or showing signs of leakage) and foods in unmarked containers should be discarded. All foods should be in their original containers or clearly labeled if they have been transferred to another receptacle. Only pasteurized milk (and food made from milk) and fruit or vegetable juice should be utilized, along with a safe water supply, or the water should be vigorously boiled for at least three minutes.

Inspection

Shipments should be inspected upon delivery by trained employees who can evaluate the quantity and quality of the food (each food-related chapter in this book covers quality under the "Selection" section). The employee should check the temperature of the arriving food and then store the products at the correct temperature as soon as possible after receipt. Employees then document whether the shipment was accepted, rejected, or corrected.

Temperature danger zone The temperature range—considered to be 40 to 140°F (4 to 60°C) by the USDA for consumers, and 41 to 135°F (5 to 57°C) according to the FDA Food Code for retailers—that is ideal for bacterial growth.

Storage

Stored food slowly deteriorates, making it vulnerable to microbial contamination. During storage, or at any other time, two main risk factors on the "Risk Road" to foodborne illnesses are (1) temperature and (2) the amount of time that food stays within a certain temperature (Figure 4-9).

For this reason, after delivery, perishable foods should be immediately placed in one of three types of storage—(1) refrigerator, (2) freezer, or (3) under dry conditions—according to the following temperatures:

1. Refrigerator:
   - USDA = 40°F (4°C) or below for consumers
   - FDA = 41°F (5°C) or below for retailers
2. Freezer: Below 0°F (218°C)
3. Dry storage:
   - 60 to 70°F (15 to 21°C) for canned goods
   - 50 to 70°F (10 to 21°C) for root vegetables (potatoes, onions) and whole citrus, eggplant, and squash (hard-rind)

The optimal storage type and temperatures recommended for foods vary; the inside back cover of this book, along with the "Storage" sections of the food-related chapters, describe these differences. For instance, some fruit is better left to ripen at room temperatures, especially bananas, tomatoes, avocados, and pears.

In any case, storage areas should be properly maintained and kept clean to prevent contamination of foods during storage. Microorganisms by their nature are ubiquitous and lodge themselves in air filters, drains, equipment, floor cracks, food scraps, and even dust.

Temperature

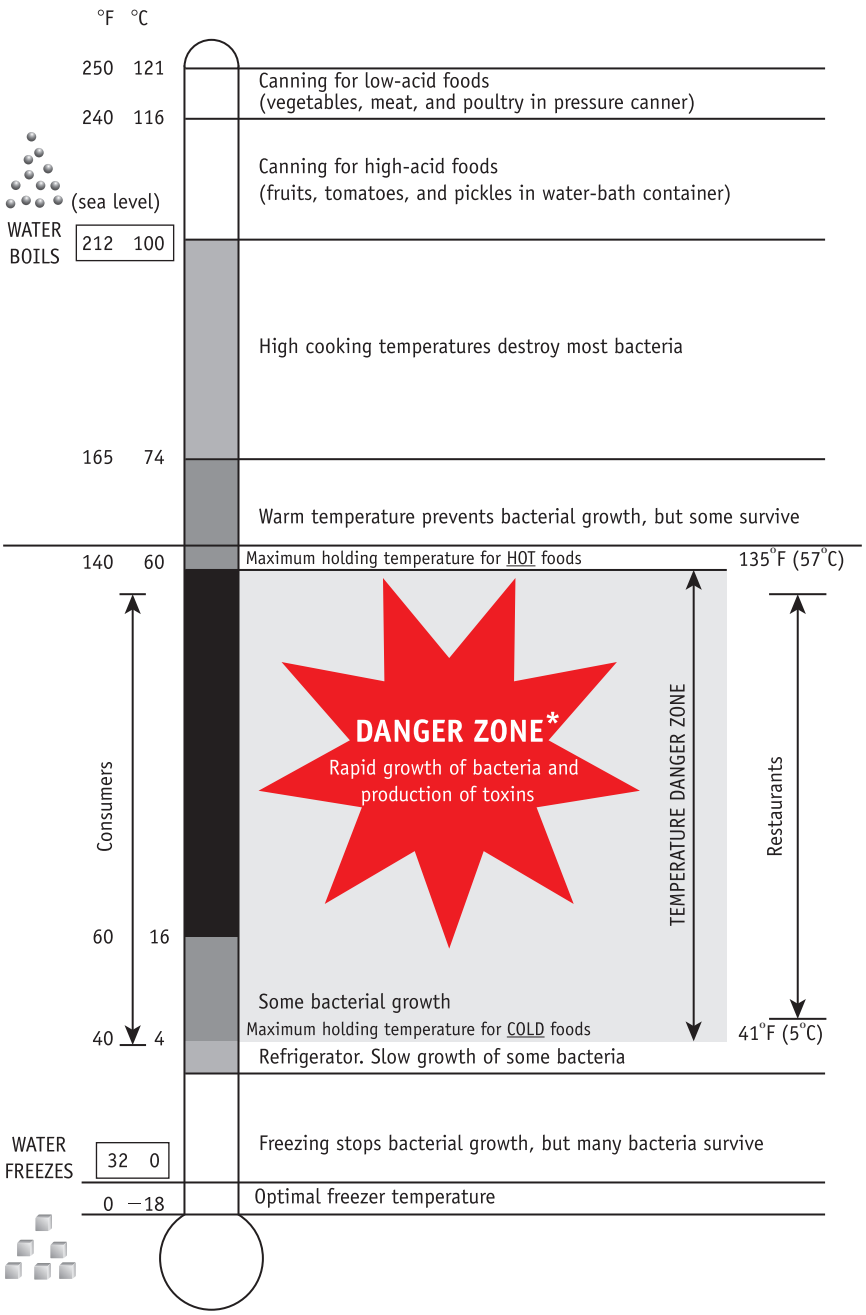
Proper storage is important because bacteria grow rapidly in the **temperature danger zone,** which includes the human body temperature of 98.6°F (37°C) (Figure 4-10). The goal is to keep foods out of the temperature danger zone. It is important to recognize that temperatures suggested by the USDA primarily for consumers and those recommended by the FDA Food Code for retailers may differ. The USDA suggests storing cold foods under 40°F (4°C) and hot foods above 140°F (60°C). The FDA Food Code recommendation is different for retailers (restaurants, etc.), which have a slightly modified temperature danger zone of 41 to 135°F (5 to 57°C). Bacteria normally do not survive temperature

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FIGURE 4-10 The temperature danger zone and its surrounding temperatures.



extremes, although a few bacteria survive below freezing (32°F [0°C]).

Despite precautions, some bacteria may survive environmental stresses in **spore** form. Spores are very resistant to drying and heating, and the bacteria may remain in this dormant state for long periods until their environment becomes more hospitable. In addition, food processing plants are vulnerable when instruments and appliances used in pathogen-killing processes, such as temperature gauges, heaters, seals, and refrigeration units, fail to work properly.

Proper Refrigerator and Freezer Use

Refrigerators and freezers, especially in a commercial food establishment, should be opened only when absolutely necessary because frequent door opening decreases their temperature efficiency. Refrigerator temperatures should be checked regularly with a refrigerator–freezer thermometer to ensure they are being maintained correctly (i.e., ≤40°F [4°C] for refrigerators, ≤0°F [−18°C] for freezers; see back inside cover). Studies show that 10 to 20% of home refrigerators are above 50°F (10°C), a temperature that cannot ensure safety (19). The refrigerator or freezer should not be overloaded because this may compromise the capacity of the unit to maintain correct temperatures. In addition, large amounts of hot food should not be placed in a cold refrigerator, as this will cause temperatures to fluctuate dangerously.

Storage Times

Any perishable food exposed to danger-zone temperatures for more than 2 hours of continuous time or 4 hours of cumulative time should be discarded. Cumulative time includes the time from the truck to the store, the store to the freezer, the freezer to the kitchen, and the time the food is on the counter where it is being prepared. Microbial growth occurs exponentially; the number of bacteria can grow from harmless to staggering in a relatively short time (Figure 4-11).

There is also a limit on how long perishable foods can be held safely in the refrigerator, the freezer, or under dry conditions. Storage limits are provided on the inside back cover of this book; however, recommendations for maximum storage times are not exact and vary from source to source. A general rule to follow is 3 days maximum for fresh meats and high-water-content fruits and vegetables. The first in, first out (FIFO) rule should also be followed—foods brought into the storage area at an earlier date should be used before those purchased later. This is especially true for the high-risk foods such as meat, dairy, and eggs. Each food-service establishment should follow a schedule for reviewing all perishable foods so those that pass their expiration dates are discarded.

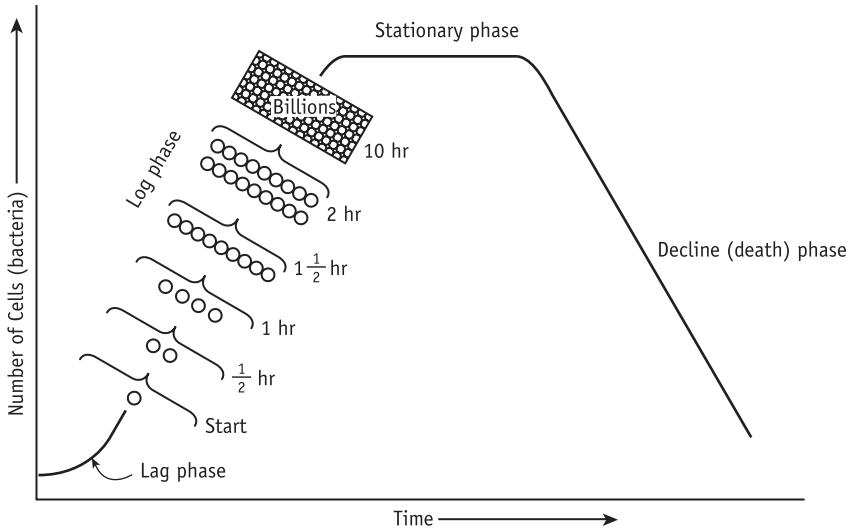
Spore Encapsulated, dormant form assumed by some microorganisms that is resistant to environmental factors that would normally result in their death.

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FIGURE 4-11 Bacteria divide to reproduce, resulting in billions from just one cell in less than 1 day.



Vulnerable Foods

A very important part of a preventing foodborne illness is to know the foods vulnerable to causing outbreaks. Just like humans, bacteria need food to survive, so it's natural for them to break down organic material as part of the earth's ecology. Foods that best support their growth—those that contain large amounts of protein and water—are known as *high-risk* foods (Figure 4-12). Other factors making foods more prone to bacterial contamination are low acid content and sufficient oxygen, although exceptions exist. These risk factors affecting bacterial growth are illustrated by the "Food Risk Road," shown earlier in Figure 4-9, and are explained further next.

FIGURE 4-12 High-risk foods (high levels of protein/water) for disseminating foodborne illness.

- Meat—beef, pork, lamb
- Poultry
- Fish and shellfish
- Dairy
- Eggs
- Broth, stocks
- Gravies/sauces (meat-, milk-, or egg-based)
- Tofu and other soy foods
- Stuffings (when exposed to poultry cavity)

High-Risk Foods

Meats, which top the high-risk foods list because of their protein and water content, are particularly susceptible to contamination because the digestive tracts of people and animals naturally contain bacteria. During the rendering of animals at the slaughterhouse, the digestive tract may be accidentally cut open or nicked, releasing bacteria that may then come in contact with meat (22). Other possible sources of contamination include any cuts, skin, feet, hair, hide, or feathers that can carry bacteria.

Other vulnerable foods include those made with the high-risk foods and extensively handled, such as meatloaf, hamburger, salads (coleslaw and pasta, chicken, egg, and tuna salads), Chinese and Mexican dishes, some baked goods, and cream fillings. The juice from marinades used to coat raw meat, poultry, pork, or lamb is particularly high in bacteria so margination should always occur in a refrigerator (bottom shelf), and the marinade should never be reused on new foods unless first brought to a boil. Egg dishes likely to become contaminated include baked or soft custard, French toast, quiches, hollandaise sauce, meringues, eggnog, and mayonnaise. Damaged eggs are good vectors for organisms that cause foodborne illnesses and should be discarded. Eggs should be cooked until firm to avoid serving runny eggs. Food establishments have the safer option of using pasteurized eggs, especially for Caesar salad dressing or Hollandaise sauce. Proper refrigeration or freezing is a must for high-risk foods and the dishes that contain them.

Foods with High Water Activity

Primarily, foods with a high water activity (a_W) of 0.85 to 0.97 are at risk (59). Bacteria cannot survive without water; if they dry out, they die. This is the principle behind drying foods, one of the oldest methods of food preservation. Meat is highly susceptible to contamination, but beef jerky lasts for a long time, making it a perfect food to transport during long trips without refrigeration. Food manufacturers also reduce water activity and hence the risk of bacterial contamination by adding sugar or salt as a preservative. Water, including that within the bacteria, is pulled by osmosis toward the sugar and salt, causing the bacteria to die.

It is also important to keep the food facility as water-free as possible. Contaminated water is a severe problem for food-service establishments, which can use water only from an approved water supply free of pathogenic microorganisms. In addition, only restaurants with adequate plumbing and proper water waste and sewage disposal are allowed to serve food. Mechanisms must be in place to prevent backflow through pipes (sewer)—an occurrence that will cause the health department to immediately close a food-service establishment.

Foods with Low Acidity

The acidity or alkalinity of a substance often determines which bacteria, if any, will grow in a food. The FDA states that proper pH (the measure of acidity, less than 7, or alkalinity, greater than 7, of a solution) must be maintained in order to prevent the growth of harmful bacteria. Because most (but not all) bacteria do not grow well below the low pH of 4.6, acidification is one way to keep various foods safe from harmful bacteria (82). The food industry uses two methods to increase the acidity of foods:

1. Acid is added to foods as a chemical:
   - Acetic acid (vinegar, salad dressing)
   - Citric or lactic acid (candy, orange juice)
   - Phosphoric acid (cola soda)
2. Acid is produced through fermentation by microorganisms such as bacteria or yeast that are added to foods:

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- Propionic acid (Swiss cheese)
- Lactic acid (yogurt, pepperoni, sauerkraut)

In general, foods that are naturally high in acid (e.g., limes) or made more acidic are less likely to engender bacterial growth than low-acid foods. The pH sensitivity of bacteria means that fruits and other high-acid content (pH <4.6) foods are less likely to be sources of microbial contamination than foods with a lower acid content (pH >4.6), such as meats and vegetables (34). Exceptions always exist. For example, tomatoes were once considered high-acid foods and relatively safe, but some newer varieties are not so acidic.

Exceptions to the High-Protein/Water/pH Rules

In recent years, foodborne illnesses have been traced to foods that do not contain high levels of protein and water. Fresh fruits and vegetables, cooked rice, sliced fruits, sautéed onions, potatoes, garlic-in-oil combinations, raspberries, strawberries, almonds, and apple cider have all been implicated (75). According to the FDA, more than 75% of produce-related outbreaks can be traced to five groups: lettuce (30%), tomatoes (17%), cantaloupes (13%), herbs (11%), and green onions (5%) (9). For this reason, it is very important to wash all produce under running water without soap or detergents. Melons and cucumbers are best scrubbed with a produce brush. Overall, the foods most commonly associated with foodborne illness in the United States in descending order of frequency are leafy vegetables, dairy, fruits and nuts, poultry, and vine-stalk vegetables (65).

The FDA has also received reports of serious outbreaks of foodborne illness traced to drinking unpasteurized fruit and vegetable juices (33). At one time, it was thought that the acidity of fresh apple cider (pH <4.0) was protective, but it is now known that one strain of *E. coli* can survive in fresh cider with a pH of 3.7. This conflicts with the FDA Food Code, which has historically considered foods with a pH of less than 4.6 as generally safe (8). Because fruits and vegetables may be contaminated by microorganisms in the soil or by manure used to fertilize crops, the FDA recommends pasteurization for juices and requires the fresh juice industry to place the following warning on untreated juice or cider:

WARNING: This product has not been pasteurized and therefore may contain harmful bacteria that can cause serious illness in children, the elderly, and persons with weakened immune systems (33).

Oxygen and Food

Many microorganisms need oxygen to grow, but others prefer oxygen-free environments such as cans, foil-wrapped baked potatoes, or untreated garlic-in-oil mixtures (59). A common method of reducing the risk of bacterial growth is to remove oxygen from a food product bag through vacuum packaging.

Preparation

The various steps of food preparation—pre-preparation, cooking, holding, cooling, reheating, and serving—are vulnerable to creating conditions for foodborne illness. These individual steps of food preparation are now discussed.

Pre-preparation

In addition to thoroughly washing fresh fruits and vegetables, two important pre-preparation steps related to food safety are thawing and cross-contamination.

Thawing

For safe thawing, only four methods are acceptable (Figure 4-13):

- In a refrigerator, on the bottom shelf to avoid contaminating other foods with any drippings. The planning required for this method is essential because thawing frozen meat at room temperature is considered an unsafe practice.
- Submerged under running water. However, running cold water over meat wrapped in protective plastic, or placing it in a bath of ice water and frequently replacing the water, are not as safe as defrosting in a refrigerator.
- Microwave oven followed by immediate cooking. This will work for smaller items, but not large roasts or turkey.
- As part of the cooking process. Be sure to check final internal temperatures.

FIGURE 4-13 Four acceptable methods for thawing foods.



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Cross-Contamination

Cross-contamination is one of the most common causes of foodborne illness during the summer months, when backyard barbecuing is popular. People carry raw meat on a plate to the barbecue, cook the meat, and place it back on the same plate, which is contaminated with raw meat juices. Common means of cross-contamination include using unwashed cutting boards or countertops, knives or other kitchen tools, or hands; or using sponges, which may harbor bacteria even after they dry (67). Commercial cross-contamination can occur on a large scale; for example, in one incident, 224,000 people became ill after eating ice cream contaminated with *Salmonella*. The bacteria was traced to the trucking company that had transported the pasteurized ice cream premix in trailers that had previously carried *Salmonella*-contaminated liquid eggs (45).

To prevent cross-contamination at any level, food should never touch contaminated surfaces unless it is to be thoroughly cooked. Surfaces should also be regularly washed and sanitized, after each use, and especially after coming into contact with raw food. Particularly susceptible surfaces include hands, utensils, tabletops, cutting boards, and slicers, as well as aprons, cleaning cloths, and sponges. Using separate chopping surfaces or boards for raw meat and salad vegetables is ideal. Dust and soil should be washed off the tops of cans before they are opened. Raw meats should never be stored in the refrigerator above cooked or ready-to-eat foods where they may drip onto the food below.

Food-service workers should not touch the surfaces of food-serving utensils. The forks, knives, and spoons for customer use should always be placed head down in serving canisters. The same rule applies to the ice scoop handle, which should never come in contact with ice after touching an employee's hands or an unclean surface. The biggest mistake to avoid is double dipping when taste-testing food. A tasting utensil used once is best. Liquids can be poured into a separate small cup for tasting.

How & Why?

What's the difference between sanitizing and sterilizing?

Sanitization is achieved by applying heat or chemicals to a properly cleaned (through removal of organic material) surface to yield a 99.999% reduction in pathogenic (harmful) microorganisms. Sterilization is the destruction of "all" living organisms, not just those that are harmful (36).

Cooking (Heating)

Temperature–time abuse contributes to most foodborne outbreaks in the United States (77). Microorganisms grow most rapidly at temperatures in the middle of the danger zone, so the three most common mistakes to avoid when heating food are as follows:

1. Failing to heat food to its minimum internal temperature
2. Failing to cool food properly
3. Failing to reheat food to its minimum internal temperature

Minimum Internal Temperatures

Heat often destroys bacteria. It is well known that bacteria die when exposed to at least 10 minutes of boiling (212°F [100°C]) and that freezing (32°F [0°C]) slows their growth. However, not all food can be boiled, so the goal is to keep foods out of the temperature danger zone and to heat foods to their minimum internal temperatures to destroy any microorganisms that may be present. Certain foods, especially meat, poultry, and fish, need to reach higher temperatures than the minimum consumer standard of 140°F (60°C), or 135°F (57°C) for retailers, during cooking in order to ensure safety (Table 4-10).

Thermometers

The only way to be sure about a food's temperature—and whether or not it is in the temperature danger zone—is to use a thermometer. Fahrenheit (nonmetric) and Celsius/centigrade (metric) scales are usually displayed together. Standard bulb thermometers work on the principle that mercury expands when heated and contracts when cooled. Mercury in the bulb at the bottom of an extended glass tube expands and contracts along a marked graduated scale. However, glass thermometers with mercury should never be used in commercial food operations because they can break. Numerous types of other thermometers are now available, including those that record the results and/or operate remotely.

Temperature–Time Monitoring Program

Every restaurant or food-related establishment should have an organized plan regarding temperatures and times for food preparation written into its standard operating procedures that states what will be monitored, when, and by whom (the person responsible). Employees should be given their own thermometers, times to check certain foods or equipment (refrigerators, freezers, fryers, serving areas), methods to log the temperature and time, and an established set of corrective action procedures. This information should then be filed in the organization's records. An active monitoring program is essential for the prevention of foodborne illnesses.

Holding

Foods being held before or after serving must also be kept out of the temperature danger zone. Thermometers should be used to ensure that the following temperatures are reached:

- Hot foods
  FDA: at least 135°F (57°C)
  USDA: at least 140°F (60°C)
- Cold foods
  FDA: under 41°F (5°C)
  USDA: under 40°F (4°C)

Time Limit

Held food must be sold, served, or discarded within 4 hours (59). Food temperatures should be checked right after cooking and at least every 2 hours thereafter to allow for corrective action. After 4 hours, the food has to be discarded if it falls outside these minimal internal temperatures. It's easier to stay within recommended temperatures by distributing evenly by stirring and preparing foods in smaller batches.

Protective Barriers

Held food should be covered as much as possible or blocked from people by plastic sneeze guards.

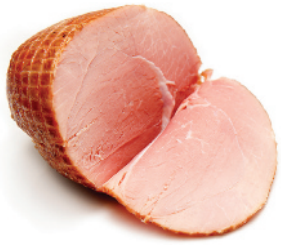
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TABLE 4-10 Minimum Internal Temperatures (for 15 Seconds)

(Temperatures vary depending on the source [FDA Food Code and the USDA], and individual states [health departments] are not required to adopt either of these recommendations, so some temperatures will vary.)

			
Sauces	Soups	Gravies	Marinades
212°F (100°C)—Bring to a boil			
			
Poultry (whole, pieces, or ground chicken, turkey, duck, etc.)*	Stuffing	Casseroles	Reheating leftovers
165°F (74°C)			
			
Ground meats (beef, lamb, pork)	Egg dishes (cook until firm)	Egg sauces	Egg custards
160°F (71°C)			
			
Beef, veal, lamb, pork**	Uncooked ham	Fish	Shellfish
145°F (63°C) + 3 Minute rest time			

Precooked ham and roast beef (reheating fully cooked commercially, vacuum sealed, ready to eat)
140°F (60°C)

*In 2006, the USDA selected 165°F (74°C) to be the single safe minimum end-point temperature. However, consumers can choose to cook poultry to higher temperatures. It is recommended to check the temperature in whole birds at three locations—thigh (deep crevice), wing joint, and breast.

**145°F (63°C) for medium rare, 160°F (71°C) for medium, and 170°F (77°C) for well done.

Source: http://www.fsis.usda.gov/Fact_Sheets/Safe_Minimum_Internal_Temperature_Chart/index.asp

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PROPER USE OF THERMOMETERS

Types of Thermometers

As shown in Figure 4-14, an array of food thermometers that include dial, digital, disposable, appliance, and others are available for different purposes in commercial food preparation (78, 80). Among the most popular are the pocket-size, instant-read (dial or digital) thermometers that can be used to check foods being held on steam tables in food-service establishments. These are portable and give a reading a few seconds after being inserted into the food.

Thermometers differ not only in style but also in temperature range, cost, ability to be calibrated, and use. For instance, a meat thermometer has a short rod for insertion into the meat and usually has an upper limit of 185°F (85°C). A candy thermometer has an upper range of 325°F (163°C), and a deep-frying thermometer goes up to at least 500°F (260°C).

Testing Temperatures

Only a few thermometers can be left in the food or appliance for checking temperatures continuously. Most are used at the end of preparation (cooking or cooling, or while being held) to test the food in two or three different areas to see if it has reached a safe temperature.

- **Instant readings.** Instant-read dial thermometers are inserted straight or at an angle at least 2 inches into the thickest part of the food without touching fat or bone and given 10 to 20 seconds before reading. Thin pieces such as hamburgers or pork chops can be measured by inserting the probe into the side of the food. Instant-read digital thermometers only need to be inserted about a half inch into the thickest part of the food and only take 2 to 10 seconds to register (73).

FIGURE 4-14 Different types of food thermometers.

Dial Thermometers

Instant-Read, Bi-Metallic



Shaped like a clock face or "dial" with a probe, these thermometers are best suited for quickly testing large amounts or big pieces of food rather than thin or quickly cooked food. They are not designed to stay in food during cooking.

Dial Oven-Safe



Only a dial oven-safe thermometer can stay in food while it cooks. Large oven-proof dial thermometers are usually inserted into roasts and whole chickens or turkeys.

Digital (Instant-Read) Thermometers: A digital readout with a battery that must be turned on and off distinguishes these thermometers from the dials (instant-read or oven-safe). It can become confusing because digital thermometers come in many shapes, including that of a "dial" thermometer.

Thermocouplers



These are the fastest thermometers, taking only 2–5 seconds to read temperatures. Their very thin probes (two fine wires) can be used on thin or thick foods.

Thermistors



Shaped like a dial thermometer, they have slightly thicker probes (ceramic semiconductor) and take about 10 seconds, but they can still measure both thin and thick foods. Probes for both thermistors and thermocouplers can be shaped for use in liquid (immersion), at the surface (flat), or inside food (penetrating).

Infrared



This thermometer, held like a gun, measures only surface temperature because the person points and shoots. No cleaning is necessary.

Fork



There is even a digital thermometer shaped like a fork.

Disposable Temperature Indicators (Single-Use)

Pop-Up



These are commonly used with whole chickens, turkeys, or roasts, but it's best to double-check the results against a conventional thermometer. The indicator pops up when the recommended temperature is reached because this is the heat required to melt the firing material, which releases the spring in the nylon device.

Disposable



Designed for just one use.

Time Temperature Indicators (TTI)



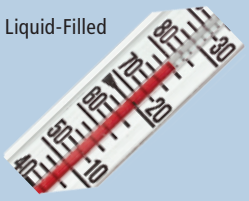
These small monitors, about the size of two stamps, have adhesive on the back so that they can stick to food products in transit or storage. They irreversibly record the high or low temperature to detect temperature abuse.

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Appliance Thermometers: Specialized thermometers (dial or digital) can be placed in or outside ovens, refrigerators, or freezers to check the accuracy of their thermostats.

Dial Oven-Safe (Bi-Metallic) 	Thermometers that can measure temperatures from 100 to 600°F (38–316°C).	Oven Cord Thermometer 	A thermometer probe inserted into the cooking food within the oven is connected by a cord to the base unit on the counter, maintaining a continuous temperature check.
Refrigerator/Freezer 	Refrigerators need to be at or below 40°F (4°C), while freezers need to be below 32°F (0°C).	Microwave 	Even though microwave-safe temperature probes exist, not all meats can be cooked in a microwave oven because the waves only penetrate to a depth of ½ to 2 inches. For this reason, it is unsafe to cook turkeys in a microwave oven, even if they are unstuffed. Short heating times are another safety concern for vulnerable foods that are microwaved.
Panel 	Many units now have the internal temperatures digitally displayed on the outside or have panel thermometers built onto the outside of the unit.		
Other Thermometers			
Candy/Jelly/Fryer 	Only these thermometers measure the very hot temperatures needed for frying and making confections: 100–400°F (38–204°C).	Liquid-Filled 	This is one of the oldest thermometers inserted into foods cooked at home, but they are not for commercial establishments; they may be unreliable because the metal stem can cause false high readings.

Source: Adapted from U.S. Department of Agriculture Food Safety and Inspection Service (FSIS). *Kitchen thermometers.* www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/appliances-and-thermometers/kitchen-thermometers/ct_index. Accessed 12/2/16.

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- **Noninstant dial readings.** Noninstant-read dial thermometers take longer than their digital counterparts to read temperatures—at least 1 to 2 minutes.

Care of Thermometers

Instant-read thermometers must be cleaned between uses (with alcohol wipes or with hot soapy water by hand, but never immersed in water) or contamination may result. It's also best to leave the sharp probe in the sheath and turn off battery-operated devices between uses. Store them away from heat or cold.

Calibration of Thermometers

Thermometers have a tendency to malfunction when dropped or jarred. They may also simply drift off in their readings, so thermometers need to be tested frequently for accuracy against a known standard by testing them in either freezing (ice-water method) or boiling water (boiling-water method). The more common ice-water method consists of blending a cup of crushed ice in a cup of water (or 50% ice and 50% water at least 2 inches deep), dipping the point into the stirred slurry for 30 seconds, and seeing if it reads 32°F (0°C). Detailed instructions are provided by one of the website links at the end of this chapter. The boiling-point method involves dipping the point of a bulb thermometer into boiling water for 30 seconds without touching the sides or bottom of the pan. Digital and dial thermometers are checked by placing them 2 inches above boiling water to obtain the reading of 212°F (100°C). The reading should be 212°F (100°C) at sea level (with 1°F [2.2°C] subtracted for every 500 feet of increase in altitude).

Some dial thermometers have a calibration nut underneath their face and can be recalibrated by gripping the hex nut with pliers and twisting the dial face until it reads the correct temperature (75). Digital thermometers are slightly more expensive but more accurate because they contain an electronic sensor near the tip that is effective when inserted only ½ inch into food. If they drift off from calibration, they need to be replaced. Exceptions to this are battery-operated digital thermometers that can be sent back to the manufacturer or independent testing facility for recalibration or that are equipped with a recalibration knob.

Ideally, thermometers would be calibrated daily before the work shift begins or at least weekly or monthly, and definitely after each time they are dropped, jarred, or exposed to extreme temperatures. Not all food thermometers can be calibrated, so it's best to determine this prior to purchase.

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Cooling

Inappropriately cooled foods are another major cause of foodborne illnesses. Larger, denser foods are the most vulnerable. According to the USDA, foods should be cooled to below 40°F (4°C) within 4 hours of removal from cooking or they pose a danger to consumers. The FDA Food Code suggests that the cooling of hot foods occur in two stages: 135 to 70°F (57 to 21°C) in the first 2 hours, and then 135 to 41°F (57 to 5°C) within 6 hours or less. Food not reaching these temperatures within 6 hours should be discarded.

Figure 4-15 shows the four safe methods for rapidly cooling foods before they are placed in the refrigerator or freezer (59). Liquid foods should be placed in shallow pans less than 3 inches deep to cool, and thicker foods should be placed in pans less than 2 inches deep. Again, stirring distributes the heat more quickly. Ice paddles can also be used to stir the food until it has cooled down.

Reheating

Within 2 hours before being served, all hot foods must be reheated to at least 165°F (74°C) for 15 seconds. Sauces, soups, and gravies need to be brought to a boil before reserving. In a food-service establishment, untouched leftovers are sometimes discarded because they are a potential source of microbial contamination.

Serving

Serving is also a vulnerable point for food contamination. Good personal hygiene on the part of food-service employees is essential to the safety of the foods and beverages being served. Even when serving, the USDA recommends that the 140°F (60°C) and 40°F (4°C) boundaries continue to be observed, while the FDA Food Code suggests ≤41°F (5°C) and ≥135°F (57°C) for retailers. See the previous sections on personnel hygiene and cross-contamination for specific methods of ensuring food safety during serving. The safest practice is to make sure that bare hands never touch food or surfaces that will touch food.

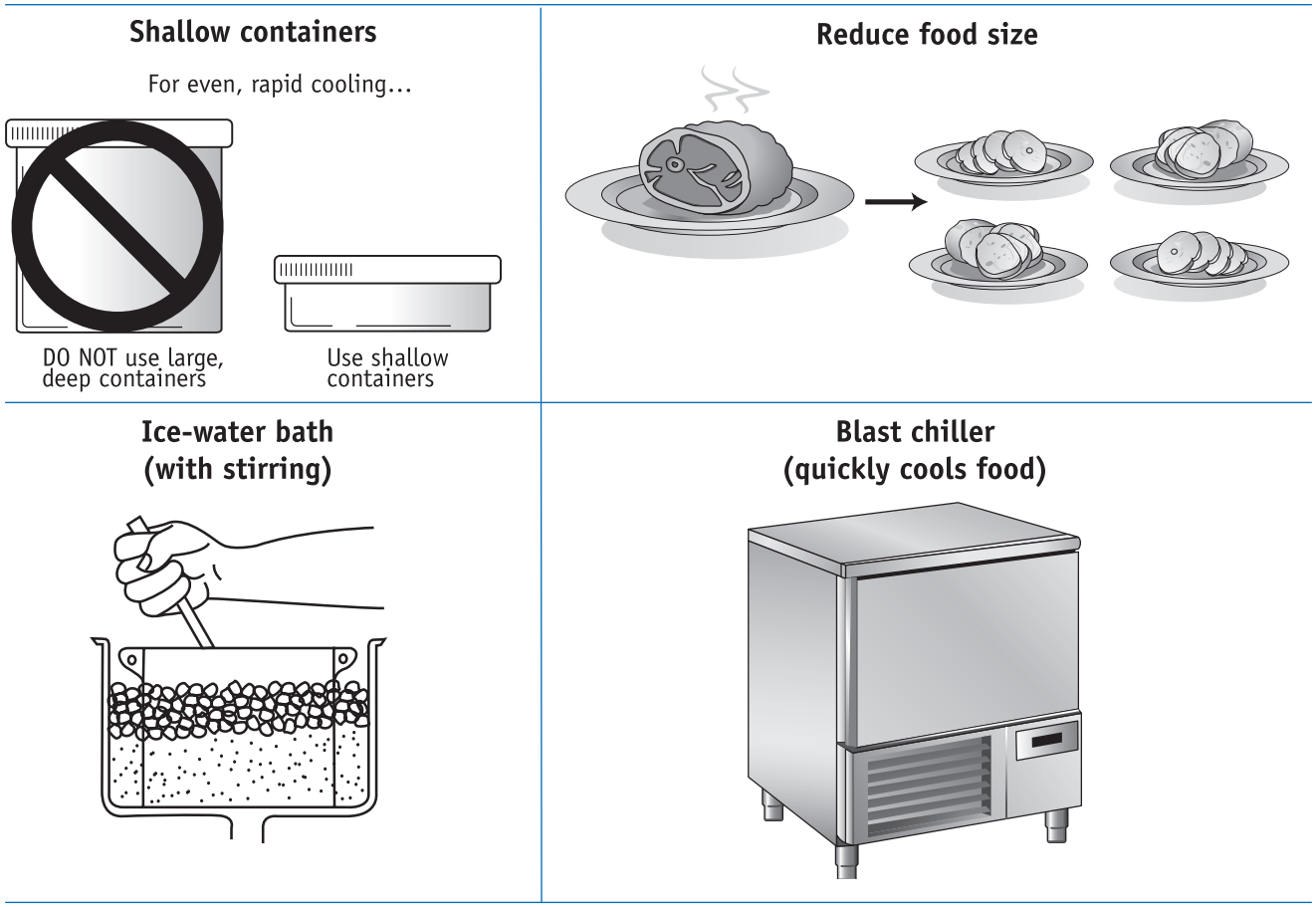
Sanitation

One of the major causes of foodborne illness is dirty utensils and equipment, but sanitation of surfaces coming in contact with food, whether dishes, utensils, counters, equipment, floors, or other parts of the food-service area, can be achieved through heating and/or chemicals. Typical sanitation steps include removing food debris, rinsing with water, applying detergent, again rinsing with water, and applying heat (very hot water) or a chemical sanitizer (86). Several important aspects of sanitation are discussed next.

Dishes

Dishes require specific processes to meet sanitation requirements for cleaning and drying.

FIGURE 4-15 Cooling foods—four safe methods.

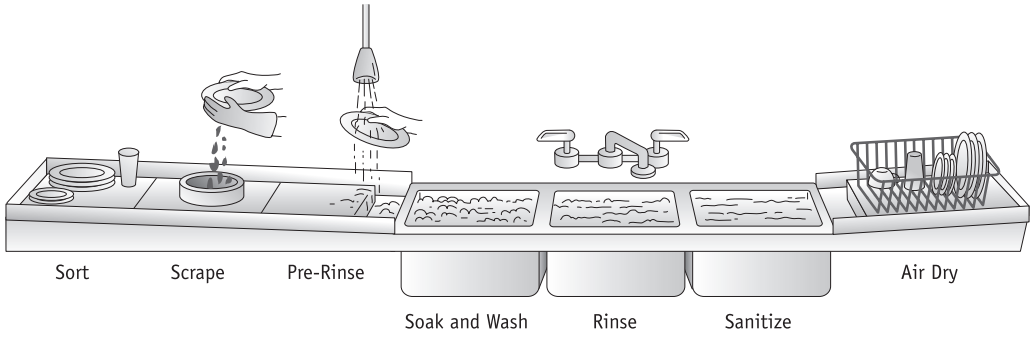


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FIGURE 4-16 Three-compartment sink.



Heating

Dishes in a food-service establishment may be hand-washed or machine-washed. Whatever method is used, the process must meet certain sanitation guidelines to pass a health department food inspection. In order to kill pathogens, dishwashing temperatures should be between 140°F and 160°F (60°C and 71°C), and rinse temperatures must be at least 180°F (82°C) for 10 seconds or 170°F (77°C) for 30 seconds. Despite concerns that dishwashing failures result in foodborne illness, only 5% of sanitation failures can be traced to faulty equipment; the remaining 95% are a result of human error.

Three-Compartment Sink

Manual washing in a food establishment requires a **three-compartment sink** for washing pots and pans, dishes, glasses, cutlery, and tools (Figure 4-16). The first compartment is used for soaking and washing items in water heated to 110°F (43°C). The second compartment is for rinsing, and the third area is for sanitation. The last compartment can sterilize items with either hot water or chemical sanitizers. If water is used, then temperatures must reach at least 180°F (82°C) for 1 minute.

Chemicals

Food establishments may also sanitize with the chemical sanitizers shown in Table 4-11. Material Safety Data Sheets (MSDS) are required for each hazardous chemical and should be available to employees because they provide information on safe use, first aid, and how to contact the manufacturer.

Drying

Items should always be air or heat dried. Damp cloth towels should be avoided because they serve as an ideal medium for microorganism growth.

TABLE 4-11 Chemical Sanitizers Used in Commercial Food Establishments

Sanitizer*	How to Use (at 75°F [24°C])
Chlorine	50 ppm† for water and equipment or 1 teaspoon for each quart of warm water or 1 tablespoon for each gallon of warm water
Iodine	12.5–25 ppm for handwashing and equipment
Quaternary ammonium compounds	200 ppm for walls; 500 ppm for floors
Organic acids (lactic, acetic, propionic)	130 ppm for stainless steel surfaces

*If manufacturer's instructions differ from this table, follow manufacturer's recommendations.
†ppm = parts per million

Scheduling

Schedules for cleaning should be posted and followed scrupulously to maintain a sanitary work environment. Floors, walls, windows, lights, and equipment should all be included in the frequent cleanup routine. Sanitation guidelines involving cleanup, personnel, equipment, facilities, pest control, and water should be set and routinely followed by establishing cleaning schedules for predetermined dates.

Euipment

The National Sanitation Foundation (NSF) sets standards for equipment to be used in food-service establishments. Equipment should be as free of crevices as possible, so it is best to buy equipment with rounded junctions. Wooden cutting boards are more prone to nicks and crevices than are those made of plastic or marble, and it once was thought that they were more prone to microbial contamination. Studies now show that after they are cleaned, bacterial levels do not differ significantly among the various types of boards (67). All equipment, utensils, containers, and meat grinders and slicers should be thoroughly cleaned after each use. Only trained employees should clean meat slicers because these instruments are the number-one cause of cuts in a food-service organization.

After cleaning, utensils are best stored covered, and glasses and cups should always be stored upside down. Disposable utensils such as plastic cups, forks, knives, and plates should never be washed and reused. Freezers and refrigerators should have at least 6 inches (10 inches is preferred) between the bottom storage shelf and the floor; this allows for adequate cleaning. They should also contain thermometers to determine that correct temperatures are being maintained.

Facilities

In order to remain sanitary, a food-service establishment should be designed and maintained in ways that promote cleanliness. Floors, walls, and ceilings should have adequate ventilation. Materials used in construction should allow for easy cleaning. Garbage should be discarded in covered, pest-proof containers that are frequently cleaned and free of litter. Lighting fixtures must be covered to prevent dust and insects from collecting on light bulbs and falling on the food. Food-service organizations are required to have dressing rooms, restrooms,

Three-compartment sink A sink divided into three sections—the first for soaking and washing, the second for rinsing, and the third for sanitizing.

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and handwashing sinks available to the employees. Having unclean restrooms is the most common complaint that consumers file with health departments against eating establishments.

Pest Control

Food naturally draws living creatures, from bacteria to bears. Even the cleanest facility can be put at risk of transmitting foodborne illness by the presence of insects, rodents, birds, turtles, or other animals. Rodents such as mice and rats can carry *Salmonella,* typhus, and the bubonic plague. Insects such as cockroaches transfer microorganisms by landing, walking, and regurgitating their stomach contents on foods when feeding. Figure 4-17 shows some common pests. To discourage pests from taking up residence, it's best to (1) establish an Integrated Pest Management (IPM) program; (2) block pests from entering the establishment, and (3) block pests from all food.

Integrated Pest Management (IPM) Program

A regular maintenance program is key to controlling pests in a commercial kitchen. The first step is to block all entrances and access to food, water, and shelter. Pests who manage to surmount these obstacles need to be removed or eliminated because that prevents them from breeding and creating exponential numbers of pests. Even though it might be tempting to spray insects, only a licensed pest-control operator can legally apply insecticides in a commercial establishment.

Blocking Entrances

Pests smell food, so all entrances should be screened (at least 16 mesh/square inch) or sealed. Doors and windows should be self-closing, closed, or covered with air curtains. Although not always possible, maintaining a low humidity (under 50%) through dehumidifiers and/or ventilation keeps cockroach eggs from hatching (59).

Blocking Access to Food

Keep counters, floors, and all surfaces as food-free as possible. Clean up all spills immediately and thoroughly. Even a crumb is a large meal for an insect. Keep all garbage covered, and remove it frequently. All food should be securely stored in pest-proof containers. Sometimes flours and grains already contain pests that then multiply within the bags; these bags should be immediately discarded. It may be necessary in humid climates to refrigerate grains, nuts, or any powdered food such as flour and dried milk. Water is critical to pest survival, so standing water should be removed, and all drains should be working properly.

FIGURE 4-17 Common pests that may transmit foodborne illness.



Cockroaches
Cockroaches are drawn to food crumbs and often regurgitate while eating.



Rodents
Signs of rats and mice include their droppings, urine markings, and holes in packaging.



Insects
Insects lay their eggs on decaying matter such as sewage, garbage, and rotting food.



Pantry Pests
Pests preferring pantry foods such as flour, sugar, rice, and other dry goods include beetles, mites, moths, weevils, and silverfish.

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Food Safety Monitoring

Food safety monitoring primarily occurs through state health department inspections, is bolstered by Food Monitoring Safety Programs within commercial kitchens, and is indirectly measured by foodborne illness surveillance. All of these methods are discussed in detail next.

Health Department Inspections

Proactive food-service organizations already perform their own internal inspections and thus are prepared to pass unannounced state health department inspections. Too many violations can result in suspension or revocation of an establishment's license. A temporary suspension is served when there is an imminent hazard to health or when there has been a failure to comply with an earlier inspection's findings. A revocation occurs with more serious or repeated violations.

Figure 4-18 shows how a sample health department inspection form assigns point values to various safety practices based on their importance. Points for any practices that are not being demonstrably followed are subtracted from 100% to obtain the score. The most common violations found by health inspectors involve food-holding temperatures, improper refrigeration, and improper cooling of cooked foods. Because food safety regulations vary from state to state, it is wise to obtain a copy of your state's inspection form in order to be absolutely sure of what is inspected by the local health department.

FDA Food Code

The FDA Food Code (28) became available in 1993 to serve as a foundation for all U.S. food safety programs. This list of government food safety recommendations is updated every several years. Although not actual law, it serves as a guide for state health departments in conducting inspections. As a result, minimum temperatures and other aspects of food safety lack uniformity across states, but the variations are often minor.

A survey of restaurant workers revealed that the main barriers to implementing safe food practices were time constraints, inconvenience, inadequate training, and inadequate resources (46). These barriers need to be overcome to ensure food safety for consumers and to pass health department inspections.

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FIGURE 4-18 Health department inspection form.

FOOD		POINTS
*01	Source; sound condition, no spoilage	5
02	Original container; properly labeled	1

FOOD PROTECTION

*03	Potentially hazardous food meets temperature requirements during storage, preparation, display, service transportation	5
04	Facilities to maintain product temperature	4
05	Thermometers provided and conspicuous	1
06	Potentially hazardous food properly thawed	2
*07	Unwrapped and potentially hazardous food not re-served	4
*08	Food protection during storage, preparation, display, service, transportation	2
09	Handling of food (ice) minimized	2
10	In use, food (ice) dispensing utensils properly stored	1

PERSONNEL

*11	Personnel with infections restricted	5
*12	Hands washed and clean, good hygienic practices	5
13	Clean clothes, hair restraints	1

FOOD EQUIPMENT AND UTENSILS

14	Food (ice) contact surfaces: designed, constructed, maintained, installed, located	2
15	Non–food-contact surfaces: designed, constructed, maintained, installed, located	1
16	Dishwashing facilities: designed, constructed, maintained, installed, located, operated	2
17	Accurate thermometers, chemical test kits provided, gauge cock (1/4" iron pipe size valve)	1
18	Preflushed, scraped, soaked	1
19	Wash, rinse water: clean, proper temperature	2
*20	Sanitization rinse: clean, temperature, concentration, exposure time; equipment, utensils sanitized	4
21	Wiping cloths; clean, use restricted	1
22	Food-contact surfaces of equipment and utensils clean, free of abrasives, detergents	2
23	Non–food-contact surfaces of equipment and utensils clean	1
24	Storage, handling of clean equipment/utensils	1
25	Single-service articles, storage, dispensing	1
26	No reuse of single service articles	2

WATER

*27	Water source, safe: hot and cold under pressure	5

SEWAGE		POINTS
*28	Sewage and waste water disposal	4

PLUMBING

29	Installed, maintained	1
*30	Cross-connection, back siphonage, backflow	5

TOILET AND HANDWASHING FACILITIES

*31	Number, convenient, accessible, designed, installed	4
32	Toilet rooms enclosed, self-closing doors, fixtures, good repair, clean; hand cleaner, sanitary towels/tissues/hand-drying devices provided, proper waste receptacles	2

GARBAGE AND REFUSE DISPOSAL

33	Containers or receptacles, covered: adequate number insect- and rodent- proof, frequency, clean	2
34	Outside storage area enclosures properly constructed, clean; controlled incineration	1

INSECT, RODENT, ANIMAL CONTROL

*35	Presence of insects/rodents—outer openings protected, no birds, turtles, other animals	4

FLOORS, WALLS, AND CEILINGS

36	Floors, constructed, drained, clean, good repair, covering installation, dustless cleaning methods	1
37	Walls, ceiling, attached equipment: constructed, good repair, clean, surfaces, dustless cleaning methods	1

LIGHTING

38	Lighting provided as required, fixtures shielded	1

VENTILATION

39	Rooms and equipment—vented as required	1

DRESSING ROOMS

40	Rooms clean, lockers provided, facilities clean, located	1

OTHER OPERATIONS

*41	Toxic items properly stored, labeled, used	5
42	Premises maintained free of litter, unnecessary articles, cleaning maintenance equipment properly stored. Authorized personnel	1
43	Complete separation from living/sleeping quarters. Laundry.	1
44	Clean, soiled linen properly stored	1

*Critical items requiring immediate attention.

Score = 100 – ☐ pts. = ☐

Source: Adapted from Texas Department of Health's Food Service Establishment Inspection Report.

HACCP

The best way to pass a health department inspection is to have a Food Safety Management System (FSMS) already in place with Standard Operating Procedures (SOP) providing a clearly written plan for employee training to ensure that safe food is served to consumers. A more formal approach for larger institutions is to incorporate **HACCP** (pronounced hass-ip)—Hazard Analysis and Critical Control Points—a seven-step procedure into existing FSMS (20). The FDA previously recommended that the HACCP system be incorporated by the food industry, including processing plants,

HACCP Hazard Analysis and Critical Control Points System, a systematized approach to preventing foodborne illness during the production and preparation of food.

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food-service establishments, and food corporations. Having a customized, written HACCP plan shifts the emphasis from policing via inspections and reacting to contamination problems after the fact to a written prevention program. HACCP is also based on the flow of food from farm to fork rather than meeting minimum sanitary recommendations.

History of HACCP

In the 1960s, the National Aeronautics and Space Administration (NASA) wanted to provide food that approached a 100% assurance against foodborne illness to astronauts during space flights. They worked with U.S. Army Natick Research Laboratories and the Pillsbury Company to develop the HACCP program (88). About 30 years later in 1989, the HACCP guidelines became the international standard for food safety.

The Seven HACCP Principles

HACCP is a food safety program based on seven steps (20): (1) assessing (identifying) potential hazards (biological, chemical, radiological, and physical); (2) identifying **critical control points (CCPs)**; (3) establishing quantifiable limits such as temperatures for each CCP; (4) monitoring CCPs to make sure that they stay within the recommended limits; (5) taking corrective action if they do not; (6) verifying through regularly evaluating records; and (7) documenting through record keeping.

How & Why?

Why was NASA so interested in food safety?

A foodborne illness in space could be life-threatening to an astronaut. Diarrhea and vomiting would be a big problem for a person in a space suit in a zero-gravity environment.

Critical control points (CCP) A point in the HACCP process that must be controlled to ensure the safety of the food.

HARPC Hazard Analysis and Risk-Based Preventive Controls, a global set of required guidelines (evolving from and newer than HACCP) that addresses food safety through the analysis and control of hazards from farm to fork.

HARPC

HARPC guidelines are newer and more stringent than the HACCP that many countries still follow. In the United States, it is now mandatory for companies to evolve to a written HARPC plan identifying potential hazards, lists of how to prevent each hazard, established monitoring procedures, actions to take during a breach, and a written record (71). HARPC consists of eight steps: (1) define the scope of the assessment; (2) identify the hazards; (3) carry out hazard analysis; (4) add preventive controls; (5) implement monitoring systems; (6) add corrective actions and corrections; (7) verify the system; and (8) reanalyze the system at least every 3 years (53).

Foodborne Illness Surveillance

To ensure food safety guidelines are being followed, some of the surveillance systems (national and global) are listed here that measure the number of outbreaks and foodborne illnesses on an annual basis (11).

FoodNet

The Foodborne Diseases Active Surveillance Network (FoodNet) established in 1995 is part of the CDC's Emerging Infections Program (EIP), but it is also a collaborative project among local health departments, the FDA, and the USDA Food Safety and Inspection Service. The network maintains surveillance of foodborne outbreaks by recording the number of foodborne illnesses reported in the United States (10). The biological hazards monitored include *Campylobacter, Escherichia coli* O157:H7 and non-O157, *Listeria, Salmonella, Shigella, Yersinia, Vibrio,* and parasites, such as *Cryptosporidium* and *Cyclospora*.

Physicians and coroners notify local health departments of certain disease cases as required by law. These reports are then sent to the state public health epidemiology office, where their laboratories may also receive food samples to test. Eventually, this information is sent to federal offices such as the CDC. Unfortunately, not every person who reports a foodborne illness provides a sample, so only about 38% of all recognized outbreaks reported to the CDC ever have their cause identified (45).

Additional Surveillance Systems

- **CaliciNet.** The National Electronic *Norovirus* Outbreak Network, or CaliciNet, rapidly links *Norovirus* clusters to outbreaks with a common food source.
- **CORE Network.** FDA's Coordinated Outbreak Response & Evaluation Network was created to manage outbreaks.
- **DPDx.** CDC's laboratory identifies parasites of public health concern.
- **EHS-Net.** Investigators in the Environmental Health Specialists Network gather information about contributing factors in foodborne outbreaks.
- **Foodborne Disease Outbreak Surveillance System (FDOSS).** The CDC collects reports of foodborne outbreaks due to enteric bacterial, viral, parasitic, and chemical agents.
- **NARMS.** The National Antimicrobial Resistance Monitoring System conducts surveillance for antimicrobial resistance among foodborne bacteria.
- **National Notifiable Diseases Surveillance System (NNDSS).** The NNDSS tracks contagious diseases that laboratory professionals and doctors are required to report to the state or territorial public health agency.
- **National Surveillance for Enteric Disease.** The CDC collects and analyzes data from all states on infections due to enteric bacterial pathogens.
- **National Outbreak Reporting System (NORS).** Health departments use this website to report foodborne and waterborne disease outbreaks to the CDC.
- **PulseNet.** The National Molecular Subtyping Network for Foodborne Disease Surveillance is a large network of laboratories (fifty states and eighty-two countries) that allows investigators from participating sites to upload pulsed-field gel electrophoresis (PFGE) patterns to an electronic database. These PFGE patterns, which represent a standardized process for subtyping bacteria, are also the origin of the organization's nickname.

World Health Organization

Globally, the WHO established the Foodborne Disease Burden Epidemiology Reference Group (FERG) that reports estimates of the incidence, mortality, and disease burden due to thirty-one foodborne hazards around the world (43).

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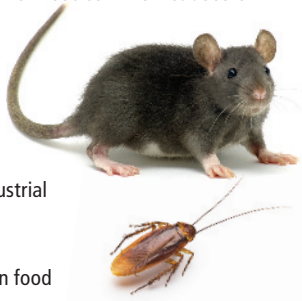
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PICTORIAL SUMMARY / 4: Food Safety

Federal and state regulations, along with regular inspections throughout the food industry, ensure that the food supply in the United States is the safest in the world.

FOODBORNE ILLNESS

Symptoms of an illness transmitted through food often include inflammation of the gastrointestinal tract lining, nausea, abdominal cramps, diarrhea, and/or vomiting. The most common causes of foodborne illness are:



Biological
- Microorganisms
  - Bacteria
  - Molds
  - Viruses
- Animal parasites
  - Prions

Chemical and Radiological
- Plants
- Seafood toxins
- Agricultural/industrial

Physical
- Foreign objects in food

FOOD ALLERGY, INTOLERANCE, AND SENSITIVITY

Recurrent sensitivities to food components include allergies (immune system reactions to food proteins) and intolerances (typically resulting from insufficient enzyme activity).

PREVENTING FOODBORNE ILLNESS

Food safety in food-related establishments is maintained by following food safety principles.

Personnel

Food management certificates ensure that employees are trained in personal hygiene habits such as avoiding hand-to-mouth movements, using handwashing sinks frequently, wearing clean uniforms, and using other safe work-related food techniques.

Purchasing

Vulnerable, high-risk foods prone to microbial contamination are those high in protein and water—meat, poultry, fish, dairy, egg, broth, stocks, sauces, tofu, soy foods, and stuffing. Other factors important for microbial growth include the acidity (pH >4.6) and oxygen exposure. Written specifications and inspections upon delivery by trained personnel help reduce problems.

Storage

Temperature and time (4 hours maximum) are two additional key factors important in preventing microbial growth. Food should be stored at correct temperatures: USDA = 40°F (4°C) in the refrigerator (FDA = 41°F [5°C]), 0°F (−18°C) in the freezer, 60 to 70°F (15 to 21°C) dry storage for canned goods, and 50 to 70°F (10 to 21°C) dry storage for root vegetables, citrus, eggplant, and hard-rind squash.

Preparation

- **Pre-preparation Thawing.** The four safe methods for thawing are in the refrigerator, submerged under running water, microwaving followed by cooking, and as part of the cooking process.

Cross-contamination—Be sure to avoid having raw, high-risk vulnerable foods come in contact with cooked food or food that will not be cooked. Surfaces such as hands, counter, and cutting boards should be carefully monitored.

- **Cooking (Heating).** Thermometers should be used to ensure foods reach minimal internal temperatures needed to destroy microorganisms:

Food	Temperature
Poultry (includes ground poultry)	165°F (74°C)
Stuffing, sauces, gravies, soups	165°F (74°C)
Reheated or microwaved foods, leftovers, casseroles, hot dogs	165°F (74°C)
Ground meats: beef, pork, veal, lamb	USDA = 160°F (71°C) or FDA = 155°F (68°C)
Precooked ham	140°F (60°C) for USDA-inspected or 165°F (74°C) for all others
Eggs	USDA = 160°F (71°C) or FDA = 145°F (63°C)
Beef, veal, lamb, pork, fish	145°F (63°C) + 3- minute rest



- **Holding and Serving.** Food must be held and served outside the temperature danger zone, which, according to the USDA, is 40 to 140°F (4 to 60°C) for consumers. The FDA Food Code suggests a slightly different range for retailers—above 135°F (57°C) for hot foods and below 41°F (5°C) for cold foods.
- **Cooling.** The four safe food-cooling methods are placing in shallow containers, reducing food size, placing in an ice-water bath, and using a blast chiller. The USDA suggests that foods be cooled to below 40°F (4°C) within 4 hours. The FDA Food Code suggests two cooling stages: 135 to 70°F (57 to 21°C) in the first 2 hours, and then 135 to 41°F (57 to 5°C) within 6 hours or less.

Sanitation

Regularly scheduled cleaning, safe equipment, and a clean facility are all part of sanitation.

- **Washing.** The water temperature in the three-compartment sink should reach 110°F (43°C) during soaking and at least 180°F (82°C) for 1 minute during final rinsing. Dishwashing machine temperatures should be between 140°F and 160°F (60°C and 71°C), and rinse temperatures should be at least 180°F (82°C) for 10 seconds or 170°F (77°C) for 30 seconds to kill most pathogens.
- **Drying.** Only air- or heat-drying is considered safe.
- **Pest Control.** Pests should be blocked from entering food establishments, prevented from accessing stored food, and eliminated by a pest-control operator.

Food Safety Monitoring

This may involve FDA's Food Code, State Health Department inspections, HARPC or HACCP (seven steps), and national surveillance (FoodNet, CDC, FDA Food Safety Modernization Act).

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. What is the overall name for illnesses transmitted to humans by food?
   a. Food outbreak
   b. Food intoxication
   c. Foodborne illness
   d. Food infection

2. HARPC is a(n) ___ designed to prevent ___ from occurring.
   a. inspection program, food outbreaks
   b. mandatory program, food outbreaks
   c. inspection program, foodborne illnesses
   d. food safety program, foodborne illnesses

3. Which temperature range represents what is called "the temperature danger zone" for consumers and retailers or restaurants, respectively, in food safety?
   a. Between 20°F (−7°C) and 80°F (27°C); between 21°F (−6°C) and 75°F (24°C)
   b. Between 80°F (27°C) and 180°F (82°C); between 81°F (27°C) and 175°F (79°C)
   c. Between 40°F (4°C) and 140°F (60°C); between 41°F (5°C) and 135°F (57°C)
   d. Between 60°F (16°C) and 160°F (71°C); between 61°F (16°C) and 155°F (68°C)

4. *Salmonella* bacteria may be found in which type of food?
   a. Poultry products
   b. Vegetable products
   c. Beef products
   d. All of the above

5. Which of the following is the safest method for thawing frozen foods?
   a. At room temperature overnight
   b. In the sun
   c. In a refrigerator
   d. In a sink overnight

6. What is the most common fish toxin–related food poisoning in the United States?
   a. Red tide
   b. Puffer fish
   c. Ciguatera
   d. Histamine

7. Foods that have a higher risk for contributing to foodborne illness are
   a. high in protein and acidity.
   b. high in protein and water.
   c. low in protein and acidity.
   d. low in water and fat.

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Discuss the difference between food infection and toxin-mediated infection. Give examples of each.
2. Identify the major hazards to food safety.
3. Define the following: *pathogenic, temperature danger zone, spore,* and *cross-contamination*.
4. For the agents of the following foodborne illnesses, indicate: (a) whether it causes an infection or intoxication; (b) the general symptoms of infection; and (c) the most commonly associated foods: *V. vulnificus, Salmonella, E. coli, Staphylococcus aureus, Listeria monocytogenes,* hepatitis A virus.
5. List and briefly describe three parasites that can cause foodborne illness.
6. List and briefly describe three natural toxicants that can cause foodborne illness.
7. Which nine food categories are particularly prone to bacterial contamination?
8. To what internal temperatures should the following be heated for safe consumption: poultry, pork, beef, fish, ground meats, reheated foods, and stuffing?
9. What are the recommended temperatures for refrigerators, freezers, and dry storage?
10. Describe the process of a county health department inspection of a food-service establishment.

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5



Food Preparation Basics

Heating Foods 91
Types of Moist-Heat Preparation 92
Types of Dry-Heat Preparation 94
Types of Heat Transfer 95
Measuring Heat 96
Cutlery Techniques 97
Measuring Ingredients 101
Mixing Techniques 104
Seasonings and Flavorings 104

"Cooking is a craft which can rise, on occasion, to an art," said Arno Schmidt, once an executive chef of the Waldorf Astoria Hotel in New York City (25). Understanding the basics of food preparation is essential to getting a meal together, but because it is not an exact science, results vary from meal to meal no matter how knowledgeable and careful the food preparer is. Schmidt also said it is "no wonder that seemingly similar foods taste and act differently depending on endless factors."

These factors include the type of heat used, the cooking utensils (Appendix A gives a summary of the equipment used in food preparation), the amount of food prepared, and the fact that a cup of, say, fresh leeks tastes more potent than twice the quantity of dried leeks. Add to the equation the foibles of human nature and the unique tastes and preferences of individuals, and it is easy to see how two chefs following the same recipe could come up with different products.

Food preparation most definitely approaches art at times, but until its basic techniques are learned and mastered, the results will more nearly resemble preschool finger painting than the work of the Great Masters. The purpose of this chapter is to describe the basic heating methods, cutlery techniques, measuring and mixing techniques, and seasonings and flavorings used in food preparation.

HEATING FOODS

Heating not only destroys microorganisms that cause illness but also changes the molecular structure of foods, altering their texture, taste, aroma, and appearance. During food preparation, heat is transferred by either moist- or dry-heat methods. Regardless of the method used, cooking food should never be left unattended because that is the leading cause of house fires.

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Moist-Heat Preparation

Moist-heat preparation techniques include scalding, poaching, simmering, stewing, braising, boiling, parboiling, blanching, and steaming. In these methods, liquids not only heat the food but may also contribute flavor, color, texture, and appearance to the final product. This is especially the case if broth and mixtures containing herbs, spices, and seasonings have been added. Moist-heat preparation helps soften the fibrous protein in meats and the cellulose in plants, making foods more tender. Liquids generated from heating foods can also be used as a flavorful stock to make soups or sauces. One possible drawback to moist-heat methods is that color, flavor compounds, vitamins, and minerals may leach out and be lost in the liquid. However, using this liquid in a sauce or gravy retains them in the meal.

The various moist-heat preparation methods are presented in the following box in order of increasing heat requirements, ranging from a low heat of 150°F (66°C) for scalding water to a high heat of 240°F (116°C) for pressure steaming.

TYPES OF MOIST-HEAT PREPARATION

Scalding

Scalding water reaches a temperature of 150°F (66°C), resulting in the appearance of relatively still bubbles on the bottom and sides of the pan that do not break the surface. Third-degree burns will result if this still-looking water touches the skin, with even lower temperatures of 120°F (49°C) scalding the skin (2). The scalding process in cooking is most frequently used to improve the function of milk in recipes. Using scalded milk can speed the combination of ingredients: in hot milk, sugar dissolves more readily, butter and chocolate melt more easily, and flour mixes in more evenly without creating lumps (28). Scalding is also necessary to destroy bacteria in unpasteurized milk; thus, many older recipes call for scalded milk.

Poaching

Water heated to a temperature of 160 to 180°F (71 to 82°C)—somewhat hotter than scalding—is used for poaching, in which the food is either partially or totally immersed. At this temperature, small, relatively motionless bubbles appear on the bottom of the pan, but the water has not yet reached the point of actually bubbling. Poaching is used to prepare delicate foods, such as fish and eggs, which could break apart under the more vigorous action of boiling.

Simmering

Water simmers at just below the boiling point, never less than 180°F (82°C). Simmering is characterized by gently rising bubbles that barely break the surface. Many food dishes, especially rice, soups, and stews, are first brought to a boil and then simmered for the remainder of the heating time. Simmering is preferred over boiling in many cases because it is more gentle and will usually not physically damage the food. In addition, foods will not overcook as quickly as they do when boiled. The lower heat of a simmer is essential when cooking tough cuts of meat that require gentle cooking in order to become tender.

Stewing

Stewing refers to simmering ingredients in a small to moderate amount of liquid, which often becomes a sauce as the food cooks. Most stew dishes consist of chopped ingredients such as meat (often browned first) and vegetables placed in a large casserole, stockpot, or slow cooker with some water, stock, or other liquid. The pot is covered and the food simmered for some time on the range or in an oven. Stews often taste better the day after their initial preparation because the overnight rest deepens their flavors.

Braising

Braising is similar to stewing in that food is simmered in a small amount of liquid in a covered casserole or pot. The liquid may be the food's own juices, fat, soup stock, and/or wine. Flavors blend and intensify as foods are slowly braised on top of the range or in an oven (16).

To generate a browner color and better flavor, meats are frequently browned with a dry-heat method such as sautéing before being braised. Frequently, meats are braised, and then the vegetables are added during the final cooking to preserve some of their texture and flavor.

How & Why?

Why are stewing and braising called by different names if both entail simmering food in a small amount of liquid?

The primary difference between stewing and braising is that stewing generally refers to smaller pieces of meat, whereas braising entails larger cuts. Stews are also most often made with more liquid and served in their sauce.

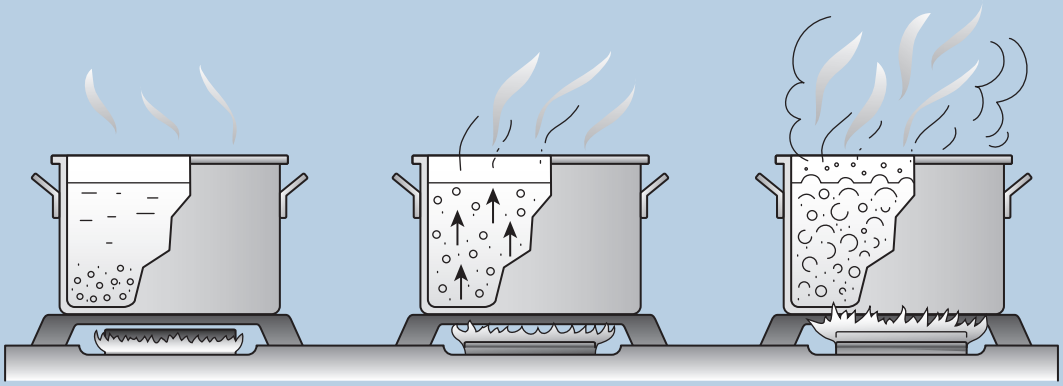
Moist-heat preparation A method of cooking in which heat is transferred by water, any water-based liquid, or steam.

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FIGURE 5-1 Bubble size and movement differ during poaching, simmering, and boiling.



Boiling

In order to boil—that is, to bubble rapidly—water must reach 212°F (100°C) at sea level. The difference in the bubbles among poaching, simmering, and boiling is shown in Figure 5-1. The high temperature and agitation of boiling water are reserved for the tougher-textured vegetables and for dried pastas and beans. A common technique is to bring a liquid to a rolling boil, gradually add the food, distributing it evenly, and then bring the liquid back to a full boil before reducing the heat so that boiling becomes gentle. A lid on the pot or pan will bring the liquid to a boil more quickly by increasing the pressure. It is always recommended to reduce the heat setting after a boil has been reached because food will not cook any faster at a setting higher than that required to maintain a gentle boil. Spillovers, burns, and loss of cooking liquid through evaporation all can be avoided if a gentle boil is used.

Food may also be **parboiled** in boiling water, after which it is removed and its cooking completed either at a later time or by a different heating method. Parboiling is used frequently in restaurant service when food must be prepared in advance and finished to order. Another use for boiling water is for **blanching**, which sets the color of green vegetables; loosens the skins of fruits, vegetables, and nuts for peeling; and destroys enzymes that contribute to deterioration. Foods are often blanched before being canned or frozen.

Steaming

Any food heated by direct contact with the steam generated by boiling water has been steamed. Cooked vegetables are at their best when steamed because this method helps to retain texture, color, taste, and nutrients. A common method for steaming is to place food in a rack or steamer basket above boiling water and to cover the pot or pan with a lid in order to trap the steam. An indirect technique, called *en papillote* (on pap-ee-yote), is to wrap the food in foil or parchment paper before it is baked or grilled. Then, in an oven or over the grill, the food cooks by the steam of its own juices, which are trapped in the packet. In a microwave oven, covering foods with plastic wrap facilitates steaming. Pressure cookers heat food by holding steam in an enclosed container under pressure. The temperature increases with increasing pounds of pressure per square inch.

Microwaving

Although microwaving is listed under moist-heat preparation, it actually belongs in an entirely separate category because it incorporates both dry-heat (radiation) and moist-heat preparation methods. Microwaves are a form of radiation aimed at the water in the food or beverage. The specifics of preparing food using a microwave oven are discussed in Appendix A as well as in chapters on specific foods.

Dry-Heat Preparation

Examples of **dry-heat preparation** include baking, roasting, broiling, grilling, barbequing, and frying. Higher temperatures are reached in dry-heat preparation than in moist-heat methods because water can heat only to its boiling point of 212°F (100°C) or slightly higher under pressure, whereas the air within an oven can reach up to 500°F (260°C).

Parboil To boil, but only partially cook, a food.

Blanch To dip a food briefly into boiling water.

Dry-heat preparation A method of cooking in which heat is transferred by air, radiation, fat, or metal.

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TYPES OF DRY-HEAT PREPARATION

Baking

Baking is the heating of food by hot air in an oven. The average baking temperature is 350°F (177°C), although temperatures may range from 300 to 425°F (149 to 219°C). Baking results can be affected by oven rack position and the color of the pan.

Rack Position

For the best outcome, the food should be placed in the middle of the center rack (Figure 5-2). Foods placed on the uppermost rack may brown excessively on their top surface, whereas on the lowest rack, foods are prone to burning on the bottom. It is also best to position foods using only one rack; if this is not possible, the foods should be staggered so that they are not directly over each other in order to allow hot air to flow more freely through the oven. At least 2 inches should be left between pans and between the pans and the oven walls. If these guidelines are ignored, the resulting inadequate air circulation may cause uneven browning, and food may not be thoroughly cooked.

Pan Color

In addition to rack position and placement of pans, the cooking pan material will affect the baking outcome. Shiny metal pans reflect heat and are best for cakes or cookies, in which only light browning and a soft crust are desired. The darker, duller metal pans (including anodized and satin-finish) tend to absorb heat, resulting in browner, crisper crusts ideal for pies or bread baking. Glass pans require that oven temperatures be reduced by 25°F (4°C) because food tends to heat more quickly in glass (exceptions are pies and bread).

Because baking times are dependent on many factors, it is important to check the food's progress at the suggested minimum baking time and then at intervals after that until the food is done. This must be done judiciously, however, because checking too soon or too frequently will allow heat and/or steam to escape from the oven, adversely affecting the baking outcome.

FIGURE 5-2 Oven rack position.



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POSITION:	USED FOR:
RACK Five	Toasting bread, or for two-rack baking.
RACK Four	Most broiling and two-rack baking.
RACK Three	Most baked goods on a cookie sheet or jelly roll pan, or frozen convenience foods, or for two-rack baking.
RACK Two	Roasting large cuts of meat and large poultry, pies, soufflés, or for two-rack baking.
RACK One	Roasting large cuts of meat and large poultry, pies, soufflés, or for two-rack baking.

Roasting

Roasting is similar to baking except that the term is usually applied to meats and poultry. Roasted meats are often **basted** every 20 minutes or so to prevent the food from drying out. Some roasted meats are initially **seared** at 400 to 450°F (200 to 230°C) for about 15 minutes before reducing the heat to normal roasting temperatures. Although searing adds a desirable texture, color, and flavor to the meat's outer surface, roasts cooked at lower temperatures are juicier, shrink less, and are easier to carve than those that are seared.

The word *roasting* can also refer to cooking on an open fire, as with roasted marshmallows and vegetables, and to cooking with a rotisserie. To make things even more confusing, meats such as ham, meat loaf, and fish are often referred to as *baked*. Chicken may be described as either baked or roasted.

Broiling

To broil is to cook foods under an intense heat source. The high temperatures of broiling cook foods in approximately 5 to 10 minutes, so only tender meats, poultry, and fish are broiled; tougher foods require longer heating times. Temperature is controlled by moving the rack closer to or farther away from the heat source. Thicker cuts are broiled farther from the heat, and thinner ones are broiled closer—on the fourth or fifth rack (up from the bottom) of a home oven. Foods are often slightly oiled to prevent drying and sticking, placed under the broiler only after it has been thoroughly preheated, and then turned over only once. Food-service operations often use a *salamander*, also called a cheese-melter, a low-intensity broiler used just prior to serving to melt or brown the top layer of a dish.

Grilling

Grilling is the reverse of broiling, in that food is cooked above, rather than below, an intense heat source. The grill may be a rack or a flat surface on a stove. *Grilled* can also refer to foods that are seared on a grill over direct heat (26).

Barbecuing

Barbecuing and grilling are no longer used to refer to the same heating method. Barbecuing was once synonymous with grilling over a pit but has since assumed a unique and more specific meaning. Barbecuing now refers

Baste To add a liquid, such as drippings, melted fat, sauce, fruit juice, or water, to the surface of food (usually roasting meat) to help prevent drying.

Sear To brown the surface of meat by brief exposure to high heat.

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to foods being slow-cooked, usually covered in a zesty sauce, over a longer period of time (26). The temperature in barbecuing is regulated by adjusting the intensity of the heat source (charcoal, wood, gas, or electric), adjusting the distance between the food and the heat source, and moving the food to different places on the grill.

Frying

Frying is heating foods in fat. Oils used in frying serve to transfer heat, act as a lubricant to prevent sticking, and contribute to flavor, browning, and a crisp outside texture (6). Although oils are liquid, frying is a method of dry-heat preparation because pure fat contains no water. Types of frying—sautéing, stir-frying, pan-broiling, pan-frying, and deep-frying—are distinguished by the amount of fat used, ranging from a thin sheet to complete submersion. Temperatures vary among the different methods: sautéing, stir-frying, and pan-frying require only a medium or moderately high heat (lower heat results in higher fat absorption), whereas deep-frying temperatures range from 350 to 450°F (177 to 232°C). Chapter 22 discusses frying with fats in greater detail.

Sautéing and Stir-Frying

These methods use the least amount of fat to heat the food. Stir-frying is predominantly used in Asian cooking; the pan is held stationary while the food is stirred and turned over very quickly with utensils. Sautéing is done in a frying pan, a special sauté pan, or on a griddle. The foods most frequently prepared on a griddle with a little fat are eggs, pancakes, and hamburgers (with the fat derived from the meat itself).

Pan-Broiling and Pan-Frying

Pan-broiling refers to placing food, usually meat, in a very hot frying pan with no added fat and pouring off fat as it accumulates. If the fat is not poured off, pan-broiling becomes pan-frying, which uses a moderate amount of fat (up to ½-inch deep), but not enough to completely cover the food.

Deep-Frying

In deep-frying, the food is completely covered with fat. Many deep-fried foods are first coated with breading or batter to enhance moisture retention, flavor development, tenderness, browning, crispness, and overall appearance. The characteristics of the coating influence a fried food's final outcome (22). A fine-crumb breading absorbs less fat, but a coarser grain produces a crisper texture. Sugar in the coating speeds up browning, but this is undesirable if the outside browns and appears done while the inside remains uncooked (Figure 5-3). Just as the breading or batter protects the food from absorbing too much fat, it can also simultaneously protect the deep-frying oil from the deterioration that occurs when it contacts the food's natural moisture and salt content.

Because deep-frying requires high temperatures, it is best to rely on the fryer's thermostat to obtain the desired temperature. If this is not possible, another method is to place a 1-inch cube of white bread into the oil and time how long it takes to turn golden brown (Table 5-1).

FIGURE 5-3 Sugar in the batter darkens fried food, as seen in the fritter on the right.



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TABLE 5-1 Deep-Frying Based on Color

Number of Seconds to Turn a 1-Inch Bread Cube Golden Brown

Temperature of Fat	No. of Seconds to Turn a 1-in. Bread Cube Golden Brown
385–395°F (196–201°C)	20
375–385°F (190–196°C)	40
365–375°F (185–190°C)	50
355–365°F (179–185°C)	60

TYPES OF HEAT TRANSFER

Energy sources for heating foods are usually electricity and gas (natural or butane), but secondary sources such as wood, coal, and charcoal may also be used. All of these produce heat energy that can be transferred through conduction, convection, radiation, or induction (Figure 5-4).

Conduction

When foods are prepared on the range or in the fryer, heat is transferred by **conduction**. Heat from the electric coil or gas flame is conducted to the pan or fryer and then to its contents through direct contact (4). Conduction is based on the principle that adding heat to molecules increases their (kinetic) energy and hence their ability to transfer heat to neighboring molecules.

Some materials and pan sizes better conduct the speed and efficiency of transferring heat. Copper is an excellent heat conductor and is often used to line the bottom of stainless steel pans. Dark, dull surfaces absorb heat more readily, which shortens the baking time. Tempered glass conducts heat in such a manner that baking temperatures should be reduced by 25°F (4°C) when it is used.

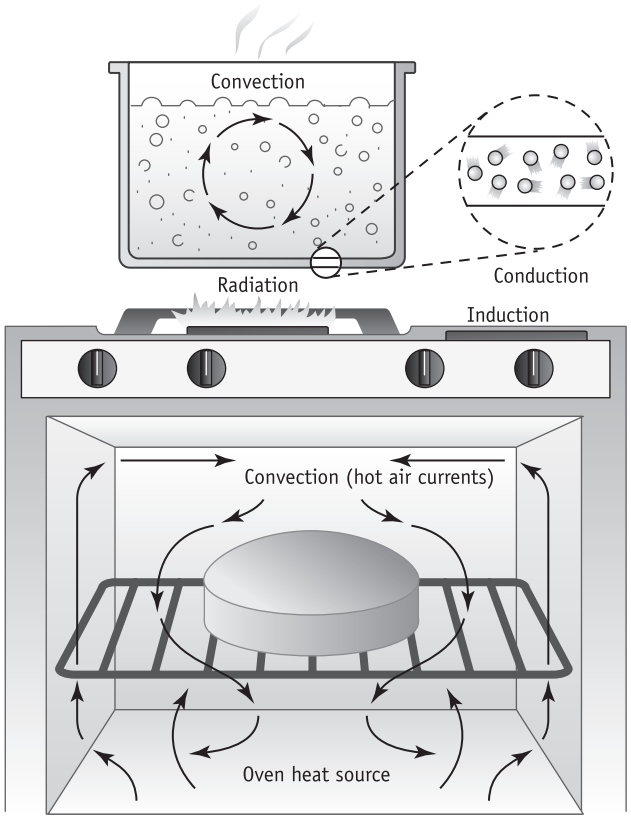
Conduction The direct transfer of heat from one substance to another that it is contacting.

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FIGURE 5-4 Four types of heat transfer: conduction, convection, radiation, and induction.



Convection

Convection relies on the principle that heated air or liquid expands, becomes less dense, and rises to the surface. The cooler, heavier air or liquid originally on top moves to the bottom, where it is heated, thus creating continuous circular currents. A common example of the use of convection in cooking is baking in an oven. Baked goods rely on convection to allow the hot air to rise. Having the heating unit located at the bottom of the oven contributes to the rising of hot air. Convection ovens, which are more common in food-service institutions than in home kitchens, have an air-circulating system, whereas standard ovens do not. Fans move the air more quickly and evenly around the food, which speeds up baking times. However, convection ovens do have drawbacks. The moving air causes foods to lose moisture, and cake batters are more prone to bake with uneven tops. Injecting steam into a convection oven helps reduce these drying and shrinking effects.

Other examples of convection cooking are simmering, steaming, and deep-frying. The use of water and fat to heat food relies on both conduction and convection. For example, after the heat from convection begins to heat a baked potato, conduction takes over when the heat penetrates the potato's water molecules and is transferred to the center of the potato. Water conducts heat more efficiently than air, so it takes much less time to boil than to bake a potato.

Convection The transfer of heat by moving air or liquid (water, fat) currents through and/or around food.

Radiation The transfer of heat energy in the form of waves of particles moving outward from their source.

Induction The transfer of heat energy to a neighboring material without contact.

Kinetic energy Energy associated with motion.

Radiation

Heat is transferred by **radiation** in broiling, grilling, and microwaving. The short electromagnetic waves that are generated by microwave ovens can pass through glass, paper, and most plastic. Infrared heat lamps and ovens are other heat sources that use electromagnetic waves for heat. These are usually found in restaurants and institutional kitchens, where they are used to keep foods warm and to prepare frozen foods.

Induction

Flat-surfaced ranges that have the coils buried underneath conduct heat through **induction**. An alternating electric current flows through the coil to produce a magnetic field, which in turn generates many smaller currents in pans made from iron or stainless steel that are placed above the coil. (Pans made from other materials should not be used.) The heat within the pan is then transferred to its contents. The smooth ceramic surface of an induction range makes cleaning easy.

MEASURING HEAT

Food preparation relies on accurate measurements of heat energy, that is, temperature. The three main scales used to measure heat intensity are Fahrenheit (°F), Celsius or centigrade (°C), and Kelvin (K) (Figure 5-5). The Kelvin scale is used primarily in scientific research and will not be discussed here.

Freezing and boiling are extremes in the range of temperatures encountered in food preparation that owe their effects to changes in the **kinetic energy** of molecules. The molecules in living organisms are always in motion; heat speeds up that motion, whereas cold slows it down. Heating or freezing foods is accomplished by increasing or decreasing, respectively, the movement of molecules. Figure 5-6 summarizes various temperatures used in food preparation.

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FIGURE 5-5 The three main temperature scales used to measure heat intensity.

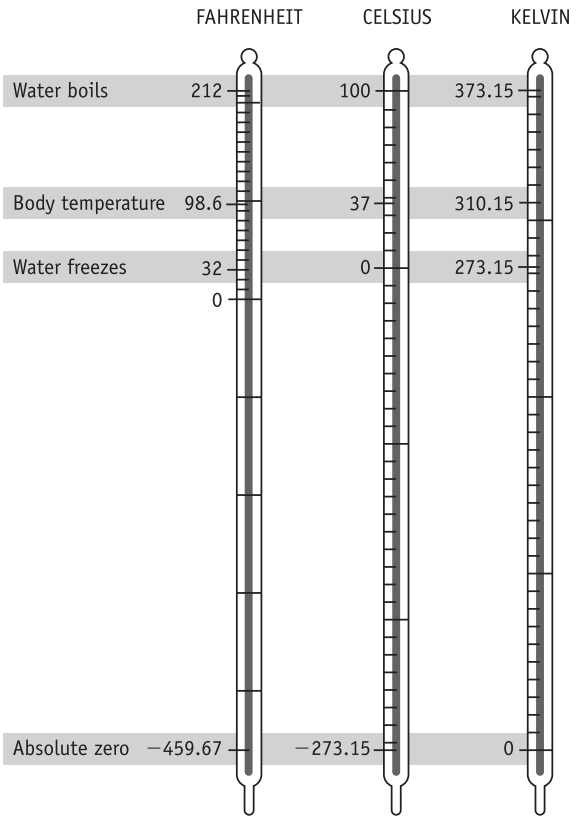
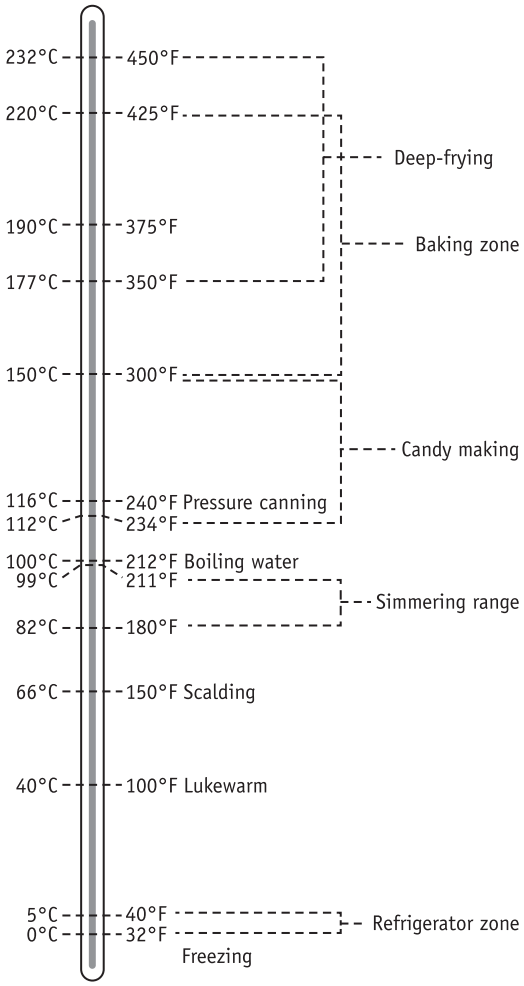


FIGURE 5-6 Temperatures important in preparing foods.



The freezing point of water is 32° on the Fahrenheit scale and 0° on the Celsius scale. Water boils (boiling point) at 212° on the Fahrenheit scale and 100° on the Celsius scale. The boiling point changes slightly with altitude; 1°F must be subtracted for every 500-foot increase in elevation up from sea level (an increase of 960 feet in elevation decreases water's boiling point by 1°C). Other compounds in the water, such as sugar or salt, influence its boiling and freezing temperatures, so those given here and in Figure 5-6 pertain to pure water. Other materials have their own freezing and boiling points.

CUTLERY TECHNIQUES

As important as it is to know how to properly heat foods, these foods must often be cut into smaller pieces before they can be heated. Thus, another basic pillar of food preparation is the knowledge and use of cutlery. Selecting and caring for knives are discussed in Appendix A. The following sections cover handling of knives and the styles of cutting food. The techniques vary according to the type of knife selected, which in turn depends on the task to be performed.

Handling Knives

The most frequently used knife is the chef's knife or French knife. The positioning of the grip and of the food under the blade influence both the degree of control and the leverage a person has over the knife (Figure 5-7). A chef's knife should be firmly held with the base of the blade between the thumb and forefinger and the other fingers wrapped around the handle. While one hand grips the knife, the other hand must hold the food and guide it toward the blade. Curling the fingers of the guiding hand under while holding the food allows the knuckles to act as a protective shield and keeps the fingertips away from the cutting edge. It is best to allow at least a half-inch barrier of food between the blade and the fingers holding the food.

Different sections of a blade are used for different tasks (Figure 5-8). Light tasks such as cutting out the stem end of a tomato can usually be accomplished with the tip of the blade or, even better, with a knife more suitable to small tasks, such as a paring knife. Heavy duties such as chopping off the tough base of a bunch of celery are

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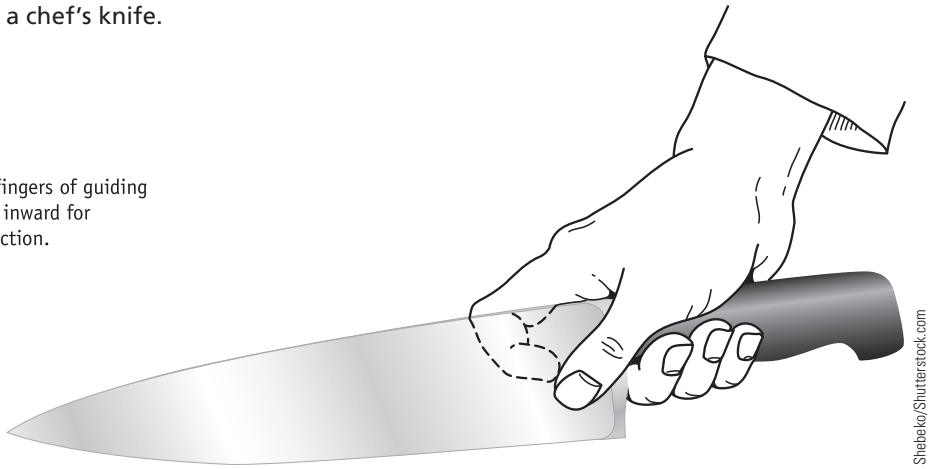
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FIGURE 5-7 Technique of holding a chef's knife.



Curl fingers of guiding hand inward for protection.

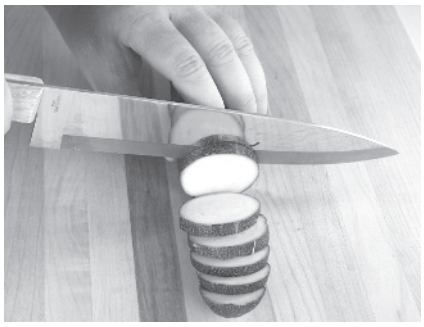


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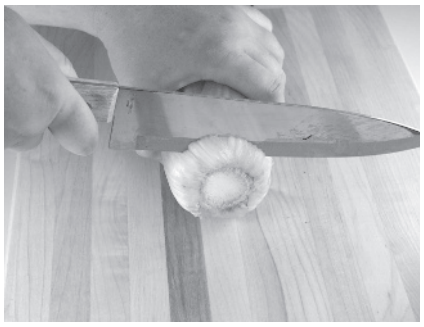
FIGURE 5-8 Blade position determined by the cutting task.



Tip—delicate tender work.



Center—all-purpose work.



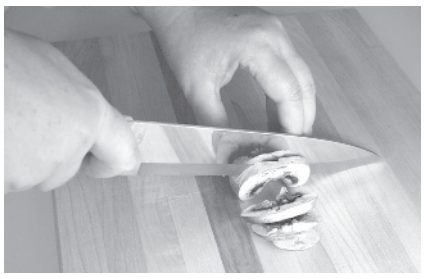
Heel—heavy work.

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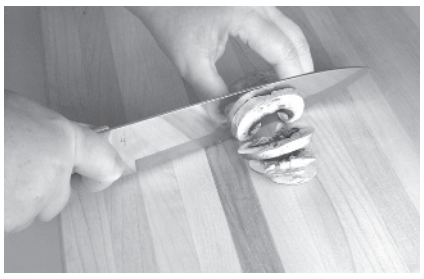
FIGURE 5-9 Slicing technique.



Start with the blade tip down.



Press down and forward simultaneously to slice.



As soon as the blade heel touches the board, it is moved up and over (keep tip down) for the next slice.

Digital Works

better accomplished by making use of the weight and thickness found at the base of the blade. Most other cutting tasks are carried out using the center of the blade (Figure 5-9).

Cutting Styles

Uniformity is the usual goal in cutting food. It allows for quicker cooking and even heating, and gives food an appetizing appearance. Cutting styles include slicing, julienne, *bâtonnet*, shredding, *chiffonade,* chopping, dicing (cubing), mincing, peeling, and parisiennes (Figure 5-10).

Julienne To cut food lengthwise into very thin, stick-like shapes.

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FIGURE 5-10 Basic cutting styles for food

Cutting Style	Description	Illustration
Slice	To move the food under the blade while keeping the point of the blade firmly on the cutting board. The base of the knife is lifted up and down with a forward and backward motion.	Round slices (Rondelles)
	Rounds (rondelles) are from slicing cylindrically shaped produce into diskshaped slices (⅛-½ inch (3 mm to 1 cm)	
	Diagonal cuts resulting in unique looking elongated slices that also cook more quickly.	Diagonal slices
		
	A mandoline is a handy cutting tool with a razor-sharp blade that can cut food into very thin slices (e.g., cucumber or zucchini), but a guard or steel-mesh glove should always be used to avoid severely cutting the hand.	Mandoline (knob adjusts slice thickness)
		
Bâtonnet (French for "little stick")	To slice food into sticks of 1-3 inches long and ¼ × ¼ inch wide (5 cm × 6 mm × 6 mm).	
Julienne (matchstick cut)	To slice Bâtonnets even further into delicate sticks that are usually 1 to 3 inches long and only ⅛ to ⅛ inch wide	
Fine Julienne	A fine julienne is slimmer yet at only ⅛ to ⅛ inch wide.	See above
Shred	To cut leaf vegetables, fruits, cheese, meats, and other foods into thin strips. This may be done by first rolling the leaves into cigar-like shapes and then cutting them into shreds. Hand shredders and food processors with different sizes of shredding blades may also be used.	
Chiffonade (*chef-fonnahd*)	To *finely* shred rolled vegetables or herbs (especially leaves) into sliver-like strips to be used as garnishes in soups or as a base under cold dishes.	

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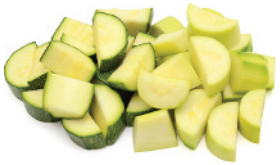
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FIGURE 5-10 Basic cutting styles for food (*continued*)

Chop

Cutting food into course, usually bitesize pieces.

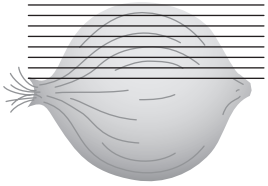


Dice or Cube Cuts

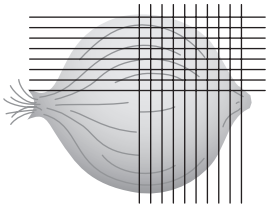
To cut food more precisely into evensize cubes:

Large	(¾ inch, 2 cm)
Medium	(½ inch, 1.2 cm)
Small	(¼ inch, 6 mm)
Brunoise	(⅛ inch, 3 mm)
Fine brunoise	(1/16 inch, 1.5 mm)
Paysanne	(½ inch × ½ inch × ⅛ inch, 1.2 cm × 1.2 cm × 3 mm) (thin cube; vegetable garnish)

First vertical cuts
(do not go all the way through onion)



Second vertical cuts
(go entirely through onion)



Mince

To "finely chop" food into very fine pieces (less than ⅛ inch; 0.31 cm). This is done by placing the holding hand on the tip of the knife and rocking the base up and down in short strokes while moving it across the food several times, and then repeating as necessary.



Peel

To remove the skin. The peel and rind can be cut from an orange or any thick-skinned fruit by first cutting off in a circular fashion the top of the fruit's skin, then scoring the skin through to the flesh of the fruit in four places. The skin can then be peeled in segments down from the top. Fruits can also be peeled directly with a paring knife.



Pitting

Many fruits can have their pits removed with a pitting tool. Avocados can be first stripped of their peel by cutting the avocado from stem to stern through to the pit. Each half is cupped in the hands and twisted gently to separate the halves. The seed (nut) can be removed with the fingers or the blade of a sharp knife. At this point the avocado can be scooped out with a large serving spoon or peeled and sliced.



Cherry pitter



Apple corer



Parisienne

To scoop out fruit (usually watermelon or other melons) into spherical-shaped balls using a melon ball cutter.

Melon baller



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MEASURING INGREDIENTS

Correct measuring is another essential aspect of basic food preparation. The four major steps in measuring are the following:

1. Measuring weight versus volume
2. Selecting the right measuring utensil
3. Using an accurate measuring technique
4. Approximating food requirements (e.g., 4 ounces of cheese yields 1 cup shredded)

Measuring Weight vs. Volume

Weight measures the heaviness of an ingredient and is expressed in grams, ounces, or pounds. Volume measures the space filled by an ingredient (height × width × length) and is expressed in teaspoons, fluid ounces, cups, pints, quarts, and gallons or liters. It's important to be aware of this distinction and its implications; for example, 1 cup of powdered sugar does not weigh the same as 1 cup of honey. In addition, a fluid ounce only measures *volume,* whereas an ounce measures *weight*. They are only equal when measuring water.

Weight, commonly used to mean mass, is a much more accurate measurement than volume. As a result, many food-service operations use weight rather than volume to measure recipe ingredients. Confusion between the two methods of measuring ingredients occurs because ounces can be measured either by volume, known as fluid ounces (fl), or by mass (weight), known as avoirdupois ounces (av). Water is the only substance whose fluid ounce is equal to its avoirdupois ounce. The mass of other substances will vary depending on the density, or weight per volume, of the object being measured. For example, half a cup of marshmallows weighs less than half a cup of vegetable oil.

Using Scales

For even better accuracy, many countries measure ingredients by weight. In the United States, Americans tend to measure using volume measurements such as teaspoons, tablespoons, cups, pints, quarts, and gallons. Weight can be measured by a number of different types of scales: spring-type scales, used principally for weighing dry ingredients such as grains, beans, dried pasta, vegetables, fruits, and cheese; portion scales and balance scales for weighing ingredients; and the baker's scale, used primarily for measuring dough ingredients (Figure 5-11). Scales are used by commercial operations because they use weight to measure ingredients. Businesses cannot afford incorrect measurements that result in a loss of food, time, and money.

FIGURE 5-11 Various scales used for measuring ingredients.



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Metric vs. Nonmetric

Another major difference in measuring is metric versus nonmetric, with metric being the most common system in the world. Metric measurements are based on the decimal system (in multiples of 10), of which weights are measured in grams and volumes in milliliters (mL).

Metric Measuring Cups

Metric cups come in sizes of 25, 50, 125, and 250 mL, and measuring spoons are divided into 1, 2, 5, 15, and 25 mL. A 250-mL metric cup is close to a nonmetric cup, which holds 236.59 mL. The 15 and 5 mL metric measures are almost equal to the nonmetric tablespoon and teaspoon, respectively. The inside back cover of this book lists the conversions between nonmetric and metric measuring units for volume and mass.

Selecting the Right Measuring Utensil

Whether an ingredient is liquid or dry determines the kind of measuring utensil that will be used. Appendix A describes these in detail. A graduated measuring cup with a lip for pouring is best for measuring liquid ingredients. Sets of flat-topped measuring cups are reserved for measuring dry ingredients. All dry ingredients are best measured by first stirring them to eliminate any packing or lumps. Amounts less than ¼ cup should be measured with measuring spoons. Sifting flour with dry ingredients such as baking soda or salt is an efficient way to blend and distribute the ingredients evenly.

It is important to be able to use measuring utensils interchangeably whether using liquid or dry measuring cups. This is easy if a few basic equivalents are remembered (see Table 5-2, and the inside back cover of this book):

1 teaspoon	= about 5 grams*
1 tablespoon	= 3 teaspoons
2 tablespoons	= 1 fluid ounce or 28.35 grams†
¼ cup	= 2 fluid ounces
½ cup	= 4 fluid ounces
1 cup	= 8 fluid ounces, 16 tablespoons, or 48 teaspoons
1 pint	= 2 cups, or 16 fluid ounces (1 pound*)
1 quart	= 2 pints or 4 cups
1 gallon	= 4 quarts, 8 pints, or 16 cups
1 pound	= 16 ounces
1 kilogram	= 2.2 pounds

*When weighing water.

†Fluid ounces refer to volume, and grams refer to mass.

Knowing the general units used in measuring allows for the next step required for accuracy—using the largest measuring device possible. For example, 3 teaspoons of sugar should be measured using 1 tablespoon; ¾ cup should be measured using ½ cup plus a ¼ cup. Accuracy is also achieved by using the guide provided in Table 5-3 for rounding off weights and measures.

Using an Accurate Measuring Technique

Specific volume-measuring techniques for liquids, eggs, fat, sugar, and flour are now discussed.

Liquids

Only transparent graduated measuring cups with pouring lips should be used to measure liquids. The cup should sit on a flat surface, and all measuring should be done at eye level to accurately read the line at the bottom of the **meniscus**

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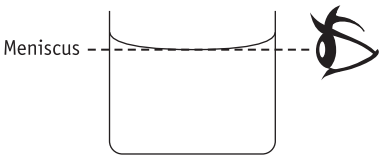
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TABLE 5-2 Basic Measuring Equivalents

The shaded equivalents serve as bridges that allow you to convert a quantity measured with one of the units shown to any of the other units shown. For example, because you know that 8 oz = 1 C and 2 T = 1 oz, you can convert 1 C into T (1 C = 8 oz; 8 oz × 2 T = 16 T).

Teaspoons (tsp) to Tablespoons (T)	Tablespoons (T) to Ounces (oz)	Ounces (oz) to Cups (C)	Cups (C) to Pints	Pints to Quarts (qt)	Quarts (qt) to Gallons
¼ tsp = 1 dash	2 T = 1 oz	2 oz = ¼ C	2 C = 1 pint	2 pints = 1 qt	4 qt = 1 gallon
3 tsp = 1 T		4 oz = ½ C	4 C = 2 pints	8 pints = 4 qt	
		8 oz = 1 C	16 C = 8 pints		
		16 oz = 2 C			

FIGURE 5-12 Read the meniscus at eye level.



(the arc formed by the liquid's surface; see Figure 5-12). The exception is milk, which is read at the top of the meniscus. Viscous liquids, such as honey, oil, syrup, and molasses, have a tendency to stick to the sides as they are poured, so the amount measured can be diminished by the amount that sticks to the sides. Should this happen, a rubber scraper can be used to remove the remaining contents.

Eggs

Eggs range in size from *pee wee* to *jumbo,* but most standard recipes are based on *large* size eggs, if not specified. When half an egg or less is called for, it can be measured by beating a whole egg into a homogeneous liquid, which can then be divided in half or smaller increments. When measuring eggs, it is helpful to remember the following volume equivalents:

1 large egg	2 ounces
4 large eggs	7 ounces
8–10 egg whites, or 12–14 yolks	(just under a cup) 1 cup

Fat

Manufacturers of butter and stick margarine have made it easy to measure their products. Both usually come in 1-pound packages.

1 pound butter or margarine	Four 1/4-pound sticks
1 stick	½ cup or eight 1-tablespoon segments
1 pound of vegetable shortening	2 cups

Glass Measuring Cups

Different methods are used to measure liquid and solid fats. Liquid fats such as oil and melted butter are measured in glass measuring cups.

Fractional Measuring Cups

Solid fats such as lard, shortening, butter, and margarine should be removed from the refrigerator and allowed to become **plastic** at room temperature. Once pliable and soft, they can be pressed into a fractional measuring cup with a rubber scraper. The fat should be pressed down firmly to remove any air bubbles and the top of the cup leveled with the straight edge of a spatula. As with liquids, amounts under ¼ cup should be measured with measuring spoons.

Water Displacement Method

Solid fats may also be measured by using the water-displacement method. For example, if ½ cup of fat is required, a 1-cup liquid measuring cup is filled with cold water to ½ cup. The fat is added and pressed below the water line until the water line reaches the 1-cup measuring line. The colder the water, the easier the cleanup will be, because cold fat is less likely to stick to the sides of the cup. Some water may cling to the fat and should be shaken free or patted away lightly with a paper towel.

Sugar

The amount of sugar needed depends on its type.

Granulated white sugar	2 cups
Brown sugar	2¼ cups
Confectioner's (powdered or icing) sugar	4½ (sifted) cups

TABLE 5-3 Guide to Rounding Off Weights and Measures

If the total amount of an ingredient is:	Round it to:
Weights	
Less than 2 oz	Measure unless weight is ¼-, ½-, or ¾ oz amounts
2–10 oz	Closest ¼ oz or convert to measure
More than 10 oz but less than 2 lb 8 oz	Closest ½ oz
2 lb 8 oz–5 lb	Closest full ounce
More than 5 lb	Closest ¼ lb
Measures	
Less than 1 T	Closest ⅛ tsp
More than 1 T but less than 3 T	Closest ¼ tsp
3 T–½ cup	Closest ½ tsp or convert to weight
More than ½ cup but less than ¾ cup	Closest full tsp or convert to weight
More than ¾ cup but less than 2 cups	Closest full tsp or convert to weight
2 cups–2 qt	Nearest ¼ cup
More than 2 qt but less than 4 qt	Nearest ½ cup
1–2 gal	Nearest full cup or ¼ qt
More than 2 gal but less than 10 gal*	Nearest full quart
More than 10 gal but less than 20 gal*	Closest ½ gal
More than 20 gal*	Closest full gallon

*For baked goods or products in which accurate ratios are critical, always round to the nearest full cup or ¼ quart.

Source: © Amy Brown

Meniscus The imaginary line read at the bottom of the concave arc at the water's surface.

Plasticity The ability of a fat to be shaped or molded.

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Granulated White Sugar

Fractional measuring cups are used, and the sugar is leveled with a spatula. If it becomes lumpy, it can be mashed and/or sifted before measuring.

Brown Sugar

This viscous sugar is best measured by pressing it firmly into a fractional measuring cup and leveling it. The packing should be firm enough that the brown sugar retains the shape of the measuring cup when it is turned out. Lump-free or free-flowing brown sugar, which weighs 25% less than regular brown sugar, is measured in the same manner as granulated white sugar. Brown sugar has a tendency to pack down and become hard because it contains 2% moisture, which has a tendency to evaporate. Lumping can be prevented by placing the brown sugar in an airtight container and storing it in the refrigerator or freezer. Hardened brown sugar can be softened by placing it in a microwave oven for a few seconds or in a conventional oven set at about 200°F (93°C) for a few minutes.

Confectioners' Sugar

Sifting before measuring is required for this sugar to break up any existing lumps. The light, airy nature of confectioners' sugar causes it to have a greater volume than the same amount of granulated sugar, which is why 1¾ cups of confectioners' sugar is equal to the weight of 1 cup of granulated sugar. After sifting, confectioners' sugar is measured the same way as granulated sugar.

Flour

Flour is one of the more difficult ingredients to measure accurately by volume because its tiny particles not only vary in shape and size but also have a tendency to pack. This influences the number of cups obtained from equal weights of various flours (Table 5-4). Professional bakers and chefs avoid the discrepancy in volume measurement by always weighing the flour.

No standard weight for a cup of flour exists because they differ in density	Range from 88 grams/cup (soy flour) to 132 grams/cup (wheat flour)
1 pound of all-purpose flour	Averages 4 cups

TABLE 5-4 Variations in Volume (no. of cups) and Weight (grams) per Pound among Different Types of Flour

Flour (1 lb)	Volume (approximate cups)	Weight (per cup)	
		g	*oz*
All purpose (sifted)	4	115	4.2
Cake (sifted)	4½	96	3.4
Rice (sifted)	3½	126	4.4
Rye (sifted–light)	5	88	3.2
Rye (sifted–dark)	3½	128	4.6
Soy (low-fat)	5½	84	3.0
Whole wheat (stirred)	3⅓	132	4.8

Source: © Amy Brown

White Flour

Sifting is recommended before lightly spooning it into a fractional measuring cup and leveling it off with a spatula. The cup should never be tapped or shaken down because doing so can pack the flour particles tightly, which may result in too much flour being used. To avoid sifting and still get consistent baking results with regular white flour, one technique is to remove 2 tablespoons from each cup of unsifted flour (19).

How & Why?

How do you make substitute cake flour?

For every cup of all-purpose flour used in the recipe, remove 2 tablespoons of flour. Sift the flour over a bowl. Add 2 tablespoons of cornstarch for every 2 tablespoons of flour that were removed. Sift the flour and cornstarch together about five times so that they are well incorporated and the flour is aerated.

Whole Grain and Graham Flours

These flours are sifted prior to being used because sifting will remove the bran particles. These flours should simply be lightly stirred before being scooped into a fractional measuring cup.

Presifted or Instantized Flours

These flours (discussed in Chapter 17) have already been processed into uniform particles and should not be sifted. Instantized flour should not be used in baked products.

Other Ingredients and Substitutions

Some foods to be measured do not fall into the basic categories described earlier. The methods for measuring foods such as cheese, nuts, chocolate, and garlic depend on their form—whole, cubed, shredded, minced, and so forth. Foods cut into pieces tend to occupy a greater volume. For example, 1 pound of cheese is equivalent to approximately 2 cups, but 1 pound of grated cheese is equivalent to approximately 4 cups. The following basic equivalents are helpful:

3 apples	About 1 pound
6 apples	Needed for average apple pie
1 medium lemon	Up to ½ cup of juice ½ to 1 tablespoon zest (grated rind)
1 medium orange	Up to ½ cup juice 1 to 2 tablespoons of zest

Approximating Food Requirements

How Much Should Be Purchased?

Appendix B lists some common food purchase quantities (weight or unit) and their approximate yields (volume; i.e., cups) (29).

Standard Can Sizes

Cans have numbers, and these numbers approximate the number of cups they contain. A helpful reference listing the number of cups found in common can sizes can be found on the inside back cover of this book.

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Substitutions

Often a basic ingredient turns up missing during the preparation of a dish. This can put a halt to food preparation, but in some situations, a substitution may save the day. Appendix C lists some substitutions that can be made for standard ingredients.

MIXING TECHNIQUES

After the ingredients have been selected and measured, the next step is often to mix them all together. *Mixing* is a general term that includes stirring, beating, blending, binding, creaming, whipping, and folding. In mixing, two or more ingredients are evenly dispersed in one another until they become one product. In general, each mixing method accomplishes the same thing, but there are distinctions.

- ***Stirring.*** This method is the simplest, as it involves mixing all the ingredients together with a utensil (usually a spoon) using a circular motion.
- ***Beating.*** The ingredients are moved vigorously in a back-and-forth, up-and-down, and around-and-around motion until they are smooth. An electric mixer is often used to beat ingredients together.
- ***Blending.*** Ingredients are mixed so thoroughly that they become one.
- ***Binding.*** Ingredients are made to adhere to each other, as when breading is bound to fish.
- ***Creaming.*** Fat and sugar are beaten together until they take on a light, airy texture.
- ***Whipping or whisking.*** Air is incorporated into such foods as whipping cream and egg whites through very vigorous mixing, usually with an electric mixer or a whisk.
- ***Folding.*** One ingredient is gently incorporated into another by hand with a large spoon or spatula.

Seasonings Any compound that enhances the flavor already found naturally in a food.

Flavorings Any substance that adds a new flavor to food.

Baked Products

There are many methods for combining the ingredients of cakes and other baked products, but the most commonly used are the conventional (creaming), conventional sponge, single-stage (quick-mix), pastry-blend, biscuit, and muffin methods. Methods for mixing yeast bread doughs are discussed in Chapter 20.

SEASONINGS AND FLAVORINGS

The most nutritious and beautifully presented meal in the world cannot be enjoyed unless it tastes good. Enhancing the flavor of foods is an art that is critical to the acceptability of foods, and a restaurant can succeed or fail depending on how that art is practiced. The most common reason for consumers to reject food is unacceptable flavor (23). **Seasonings** and **flavorings** help food taste its best. They are rarely, however, capable of redeeming foods that are not of good quality to start with or of rejuvenating foods that have lost their quality during preparation. No amount of cinnamon will raise the flavor quality of an apple pie made from frozen apple slices to the level of one made from fresh, juicy apples.

Types of Seasonings and Flavorings

The number and variety of seasonings and flavorings available from all over the world would be nearly impossible to catalog, so this chapter focuses on the basics: salt, pepper, herbs and spices, flavor enhancers, oil extracts, marinades, batters, and condiments.

Salt

Salt was esteemed so highly in ancient times that the word *salary* is derived from *salt*. Salt, or sodium chloride (NaCl = 40% Na, 60% Cl), is the second-most frequently used food additive by weight. Sugar, which is fully discussed in Chapter 21, is first. Salt was originally introduced into foods as a preservative because salting, or curing, meat and fish was the only way to preserve food prior to refrigerators, freezers, and canning. The function of salt in foods expanded to those shown in Table 5-5. Salt in its most common form is a crystalline seasoning that may or may not be iodized and combined with an anticaking material.

Types of Salt

The two primary sources of salt are seawater and underground salt deposits. A variety of salts may be purchased, including sea salt, rock salt, kosher salt, and a number of flavored salts, the most common being garlic, onion, and celery (Figure 5-13) (5). There are also some expensive and rare sea salts known as *fleur de sel* and *sel gris* that are used only in the finest restaurants.

Adding Salt in Food Preparation

Regardless of the type, salt should be added in small increments because of its potential to overwhelm the taste buds when too much is added. The preparer should also be aware that any liquid, such as a sauce or soup, that will

FIGURE 5-13 Different types of salt used in food preparation.



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Sea salt
Obtained from evaporated seawater. Sea salt is more costly than other salts, yet often preferred because it has a pure, mineral-like taste.

Rock salt
Mined from ancient sea beds that have dried up and are now underground.

Table salt
Refined rock salt that is often fortified with iodine and contains additives to prevent caking.

Kosher salt
Rock salt with no additives. Preferred by professional chefs because of its large, flaky crystals that are picked up easily with fingers (use one-third more if substituting for table salt and vice versa).

Flavored salts
Garlic, onion, and celery salt mixtures.

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TABLE 5-5 Mixing Methods for Baked Products

Mixing Method (other names)	Baked Product	How-to Steps	Notes
Conventional (Creaming, cake, fat-sugar)	Shortened (butter) or conventional cakes – chocolate, yellow, white, pound, spice, fruit Fine-grained velvety textured cakes	1. Creaming 2. Egg incorporation 3. Alternating addition of dry and moist ingredients **1) Cream.** The fat and sugar are creamed together by working the fat until it is light and foamy and then gradually adding small portions of sugar until all of it is well blended. A well-creamed combination of fat and sugar incorporates air while suspending sugar crystals and air bubbles in the fat. As the fat melts during baking, it creates air cells that migrate toward the liquid, resulting in a very fine-grained texture. **2) Egg Addition.** The eggs or egg yolks are then added one at a time to the creamed fat and sugar. An alternative method is to whip the egg whites separately and fold them into the cake batter after all the other ingredients have been mixed. **3) Alternate Adding of Dry and Moist Ingredients.** Finally, flour, baking powder or soda, and salt are sifted together with other dry ingredients such as cocoa in order to distribute the leavening agent evenly. The sifted dry ingredients, divided into three or five portions, are then added alternately with a liquid (usually milk) into the fat, sugar, and egg base. After one portion of dry ingredients has been incorporated, a portion of liquid is added and stirred or beaten until well blended. The process begins and ends with the dry ingredients.	The most common, but time-consuming method used for mixing cake ingredients **1) Overstirring** a cake batter creates such a viscous mass that the cake may not be able to rise during baking, and the texture will tend to be fine but compact or lower in volume, be full of tunnels, and have a peaked instead of a rounded top. **2) Too little stirring** can also result in a low-volume cake from an uneven distribution of the baking powder or soda. Understirring can result in large pores, a crumbly grain, and excess browning.
Conventional Sponge (Conventional, meringue)	Unshortened foam or sponge cakes (angel food, sponge, meringue, dacquoise, génoise, and roulade)	Identical to creaming method except that: 1) A portion of the **sugar is mixed in with the beaten egg** or egg white. 2) The **egg foam is folded** into the batter in the end.	The air in the foam that is folded in during the last stage **increases volume**.
Single Stage (Quick mix, one-bowl, dump, all ingredient)	Packaged cake mixes Biscuits Other baked goods	All the dry and liquid ingredients are mixed together at once. 1) Starts with the **dry ingredients in a bowl**; add the fat (usually vegetable oil), part of the milk, and flavoring; stir for a specified number of strokes or amount of time (if an electric mixer is being used). 2) The **eggs and remaining liquid are then added**, and the batter is mixed again for a specified period of time. To attain a uniform blend, the bottom and sides of the **bowl should be scraped** frequently.	Only baked products containing **higher proportions of sugar, liquid,** and possibly an emulsifier in the shortening can be mixed by this method. Quick-mix batters are **more fluid** than conventional batters. The sequence and mixing of ingredients is important because creaming is not a part of the process.
Chiffon	Chiffon cakes (**hybrid** of shortened and unshortened cakes)	1) **Combine dry** ingredients. 2) **Combine wet** ingredients—egg yolks and oil. 3) **Whip egg whites**. 4) **Make a well in the dry** ingredients, **add wet** ingredients, and **whisk** until smooth. 4) **Fold egg whites** into mixed batter.	**Light and airy**, but fats (yolk and oil) make it richer and **denser** than shortened or unshortened cakes.

(*continued*)

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TABLE 5-5 Mixing Methods for Baked Products (*continued*)

Mixing Method (other names)	Baked Product	How-to Steps	Notes
Pastry Blend	Pastries	1) **Fat is first cut into flour** with a pastry blender, or with two knives crisscrossed against each other in a scissor-like fashion, to form a mealy fat-flour mixture. 2) **Half the milk and all of the sugar, baking powder, and salt** are then blended into the fat-flour mixture. 3) Last, **eggs and more milk** may then be blended into the mixture.	
Biscuit	Biscuits	Similar to the pastry blend method except that: 1) **All the dry ingredients**—flour, salt, and leavening—are first combined. 2) The **fat is then cut into the flour** mixture until it resembles coarse cornmeal. 3) Just enough **liquid to moisten** is added last.	When adding water in the last step, mix until **just moistened** and not more or the biscuits will be **tough**.
Muffin	Muffins	This is a simple, two-stage mixing method. 1) Mix the **dry** ingredients. 2) Mix the **wet** ingredients. 3) **Combine** the dry and moist ingredients until the dry ingredients **just become moist**, and then stop.	**Overmixing** will result in a **tough** baked product riddled with tunnels.

be reduced should be only lightly salted because the salt becomes more concentrated as the volume of the liquid diminishes. Although removing excess salt is almost impossible, salty soup may be partially neutralized by adding a touch of sugar or by dropping in a raw, peeled potato to absorb some of the salt.

Processed Foods

Foods that are canned, frozen, cured, or pickled provide more than 75% of all the sodium ingested (17). Because high sodium intake has become a health concern, food companies have developed lower-sodium versions of many processed food products. To make it easier to look for these lower-sodium products, food labels carry the following terms describing sodium/salt content:

Very low salt	=	35 mg or less per serving
Low salt (sodium)	=	140 mg or less per serving
Reduced salt	=	at least a 75% reduction as compared with original food
Unsalted	=	no salt added
Salt-free	=	5 mg or less per serving

Other Dietary Salt Sources

Sources of sodium to watch out for when preparing food are seasoning salts (garlic, parsley, onion, celery), meat tenderizers, meat flavorings (barbecue sauce, smoke-flavored products), salad dressings, molasses, party spreads, dips, condiments (mayonnaise, mustard, ketchup, tartar sauce, chili sauce, soy sauce, relish, horseradish, Worcestershire sauce, and steak sauces), monosodium glutamate (MSG), and bouillon cubes.

Salt Substitutes

Replacing salt with salt substitutes is an option for some people. However, the most popular substitute, potassium chloride (KCl), has a bitter, metallic aftertaste for some individuals, and it may be inappropriate for those with kidney, heart, or liver problems, who must limit their potassium intakes. Calcium chloride and magnesium sulfate are also sold as salt substitutes. "Low sodium" salt, which contains half the sodium of regular table salt, is not considered a salt substitute. "Lite" salt products sold to replace the salt-shaker likewise contain some sodium. Ultimately, the craving for salt is an acquired taste, so gradually cutting back on salt will eventually decrease cravings (21).

Pepper

Pepper is just behind salt in popularity as a seasoning. Pepper is added most frequently to meats, soups, sauces, and salads. Ground black or white pepper comes from the berries of a tropical climbing shrub. The color of pepper depends on the berry's ripeness. Black pepper is from the dried, unripe berry, while white pepper is from the ripe berry from which the dark outer skin has been removed. Green peppercorns, a less common variety, are from underripe berries that are preserved in brine or freeze-dried.

Peppercorns belong to an entirely different genus than the *Capsicum* family of chili peppers, which are classified as vegetables. Many varieties of *Capsicum* peppers are dried and used in chili powder, cayenne pepper, and paprika.

Herbs and Spices

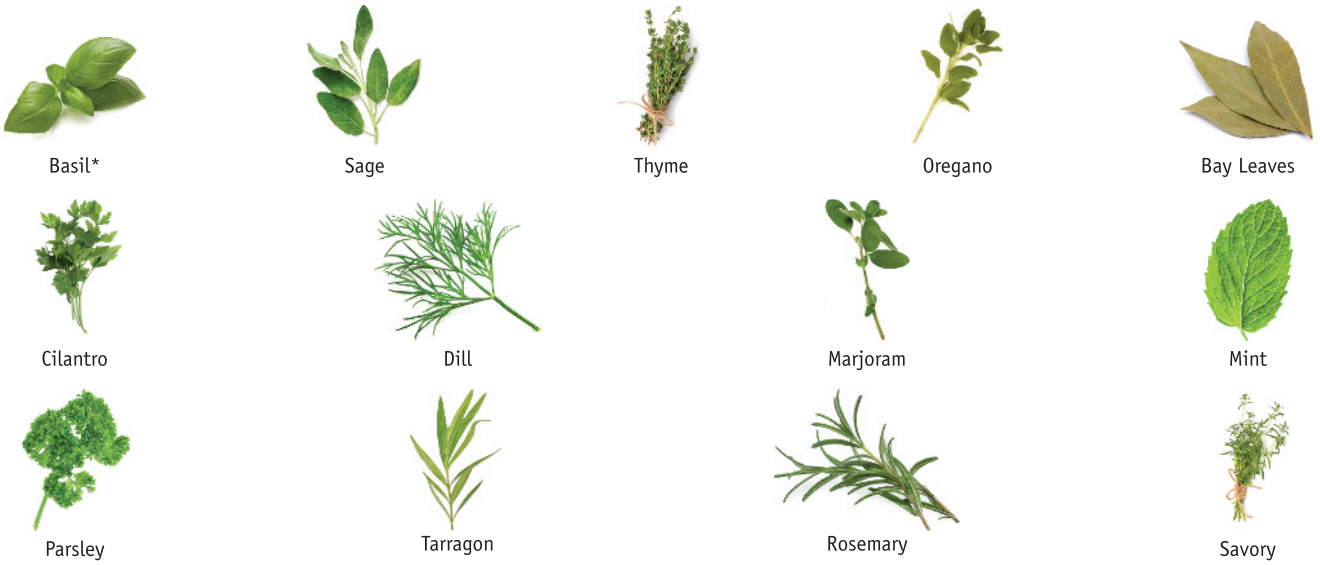
Foods would be boring if salt and pepper were the only two seasonings/flavorings. A variety of herbs and spices from all over the world are used to improve food flavors.

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FIGURE 5-14 Herbs most commonly used in food seasoning.



*Basil has many different varieties, including: sweet, lemon, lime, Thai, spicy saber, and purple.

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NUTRIENT CONTENT

Reducing Salt Sodium is the portion of salt that has raised concerns because of its possible connection to high blood pressure, or hypertension (30). Table salt is 40% sodium, so 1 teaspoon contains 2,300 milligrams of sodium. Not everyone is susceptible to high blood pressure caused by a high-sodium diet, but about 26% of the global adult population has hypertension (20). The average North American diet is high in sodium, which automatically puts these people at risk (8).

To safeguard these sodium-sensitive individuals, the surgeon general recommends that all Americans lower their sodium intake. The concern is that high blood pressure, regardless of its cause, is a known risk factor for heart disease, kidney disease, and stroke (20). How much should sodium intake be reduced? Most Americans consume more than 3,400 mg of sodium per day (30). The Dietary Guidelines suggest that amount be lowered to approximately 2,300 mg of sodium for adults in general, and further reduced to 1,500 mg per day for individuals 51 years of age and older, African Americans, and individuals with hypertension, diabetes, or chronic kidney disease. Three steps that help reduce sodium intake are (1) cutting back on major sodium sources such as processed foods, (2) not adding salt during food preparation, and (3) removing the saltshaker from the table.

Herbs

Herbs were described by Charlemagne as "a friend of physicians and the praise of cooks" (31). The Food and Drug Administration (FDA) groups culinary herbs and spices together and considers them both to be spices. Regardless of how they are defined, herbs are well known for their seasoning capabilities in food preparation (Appendix D). The best-known seasoning herbs include basil, sage, thyme, oregano, bay leaves, cilantro, dill, marjoram, mint, parsley, tarragon, rosemary, and savory (Figure 5-14). For the best in flavor and texture, fresh herbs are generally preferred over dried.

Spices

Spices are distinguished from herbs by their origin: herbs are derived from leaves, whereas spices are derived from other parts of the plant. Some examples include the following:

- Allspice (from a fruit)
- Saffron (flower)
- Cinnamon (bark)
- Anise, caraway, celery, cumin, fennel, mustard, poppy, and sesame (seeds)
- Ginger and turmeric (**rhizomes**)

Although garlic, onions, and shallots can serve as spices, they are officially recognized as vegetables. Appendix D also lists some of the more common spices.

History records a time when spices had a greater value than gold. In fact, they have been called "vegetable gold" and were once used as currency. A Goth leader once demanded 3,000 pounds of pepper as a partial ransom for calling off his siege of Rome (12). The search for these flavoring ingredients resulted in the carving of trade routes between countries, the founding of wealthy empires, and the exploration

Herb A plant leaf valued for its flavor or scent.

Spice A seasoning or flavoring added to food that is derived from the fruit, flowers, bark, seeds, or roots of a plant.

Rhizome An underground (usually) stem that generates (1) shoots that rise up and/or horizontally to propagate new plants, and (2) roots that grow down to the ground.

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of far-off lands. Their value now rests in their unique ability to add a flavorful difference to dishes. The various world cuisines owe their distinctiveness to the unique combinations of spices in foods. Thai food relies heavily on hot peppers, and Central American dishes are distinguished by their use of chili peppers or chili powder. Mexican meals often incorporate cumin, coriander, paprika, pepper, and cilantro. Indian dishes are enhanced with curry mixtures, which are combinations of spices whose exact ingredients and proportions can be closely guarded family secrets. Spice blends and pastes add to the plethora of tastes provided by herbs and spices.

How & Why?

How do cayenne pepper and chili powder differ?

Both are derived from chili (also chilli or chile) peppers or pods, berries that can be used fresh or dried. Chili powder consists of the dried, pulverized fruit of one or more chili pepper varieties, either alone or combined with other spices such as cumin, oregano, garlic powder, and salt. The degree of hotness of chili powder depends on the kind of chili peppers and their ratio to any other ingredients used in the mix. There are five common types of chili peppers, one of which is *Capsicum annuum* with the varieties of cayenne, bell peppers, wax, jalapeños, and chiltepin. Plain cayenne peppers are dried and pulverized to create cayenne powder.

Purchasing Herbs and Spices

Herbs and spices can be purchased in whole, crushed, or ground form. Whole herbs retain their freshness longer than crushed herbs, which in turn keep longer than ground. Whole seeds and leaves provide a visual and textural appeal, although the flavor release may be slow and unevenly distributed. Ground spices provide a quick infusion of flavor that is more uniform, but their aromas are easily lost when exposed to oxygen (oxidized) during storage. The natural antioxidant properties of certain herbs are also lost when they are exposed to oxygen (34) or the cooking methods of frying, grilling, and dry heating. However, simmering, stewing, and microwave all increase the antioxidant capacity of herbs (24).

Storing Herbs and Spices

According to the American Spice Trade Association, dried spices and herbs should be kept below 60°F (16°C) for optimal potency and replaced every 12 months. Herbs and spices deteriorate rapidly when exposed to air, light, and heat. They keep best in airtight, opaque containers stored in cool, dry places. Green herbs such as chives and parsley are light sensitive and will fade if exposed to light (3). The freshness of a particular spice or herb is tested by crushing it in the palm of the hand and then sniffing it to detect its intensity. The full-bodied aroma of fresh herbs becomes weak and barely detectable over time. If an herb or spice is to be used only occasionally, it is best to buy it in small quantities.

Flavor Enhancers

Several food additives serve as flavor enhancers; these include amino acids (glutamic acid and its salts, glycine, and leucine), guanylic acid (and its salts), inosinic acid (and its salts), and maltol. Monosodium glutamate (MSG) is a salt of glutamic acid. It influences flavor without contributing any flavor of its own. Hundreds of years ago in Asia, people found that food cooked in a seaweed-based soup stock had a unique flavor. In 1907, this compound was isolated from seaweed by a Japanese scientist and called *umami,* meaning "delicious" (see Chapter 1 for defining *umami* as the fifth taste) (15). Its scientific name, *monosodium glutamate,* comes from glutamic acid, an amino acid found in seaweed. It is now widely used in processed foods, including canned/dried soups, spaghetti sauces, sausages, and frozen meat dishes. It has been implicated in "Chinese Restaurant Syndrome," in which MSG-sensitive people experience nausea, diarrhea, dizziness, grogginess, sleepiness, warmth, headache, chest pain, and arthritis-like symptoms from consuming MSG. Although a number of anecdotal reports and small clinical studies have demonstrated that MSG can cause these symptoms, clinical trials have not consistently supported this claim (33).

Oil Extracts

Oil extracts can be used as food flavorings. These essential oils are obtained from natural sources such as flowers (orange), fruits (oranges, lemons), leaves (peppermint), bulbs (garlic), bark (cinnamon), buds (clove), and nuts (almonds). The flavor in essential oils is so concentrated that only a small amount is required for flavoring purposes. Oil extracts are primarily used to flavor puddings, candy, ice cream, cakes, and cookies.

Vanilla beans from the cured pod of a tropical orchid provide the purest, most intense vanilla flavor. The small black specks in vanilla sauces and ice cream are the seeds of the pod. To obtain pure vanilla extract, cured vanilla beans are steeped in alcohol. The FDA defines "pure vanilla extract" as containing 35% alcohol by volume, while those of lesser content are labeled "pure vanilla flavor." Vanilla/vanillin blends or imitation versions should be avoided because they contribute an artificial flavor to foods.

Extracts are made by steam-distilling the oils from various plant sources and blending them with ethyl alcohol, which can evaporate. For that reason, they should be stored in a cool, dark place and used within a year to retain maximum flavor.

Marinades

Marinades are seasoned liquids that flavor and tenderize foods, usually meats, poultry, and fish. A vinaigrette is a marinade used for vegetables served cold. The basic marinade consists of one or more of the following ingredients: oil, acid (lemon juice, vinegar, wine), and flavorings (herbs, spices). The food is completely submerged in the marinade and refrigerated from a few minutes to several days. The food should be turned occasionally in order to evenly distribute the marinade. Meat, fish, and poultry marinades should be discarded after use and never served raw with the cooked food.

Rubs and Pastes

Lots of flavor can be added to meats, fish, and poultry through the use of rubs and pastes. A rub is a flavored blend of seasonings (dry or fresh herbs and or spices) that have been ground so they can be added to the surface

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FIGURE 5-15 Meat covered by a drug rub (use gloves).



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of the food prior to dry-heat cooking (Figure 5-15). Sources of rubs include commercial products, your own mixture of preground ingredients, or grinding your own special combination with a spice grinder or mortar and pestle. A paste is made by moistening the rub with oil, butter, prepared mustard, lemon juice, ground garlic or ginger, anchovies, or other moist ingredients. Sometimes the meat is oiled before a dry rub is applied to better hold the seasonings and increase moisture. It's best to use disposable gloves to avoid cross-contamination.

See this YouTube video on how to apply a rub: www.youtube.com/watch?v=SeqJXt0Ju_.

Breadings

Wheat- and corn-based flours are the most frequently used for breading. Coating the food lightly in flour, called dredging or *à la meuniere* (ala moonyare), results in a light, golden crust. Crumb coatings differ in that they are applied in three steps (Figure 5-16). First, the food is dredged lightly in flour to seal in moisture and provide a base for the next step. The flour-coated food is then dipped quickly in an egg wash consisting of beaten eggs plus a tablespoon of water or milk. (Substituting oil for the water or milk results in a richer, more tender coating.) The proteins in the eggs or milk act as binding agents to "glue" the breading to the surface of the food (7). Finally, the sticky-coated food is placed in a bowl of crumbs for the final coating. Seasoned breadcrumbs, cracker crumbs, cornmeal, or cereal (cornflakes) may be used to coat foods. Smaller, more delicate foods such as mushrooms require finer-grained breadings. Seasonings or flavorings such as salt, pepper, rosemary, thyme, sage, or others can be added at any of the three steps of breading, although mixing them into the egg wash ensures that they are evenly distributed (32). Sugar can also be added, but be aware that it results in a browner product (10).

Batters

Another way to coat foods is through the use of batters, which are wet flour mixtures containing water, starch, and seasonings into which foods are dipped prior to being fried. Commercial batters that require simply adding water are available. There is no one recipe for a batter, and formulas can be extremely flexible (13). The addition of eggs to the batter will produce a darker coating because of the yolk content. Commercial batters often have added ingredients such as gums for viscosity and starches to increase adhesion by the swelling of their granules. Shortening or oils contribute to overall flavor and mouthfeel (1). Figure 5-17 shows the basic differences between using a breading process and a batter process to coat foods.

FIGURE 5-16 Breading—application of a crumb coating.



Roll in flour and shake off excess.



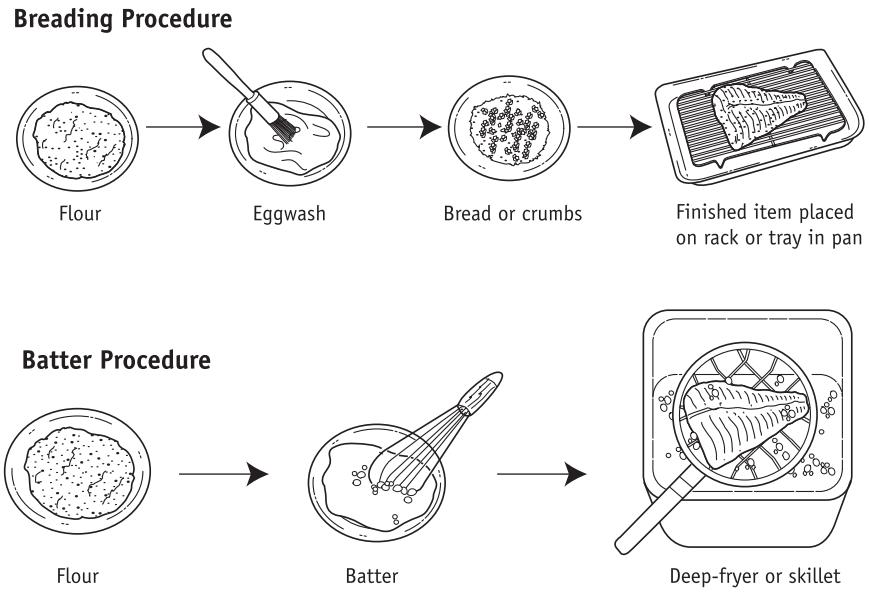
Dip floured piece in egg wash.



Digital Works

Dip in bowl of crumbs and toss more crumbs on top.

FIGURE 5-17 The difference between using breading and batters.



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TABLE 5-6 Functions of Salt in Foods

Flavor enhancer	Salt's best-known function is to enhance the flavor of foods. People like salt because our bodies need sodium chloride. Breads are less bland, cheeses are not as bitter, and processed meats are more flavorful in part because of the addition of salt.
Preservative	Salt has been used for thousands of years to preserve foods. Refrigerators and freezers have not always been around, and drying out the moisture in foods with salt prevented bacteria from being able to live on the food (by dehydrating them).
Binder	Food manufacturers use salt to help form a gel in sausage and other smoked meat products.
Texture enhancer	Salt contributes to the texture of ham, processed meats, bread, and certain cheeses.
Color aid	The color of processed meats such as ham, bacon, hot dogs, and sausage is partially due to salt.
Fermentation control	Bacteria and yeast are sensitive to salt concentrations, so salt is used to control their growth during fermentation in such foods as bread, cheese, pickles, sauerkraut, and sausage.

Source: Adapted from http://www.saltinstitute.org/research/salt-and-food-technology/

Condiments

Condiments are seasonings or prepared relishes used in cooking or at the table. Some of the most common condiments are mustard, ketchup, mayonnaise, relish, tartar sauce, salsa, barbecue sauce, chili sauce, soy sauce, horseradish, Worcestershire sauce, chutney, and steak sauce.

CALORIE CONTROL
Lowering Fat

Avoiding fried foods is one of the most effective ways to reduce excess fat and kcalorie intakes. A potato provides only 145 kcalories when baked but 750 kcalories when prepared as French fries (11). All of the moist- and dry-heat preparation methods discussed earlier, with the exception of frying (pan and deep), are healthful options for preparing food (that includes sautéing). Note that many pan- and deep-fried foods are breaded, and the added flour contributes even more kcalories.

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Adding Seasonings and Flavorings to Food

Knowing how much of the different seasonings and flavorings to add to foods and when to add them is essential to food preparation.

How Much to Add?

If tested recipes are available, they should be followed. If there is no recipe, start by adding ¼ teaspoon of spice (or ⅛ teaspoon for chili, cayenne, or garlic powder) for every pound of meat or pint of liquid (soup, sauce). Test flavor and add more seasonings as desired. It is always easier to add than to subtract, and because it is important not to overpower other ingredients in a dish, it pays to be cautious. There really is no easy set rule or formula for adding seasonings and flavorings to foods. The freshness of herbs and spices will influence how much should be added, and evaporation of liquid during heating will concentrate what is already present. Successfully prepared foods have well-balanced flavors that are complementary.

When to Add?

Seasonings should be added to prepared foods early enough in the cooking process to release their flavor but not so soon that their flavor is lost. Most seasonings (especially ground) are added near the end of the heating period, whereas a few (whole or lightly crushed) need more time to release their flavors and aromas to blend with the other ingredients. Foods tend to retain the flavor of seasonings and flavorings better if their surfaces are partially cooked and therefore permeable to what is added. This stage is commonly referred to by professional chefs as **sweating** (14). It is particularly important to delay the addition of salts, which tend to shrink meats if they are added too soon. However, some chefs salt during the entire process of cooking to allow time for the salt to disperse and interact with the food (18). Flavor retention is influenced by the length of the heating and the final temperature attained. Experience may well be the best teacher.

How & Why?

How much dried herbs should one use in place of fresh herbs?

When substituting dried herbs for fresh, the general rule is to use about one-third as much as you would fresh herbs because the flavor of dried herbs that have not become stale is generally more intense.

Food Industry Uses

Food corporations sometimes add seasonings to their products with the aid of rotating metal drums. These are equipped with spray bars that can lightly coat the chips, pretzels, or other snacks with an oil so that the seasoning will stick. The dry seasoning mix such as salt, powdered cheese, or garlic is then released through a feeder inserted into the drum. The drums are only 30% full to prevent pieces from falling out. Another option is to spray the snacks as they exit the oven on a flat conveyer belt (9).

Sweat The stage of cooking in which food, especially vegetables, becomes soft and translucent.

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PICTORIAL SUMMARY / 5: Food Preparation Basics

Mastering the basics of food preparation is essential to putting a good meal together, but food preparation is not an exact science. Understanding and adjusting for the many variables at play in preparing even the simplest recipe can elevate food preparation from a craft to an art form.

METHODS OF HEATING FOODS

Moist-heat preparation: Heat is transferred by water, water-based liquid, or steam.

Dry-heat preparation: Heat is transferred by air, radiation, fat, or metal.

Microwaving: Usually listed as moist-heat, microwaving actually incorporates both dry-(radiation) and moist-heat methods.

Moist Heat		Dry Heat	
Scalding	Poaching	Baking	Roasting
Simmering	Stewing	Broiling	Grilling
Braising	Boiling	Frying	Sautéing
Parboiling	Blanching	Stir-frying	Pan-broiling/frying
Steaming		Deep-frying	

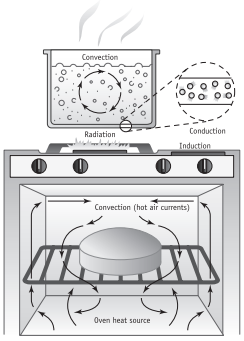


Temperature scales used to measure heat in cooking are Fahrenheit and Celsius (centigrade). These scales are based on the freezing and boiling temperatures of pure water at sea level (32°F [0°C] and 212°F [100°C], respectively).

HEAT-TRANSFER METHODS

Conduction: The direct transfer of heat from one substance to another by direct contact; for example, heat from a gas flame warms the pot on the stove and then its contents.

Convection: Air or liquid expands and rises as it heats up, creating a circular current. Oven baking, simmering, steaming, and deep-frying are all examples of convection cooking. The use of water and fat to heat foods combines both conduction and convection.

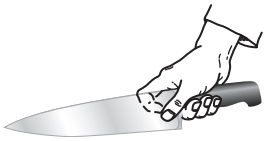


Induction: Transferring heat energy to adjacent material without contact.

Radiation: Radiant heat in the form of particle waves moving outward is generated by broiling, grilling, and microwaving. Infrared heat lamps and ovens use electromagnetic waves to keep foods warm and to prepare frozen foods.

CUTLERY TECHNIQUES

Knowing knives and how to use them is essential to basic food preparation.



Holding a Chef's Knife.

It is important to know how to hold the knife; the different sections of the blade assigned to various tasks; and the different cutting styles: *slicing* (include *julienning*), bâtonnet, *shredding, chiffonade, dicing or cubing, mincing, peeling,* and *parisienning.*

MEASURING INGREDIENTS

The four major steps in correct measuring:

- Choosing Weight vs. Volume measuring system (weight is more accurate)
- *Selecting* the right measuring utensil:
  - ***Wet ingredients:*** transparent, graduated cup with pour spout
  - ***Dry ingredients:*** flat-topped measuring cups for leveling
- Using an accurate measuring technique
- Knowing the approximate pound to cup yields (e.g., 4 ounces of cheese yields 1 cup shredded)

Know your substitutions: Sometimes knowing what item can replace a missing ingredient can save the day!

MIXING TECHNIQUES



Mixing is a general term for several techniques: stirring, beating, blending, binding, whipping (whisking), and folding. The ingredients for baked goods can be mixed in several different ways, but the most common methods are the conventional (creaming), conventional sponge, single-stage (quick-mix), pastry-blend, biscuit, and muffin.

SEASONINGS AND FLAVORINGS

Seasoning: Any compound that *enhances the flavor* already found naturally in a food.

Flavoring: An addition that *adds a new flavor* to a food.



The major seasonings/flavorings are the following:

- Salt and pepper
- Herbs and spices
- Oil extracts
- Flavor enhancers
- Marinades
- Breading and batters
- Condiments

The freshness of herbs and spices influences how much should be added, and evaporation of liquid during heating will concentrate the effect of added flavorings/seasonings.

Adding is always easier than subtracting! Test flavor and add more seasoning as desired.

Most seasonings are added near the end of the cooking time.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The cooking method where food simmers in a small amount of liquid covered pot or casserole dish is called _____.
   a. braising
   b. scalding
   c. broiling
   d. steaming

2. Food that is cut into very thin, stick-like shapes has been _____.
   a. chopped
   b. minced
   c. peeled
   d. julienned

3. Three teaspoons is equivalent to _____.
   a. 1 tablespoon
   b. 1½ tablespoons
   c. 2 tablespoons
   d. 2⅕ tablespoons

4. When using the muffin method of mixing, overmixing will produce what type of unwanted result?
   a. Tender
   b. Tough
   c. Overly moist
   d. Overly dry

5. What is the best environment for storing herbs and spices?
   a. A cool, moist place
   b. A warm, bright place
   c. A cool, dry place
   d. A hot, moist place

6. Which of the following heating methods is based on the principle of conduction?
   a. Heat from an electrical coil or gas flame touches a pan that heats the pan's contents.
   b. Heated air in an oven rises, and cooler air moves downward.
   c. Heat is transferred by waves during grilling, broiling, and microwaving.
   d. Heat is moved from the coils under a flat-surfaced range to the pot.

7. The correct sequence for breading is _____.
   a. egg wash, flour, crumbs
   b. flour, crumbs, egg wash
   c. egg wash, crumbs, flour
   d. flour, egg wash, crumbs

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Briefly describe each of the following moist-heat preparation methods: *scalding, poaching, simmering, stewing, braising, boiling,* and *steaming*.
2. Explain the difference between dry-heat and moist-heat preparation. Define the following dry-heat preparation methods, providing examples for each: *baking, roasting, broiling, grilling,* and *frying*.
3. Define the following cutting styles: *slicing* (include *julienning*), bâtonnet, *shredding, chiffonade, dicing or cubing, mincing, peeling,* and *parisienning*.
4. Fill in the following equivalent measurements:
   _____ tsp = _____ T _____ oz = _____ 1 lb
   _____ oz = _____ C _____ grams = _____ 1 tbsp
   _____ C = _____ pint _____ pints = _____ quart(s)
5. How would you measure each of the following items: *liquid, eggs, fat, sugar,* and *flour?*
6. List and briefly describe three mixing methods.
7. Explain the difference between seasonings and flavorings, herbs and spices, and breading and batters.
8. What is a marinade, and how is it used?
9. What is the purpose of a mandoline and how is it used?

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6



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Meal Management

Food-Service Organization 113
Types of Meal Planning 116
Purchasing 118
Time Management 124
Type of Meal Service . . 125
Table Settings 127

A successful meal is both psychologically and physiologically satisfying. Planning such meals requires a basic knowledge of food preparation, nutrition, and presentation strategies. Effective meal planning and preparation, whether for a household, an institution, or a restaurant chain, are made possible by the efficient management of money, time, and energy. These resources are used in the various steps of meal production: food procurement, storage, preparation, serving, and cleanup. All these steps require organization on the part of the individual or the food service manager. For the latter, good organization involves people working together toward the common goal of preparing and serving attractive, tasty, nutritious, and profitable meals. This chapter covers the organization of food-service establishments, meal planning, purchasing, time management, types of meal service, and table settings.

FOOD-SERVICE ORGANIZATION

At the core of every food-service operation is an organization with a structure set up to achieve specific goals. Management determines the objectives necessary to reach those goals and then mobilizes people toward meeting them. This entails the division of work, which necessitates clear and effective **job descriptions.** Positions are often described more fully in a job description than they are in a newspaper ad for that job or even in the verbal description an employer provides when interviewing or training a new employee. Anyone applying for employment in a food-service operation should ask the employer to provide the formal job description in writing and check that it matches the job duties, performance evaluations, and salary as explained by the person doing the hiring. If there's

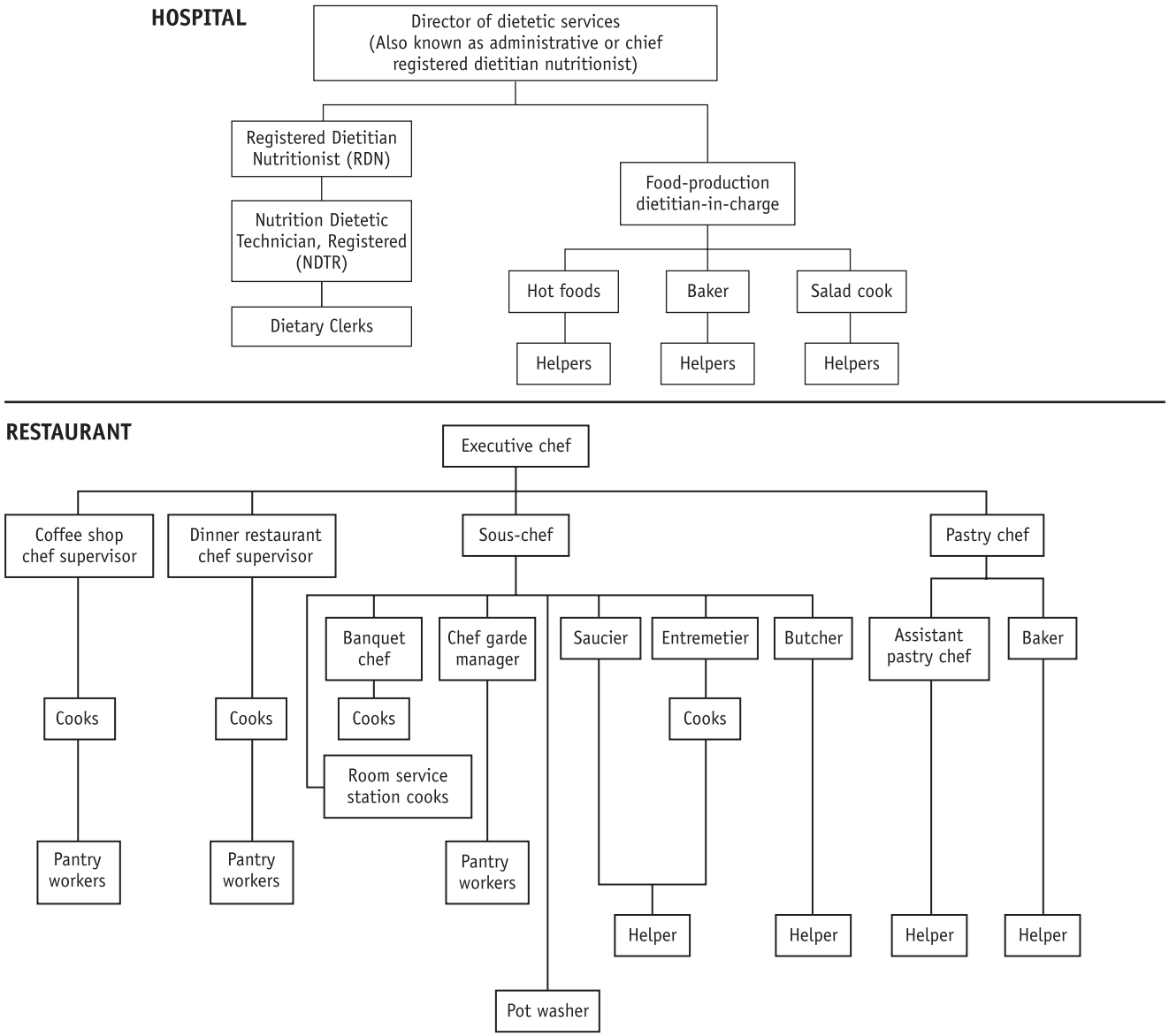
Job description An organized list of job duties used for finding qualified applicants, training, conducting performance appraisal, defining authority and responsibility, and determining salary.

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FIGURE 6-1 Organizational chart comparison of a hospital and a restaurant.



Source: Adapted from Mizer DA, M Porter, B Sonnier, and KE Drummond. *Food Preparation for the Professional*, 3rd ed. Wiley, New York, 1999.

a performance evaluation form, ask to see it so that you can attempt to meet the performance criteria. It's also a good idea to get a copy of the annual evaluation form when you start the job. An **organizational chart** is also helpful to a new employee. Figure 6-1 compares the organizational charts for a hospital nutrition department and a restaurant.

Organizational chart A descriptive diagram showing the administrative structure of an organization.

Commercial Food-Service Organization

Large food-service organizations usually follow the structure that was pioneered by Georges Auguste Escoffier (1846–1935). Escoffier, called the father of twentieth-century cookery, created stations for particular areas of food production. Escoffier's system of dividing up large kitchens into various preparation areas led to the creation of jobs requiring specific skills. The team of kitchen employees within this type of food-service organization is called the *brigade de cuisine* (bree-gahd-de-kwee-zeen).

Escoffier's System of Organization via Stations

Each station in the kitchen is overseen by station chefs or heads with a particular area of expertise:

- Sauce chef/*saucier* (so-see-ay). The highest position among the stations. This chef specializes in the production of sauces, sauce-related dishes, hot hors d'oeuvres, stews, and sautéed foods.
- Fish cook/*poissonier* (pwah-so-nee-ay). Sometimes this station is covered by the sauce chef.
- Vegetable cook/*entremetier* (on-tra-met-ee-ay). Prepares vegetables.

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TABLE 6-1 Brief Summary of Hospital Diets

Diet		Other Common Names	Definition	Purposes
Standard		Routine, house, selective, regular, or progressive diet	For adults who are not on any dietary restriction	Maintain optimal nutritional status
Therapeutic/ selective		Low-fat, low-carbohydrate, low-sodium, low- or high-fiber, renal, low-oxalate, high- or low-protein, etc.	Prescribed by physician as medical nutrition therapy for patient	As part of treatment for a clinical condition, or to eliminate or decrease specific nutrients in the diet or to increase specific nutrients, or to provide food the resident is able to eat (mechanically altered)
Mechanically altered diets (texture of diet is altered)		Modified consistency diets	Diet in which the texture of foods/ beverages is altered	To provide food the patient is able to eat
	Clear liquid	—	Foods that are clear liquids containing minimal fiber	Initial feeding after surgery that provides some electrolytes and energy while minimizing gastrointestinal stimulation
	Full liquid	Surgical liquid diet	Foods that are liquids or semi-liquids at room or body temperature (strained items such as milk, juice, and eggs if in drinks/custards)	Provides nourishment for patients who cannot chew, swallow, or digest solid foods
	Blenderized liquid	—	Foods blenderized to liquid form	For patients unable to tolerate solid food following oral or plastic surgery; chewing or swallowing problems; wired jaws
	Pureed	Strained soft	Cooked food that has been pureed to a soft, creamy paste or thick liquid	For those with chewing or swallowing problems
	Soft diet	Surgical soft, mechanical soft diet, mechanically altered diet	Food modified only in texture—blended, chopped, ground; low fiber, mild seasoning, smooth texture, low on fried and strong-flavored foods or gas-forming vegetables	Transition between liquid and standard diets, provided after surgery to prevent nausea and vomiting, gas and distention from anesthesia, and gastrointestinal immobility; promotes ease of chewing following head and neck surgery or radiation; swallowing problems; oral or dental problems

- Soup cook/*potager* (poh-ta-zhay). Prepares soups and stocks.
- Roast cook/*rotisseur* (ro-tee-sur). Responsible for meat dishes, particularly if they are roasted or braised.
- Broiler cook/*grillardin* (gree-yar-dan). Specializes in preparing grilled, broiled, or deep-fried meats, poultry, and seafood.
- Pantry chef/*chef garde manger* (guard-mon-zhay). Prepares all nondessert cold foods, such as salads and cold hors d'oeuvres.
- Pastry chef/*patissier* (pa-tees-see-ay). Prepares baked goods—pastries, desserts, and breads.
- Relief, swing, or rounds cook/*tournant* (tour-non). Capable of handling any station in order to relieve one of the other chefs.

In smaller kitchens, there may be only two stations, one for hot foods and one for cold foods. In such kitchens, the pantry chef is a major position. Each station head has cooks and helpers or assistants that aid with that area of food production. The first step on the job ladder in a large kitchen is the entry-level position of helper or assistant, which requires virtually no skills. After the skills are acquired, however, the person may be promoted to cook. People can sign on as apprentices and receive formal training in food service by rotating through each of the kitchen stations.

Administrative Positions

In general, after about 5 to 10 years of experience in all stations as a chef, a person can be promoted to administrative positions in the kitchen:

- Executive chef/*chef executif*. The person in charge of the entire operation, including kitchen administration, hiring, budgeting, purchasing, work scheduling, menu planning, and more.
- Production manager/*sous* (soo) chef. The second-highest position in the kitchen. The sous chef is in charge of all areas of production and supervision of the staff.

Hospital Food-Service Organization

A hospital's nutrition/food service department is responsible for feeding its patients, some of whom may need specialized meals (Table 6-1). Many larger hospital food operations are professionally managed by Sodexo Corporation. Working for this or a similar company allows the hospital food-service employees more flexibility in shifting positions geographically. Hospital food-service operations differ

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slightly from large hotel or restaurant establishments in that the person in charge is the food-service director, or administrative or chief **dietitian.** Working for the chief dietitian are other dietitians; their number depends on the size of the hospital, often described in terms of the *number of beds*. Assisting the dietitians are the dietetic technicians, who hold at least a 2-year degree. The entry-level employees in a hospital dietary department, who may start out relatively untrained, are the dietary aides. People working in this position assist the dietitians and dietetic technicians, often filling out diet orders, taking care of paperwork, and sometimes working the tray line where meals are put together before being delivered to hospital patients.

TYPES OF MEAL PLANNING

The ultimate goal of a food-service organization is to plan, prepare, and serve meals. Food production begins with planning the menu. The menu dictates all other actions that will follow, such as purchasing, choosing equipment to use, scheduling labor, and serving.

USDA Menu Patterns

What is typically served for breakfast, lunch, and dinner? The meal pattern varies tremendously from country to country. In North America, the standard fare for adults can be divided into the selections shown in the U.S. Department of Agriculture's (USDA) Adult Care Meal Pattern (Figure 6-2). A similar meal pattern for infants

Dietitian (registered dietitian [RD] or registered dietitian nutritionist [RDN]) A health professional who counsels people about their medical nutrition therapy (carbohydrate-controlled, low-fat, low-sodium, and so on to treat diabetes, kidney disease, etc.). Registration requirements consist of completing an approved 4-year college degree, exam, internship, and ongoing continuing education.

FIGURE 6-2 USDA's adult care meal pattern.

Adult Care Meal Pattern[1]

Breakfast Meal Pattern for Adults		
(Select all three components for a reimbursable meal)		
1 Milk[2]	1 cup	Fluid milk
1 Vegetable[3], fruit, or portions of both	½ cup	Vegetable
1 Grains[4,5,6,7]	2 slices	Whole grain or enriched bread
	2 servings	Biscuit, roll, muffin
	1 cup	Hot cooked cereal, grain, or pasta
	½ –2 ½ cups	Cold cereal: flakes or rounds (2 cups), puffed cereal (2 ½ cups), granola (½ cup)
Lunch for Supper Meal Pattern for Adults		
(Select all five components for a reimbursable meal)		
1 milk[2,8]	1 cup	Fluid milk
Meat/meat alternative[9,10,11]		
	1 ounce	Lean meat, poultry or fish
	1 ounce	Tofu, soy products, or alternative protein products
	1 ounce	Cheese
	½	Large egg
	¼ cup	Cooked dry beans or peas
	2 TB	Peanut butter, soy nut butter or other nut or seed butters
	4 ounces or ½ cup	Yogurt, plain or flavored unsweetened
	1 ounce	Peanuts, soy nuts, tree nuts, or seeds
1 Vegetable[3,11]	½ cup	Vegetable
1 Fruit[11]	½ cup	Fruit
1 Grains[4,5,6,7]	2 slices	Whole grain or enriched bread
	2 servings	Biscuit, roll, muffin
	1 cup	Hot cooked cereal, grain, or pasta
	½ – 2 ½ cups	Cold cereal: flakes or rounds (2 cups), puffed cereal (2 ½ cups), granola (½ cup)

[1] Must serve all 3 components for breakfast and all 5 components for lunch/supper for a reimbursable meal. Serving sizes for infant (0–12 months) and children (ages 1–18) are in the URL below.

[2] Must be unflavored whole milk for children age one. Must be unflavored low-fat (1 percent) or unflavored fat-free (skim) milk for children two through five years old. Must be unflavored low-fat (1 percent), unflavored fat-free (skim), or flavored fat-free (skim) milk for children six years old and older and adults. For adult participants, 6 ounces (weight) or 3/4 cup (volume) of yogurt may be used to meet the equivalent of 8 ounces of fluid milk once per day when yogurt is not served as a meat alternate in the same meal.

[3] Pasteurized full-strength juice may only be used to meet the vegetable or fruit requirement at one meal, including snack, per day.

[4] At least one serving must be whole grain. Grain-based desserts do not count toward meeting the grains requirement.

[5] Meat and meat alternatives may be used to meet the entire grains requirement a maximum of three times a week. One ounce of meat and meat alternatives is equal to one ounce equivalent of grains.

[6] Breakfast cereals must contain no more than 6 grams of sugar per dry ounce (no more than 21 grams sucrose and other sugars per 100 grams of dry cereal).

[7] Beginning October 1, 2019, ounce equivalents are used to determine grain quantities.

[8] The milk serving at supper is optional for adults.

[9] Yogurt must contain no more than 23 grams of total sugars per 6 ounces.

[10] Alternate protein products must meet USDA requirements in Appendix A (see URL).

[11] A vegetable may be used to meet the entire fruit requirement. When two vegetables are served at lunch or supper, two different kinds of vegetables must be served.

Source: Food & Nutrition Service of the USDA.

https://www.gpo.gov/fdsys/pkg/FR-2016-04-25/pdf/2016-09412.pdf

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FIGURE 6-3 Healthy 1-day, 2,000-kcalorie meal plan.

BREAKFAST
Cold cereal and toast:

1 cup	ready-to-eat oat cereal
1 medium	banana
½ cup	fat-free milk
1 slice	whole wheat toast
1 tsp	margarine

Beverage:

1 cup	Orange juice

LUNCH
Tuna salad sandwich and fruit:

2 slices	rye bread
2 ounces	tuna
1 Tbsp	mayonnaise
1 Tbsp	chopped celery
½ cup	shredded lettuce
1 medium	peach

Beverage:

1 cup	fat-free milk

DINNER
Roasted chicken, vegetables, and roll:

3 ounces	cooked chicken breast
1 large	sweet potato, roasted
½ cup	succotash (limas beans & corn)
1 tsp	tub margarine
1-ounce	whole-wheat roll
1 tsp	tub margarine

Beverage:

1 cup	water, coffee, or tea

SNACKS

¼ cup	dried apricots
1 cup	flavored yogurt

FIGURE 6-4 An example of a 1-week (minus Friday) cycle menu.

	Month 1, Week 1		
	Breakfast	***Lunch***	***Dinner***
MONDAY	Oatmeal Fruit cup Yogurt Tea/Coffee	Chef's salad French bread Pudding Vegetable juice	Baked chicken Asparagus Mashed potatoes Carrot raisin salad
TUESDAY	Scrambled eggs Wheat toast/Jam Orange juice Tea/Coffee	Fish almondine Red potatoes Spinach Fruit juice	Linguini with marinara Garlic bread Greek salad Tapioca cup
WEDNESDAY	Cold cereal Banana Tomato juice Wheat toast/Jam	Vegetable stew Whole-wheat bread Cabbage salad Apple pie	Steak Baked potato Green beans Tossed salad
THURSDAY	Waffle Fruit bowl Grapefruit juice Tea/Coffee	Tuna sandwich Apple or banana Romaine salad Cream cheese pie	Baked fish Broccoli Papaya salad Apple cobbler

(birth to 1 year) and children (1 to 2 years; 3 to 5 years; 6 to 12 years) is called the USDA's Child Care Meal Pattern and is available at the USDA's website: www.fns.usda.gov/cacfp/meals-and-snacks. The USDA has also published recommended food group–based menu plans for adults with various kcalorie needs (including vegetarians) as part of the 2010 *Dietary Guidelines for Americans*. Figure 6-3 is an example of a healthy 1-day menu based on these USDA Food Patterns.

The Healthy, Hunger-Free Kids Act of 2010 established new standards for school lunches in an effort to offer healthier meals to children nationwide (17). These standards both emphasize healthier foods and specify portion sizes that are appropriate for children's caloric needs based on age (18). The specifics of the USDA's nutrition standards for the National School Lunch and School Breakfast Programs are repeatedly updated and available online. The 2010 legislation also authorized the USDA to establish science-based nutrition standards for competitive foods and beverages sold in schools based on the latest *Dietary Guidelines for Americans* (14, 19).

Hospital Menu Patterns

Patients in a hospital have various nutritional needs. They may be on a regular or general diet, a modified-consistency diet, or a prescribed diet, depending on their current health condition (Table 6-1). It is the responsibility of the hospital's nutrition department to ensure that all patients are being provided the appropriate diet. Dietitians also provide nutrition counseling/education to patients who require medical nutrition therapy.

Types of Menus

Regardless of what menu pattern is followed, planning menus is the essential first step of food production. The first decision to make is what type of menu will be used: a no choice, limited choice, or choice menu. The menu can reflect what is offered daily, weekly, or for several weeks (**cycle menus**).

Because dinners are usually the most prominent meal, most people plan dinner first. Meals then are built around the main entrée, and the remaining items are usually decided on in the following order: vegetable, starch, salad, bread, soup, appetizer, and dessert. Some provision must also be made for breakfasts, lunches, beverages, and snacks. Fruit is recommended twice a day, and it can be incorporated into the menu as a salad, dessert, snack, breakfast, and/or a beverage. At least three vegetable portions a day should also be part of the menu.

Cycle Menus

Creating several weekly menus in a row sets up a cycle menu (sometimes referred to as a "menu cycle"; Figure 6-4). This is a common practice for food-service institutions, especially schools. Three-week cycles improve cost control, but four-week cycles are less monotonous, and longer cycles are preferred for people who are unable to eat elsewhere, such as those residing in nursing homes or other long-term care institutions. After

Cycle menu A menu that cycles through a certain order of meals over a period of 1 or more weeks (usually 3 or 4). Cycle menus offer a combination of variety and controlled costs.

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the number of weeks in the cycle menu is determined, the meals for each week are then planned.

Planning a weekly cycle menu is usually the responsibility of the food service establishment's management team, which attempts to balance numerous factors, such as those itemized in the checklist in Figure 6-5.

Nutrition

The caloric and nutritive value of meals is another responsibility of the foodservice manager or director. Fortunately, the trend toward healthful eating is spurred on by numerous chefs publishing culinary books on how to prepare healthful foods (3). Many student chefs entering the culinary field believe that nutrition is an important part of the meal (19).

The Patient Protection and Affordable Care Act of 2010 mandated that kcalorie labels be added to menu boards of chain restaurants with twenty or more locations (11). Several states and cities had already passed laws requiring certain restaurants to post kcalories (16). Although many restaurants already provide nutrient information when asked, and many of the fast-food chains publish this information online, it may take time for this growing trend to spread throughout the United States (20). The kcalorie contributions of menu items may assume greater importance for restaurants required to post this information.

How & Why?

Why are obesity rates increasing in the United States if fat intake has decreased?

Though Americans have decreased their percentage of kcalorie intake from fat, they continue to increase their overall consumption of kcalories (6). Excess kcalorie intake from any food source results in weight gain.

Food cost The cost of foods purchased, often expressed as a percentage obtained by dividing the raw food cost by the menu price.

FIGURE 6-5 Cycle menu evaluation checklist.

- ❑ **Clientele**
  - Age
  - Religion
  - Cultural preferences
  - Regional differences
- ❑ **Cost**
- ❑ **Taste**
  - Does the entrée selection include meals that taste better than the competition?
- ❑ **Holiday meals**
- ❑ **Seasonal availability** (fruits and seafoods)
- ❑ **Nutrition guidelines**
  - *Dietary Guidelines for Americans*
  - Risk factors for diseases
  - Fat — 20–35% kcalories
  - Complex carbohydrates — 45–65% kcalories
  - Saturated fat — less than 10% of kcalories
  - Added sugars — less than 10% of kcalories
  - Fiber — at least 25 g/day for women, 38 g/day for men
  - Vitamins — a variety of different-colored vegetables/fruits each week
  - Minerals — avoid excess sodium
  - National Cancer Institute recommendations
  - Exchange Lists for Diabetes
- ❑ **Appealing menu items**
  - Flavor/color/texture/shapes (diced/strips/chopped)/temperature variation
  - Type of preparation (fried/baked/broiled/sauced/plain)
  - Are records of consumption/popularity incorporated?
  - Garnishes
- ❑ **Equipment use balanced**
- ❑ **Workload/schedules balanced** (broiling, frying, microwave, oven, etc.)
- ❑ **Cycle/day sequence**
  - Is the end of the cycle different from the beginning?
  - Are the day's options for breakfast/lunch/dinner different?
  - Is any one item repeated too frequently in the cycle?
- ❑ **Descriptive menu**
  - Steak — Sizzling Swiss Steak
  - Peas — Buttered Peas and Mushrooms
  - Potatoes — Boiled New Potatoes
  - Salad — Fresh Garden Salad
  - Brownies — Chewy Fudge Brownies

How & Why?

How do you analyze a diet?

Actual energy and nutrient intakes are best determined through a nutrient analysis. Individual foods can be analyzed for free using the USDA's "National Nutrient Database for Standard Reference," and diets can be evaluated using one of the many free online tools (see the websites at the end of this chapter). In addition, both consumer and professional nutrient analysis software applications are available for purchase. After the person enters profile information (sex, age, height, desired weight, activity level), along with the types and amounts of foods consumed in a day(s), the program generates a summary of total kcalories and amounts of nutrients. These are often presented as a percentage of the government standard—which in the United States is the Dietary Reference Intakes (DRI)—for an individual with the profile characteristics.

The U.S. government also encourages citizens to learn about their energy needs and improve their diets through the USDA's Center for Nutrition Policy and Promotion. The center offers the Super Tracker at www.choosemyplate.gov so that people can use it to analyze their own diets. This diet self-assessment tool allows users to input their daily food intake and receive an evaluation of their overall diet. Implementation of the *Dietary Guidelines* by consumers would improve their nutrient intakes and possibly reduce their risks for degenerative diseases. The Calorie Control feature that follows explains how to ensure that meals provide the recommended amounts of energy and nutrients.

PURCHASING

Another aspect of meal planning is deciding how much of each food to buy. The **food cost** accounts for about half of all operating expenses in foodservice establishments, with the majority of the other half incurred by labor

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CALORIE CONTROL
Balanced Energy and Nutrient Intakes

***Choose Your Foods: Food Lists for Diabetes* – A Kilocalorie Control Tool**

A growing concern among North Americans is the increase in the obesity rate and the resulting health problems. Excess food energy intake is a major contributor to obesity, and it would help many "kcalorie challenged" consumers to learn (1) how many kcalories they actually need (see Calorie Control box in Chapter 1) and (2) how many kcalories are provided by foods and beverages. The *Dietary Guidelines,* ChooseMyPlate, and the *Choose Your Foods* guide lists all provide consumer guidance for regulating kcalorie intakes. The first two are discussed in Chapter 1 and in the *Choose Your Foods: Lists for Diabetes* booklet published jointly by the American Diabetes Association and the Academy of Nutrition and Dietetics (see websites section at the end of this chapter). Although developed to help clients with diabetes manage blood glucose by keeping carbohydrate intake consistent, they can also be used by anyone wanting to lose weight. After the daily caloric level is known, specified quantities from each food list are combined to create a healthful meal plan within the individual's daily kcalorie goal. Using the *Choose Your Foods* publication is a good way for people to (1) recognize how many grams of carbohydrate, protein, and fat are found in foods; and (2) control their food intake based on their personal daily kcalorie recommendations.

Planning Healthful Meals

A counseling session with a registered dietitian will provide the actual amounts from each food list recommended depending on a person's sex, age, activity level, and desired weight. According to *Choose Your Foods: Food Lists for Diabetes,* a healthy daily meal plan starts with at least 6 servings (exchanges) of starch, 2 servings of fruit, 2 servings of milk, 2 to 3 servings of nonstarchy vegetables, and 6 ounces of meat/substitutes. These add up to approximately 1,325 kcalories, none of which are derived from fat (45 kcalories for each teaspoon), sweets (such as soft drinks or sodas), or alcohol.

The next step is to design a meal plan by distributing the prescribed number of exchanges among meals and snacks; the exchanges can then be translated into quantities of particular foods using the *Choose Your Foods* guide. Figure 6-6 shows how to choose a more healthful diet based on a given number of daily exchanges. Diet B based on the Exchange Lists provides more food volume but delivers about 2,000 fewer kcalories than diet A. Large portions (increasing your number of exchanges) or sugary and/or fatty food choices make it easy to go over the daily kcalorie cap, and an excess of only 500 kcalories a day leads to a weekly gain of 1 pound (500 kcalories × 7 days = 3,500 kcalories).

Healthful Portions

Another important part of kcalorie control is overcoming portion distortion. A standard "serving size" is not equal to what is served on the plate. In addition, a serving size is not equal to an "exchange." When using the *Dietary Guidelines,* ChooseMyPlate, the *Choose Your Foods* guide, or any other means of limiting food intake, it's important to realize how servings are defined (because they are not always the same) and how big (or small) these servings really are. Figure 6-7 provides a visual reference for quantities such as ½ cup, 1 cup, and 1 and 3 ounces. A 12-ounce glass is really 1½ cups. A 12-ounce steak is double the 6 ounces of protein foods recommended each day (for a 2,200-kcal diet)—3 ounces is equivalent to a deck of cards. A 12-ounce regular soft drink (soda) often delivers approximately 150 kcalories. Many people must downsize their ideas of how much food they need and consume less, especially if they are overweight or obese.

Nutrients

After establishing a healthful kcalorie balance goal coupled with realistic portion sizes, the next step is to make sure the diet is balanced in terms of the nutrients it provides: macronutrients

FIGURE 6-6 Choosing a healthier diet.

Diet A (fast-food diet)		Diet B ("B" for "better")		
Breakfast		**Breakfast**		**Exchange (for Diet B)**
1	donut	1C	bran cereal	2 starch
1C	coffee	1C	2% milk	1 milk
1 Tbsp	cream	1C	cantaloupe	1 fruit
Lunch		**Lunch**		
1	burger (deluxe)	3 oz	baked chicken	3 meat
1	fries (medium)	½ large	potato with skin	2 starch
1	milk shake (medium)	½ C	carrots	1 vegetable
		1 C	spinach	1 vegetable
		1 tsp	margarine	1 fat
Dinner		**Dinner**		
1	fried chicken breast	3 oz	round steak	3 meat
1 C	coleslaw	½ C	broccoli	1 vegetable
20	potato chips	2/3 C	brown rice	2 starch
1	pickle	1 tsp	margarine	1 fat
Snack		**Snack**		
1C	ice cream	1 C	frozen yogurt	1 milk

(*Continued*)

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Nutrient Analysis[1]		
	Diet A	**Diet B**
Kilocalories	3,350 (high)	1,300
% Carbohydrate	39% (low)	55%
% Fat	49% (high)	22%
% Protein	11%	23%
Protein (g)	95	85
Fat (g)	183 (high)	34
Fiber (g)	16 (low)	33
Cholesterol (mg)	502 (high)	180
Vitamins	8+ low	2 low
Minerals	4+ low	within normal limits
Sodium (mg)	5,150 (high)	1,0121

Analyzed using FoodProSQL (Esha Research; © 2010 Amy Brown.[1]www.esha.com)

(carbohydrates, fat, and protein), cholesterol, fiber, and micronutrients (vitamins and minerals).

Macronutrients

The overall percentage of kcalories from carbohydrates should be at least 45 to 65%, with fat providing 20 to 35%, and protein approximately 10 to 35%. Acceptable ranges for children are similar to those for adults, except that infants and younger children need a slightly higher proportion of fat (25 to 40%) (8).

Carbohydrates An Institute of Medicine publication recommends an intake of at least 130 grams of carbohydrate daily—this is the average minimum amount of glucose the brain needs. Most people exceed this amount; the median intake averages 180 to 230 grams per day for women and 220 to 330 grams a day for men, and falls within the recommended range of 45 to 65% of energy (9).

Carbohydrate Sources About 15 grams of carbohydrates are found in an Exchange List serving of starches (bread, cereal, grain, and some starchy vegetables), fruit, or sweets. A cup of milk contains almost the same amount of carbohydrate (12 grams) but in the form of lactose. Nonstarchy vegetables also contain some carbohydrates (5 grams). Meat, fats (including nuts), and water contain very little to no carbohydrates.

FIGURE 6-7 Size-up your food.

Three methods for measuring portion sizes

1. Hand
2. Common items
3. Measuring utensils (See measuring ingredients in Chapter 5.)

1. Using "hand" measurements (portion sizes based on using different parts of your hand)

Fist	=	1 cup (8 ounces) Used to measure beverages, grains, pasta, cereal, mashed potatoes, vegetables, ice cream, yogurt, etc.
½ Fist	=	½ cup (4 ounces)
Palm	=	3 ounces (oz) Used to measure an average meat serving
Closed palm	=	1 ounce (oz) held within space under closed fingers (fingers flat, not curled as in fist)
Whole thumb	=	1 ounce (oz) Used to measure cheese, nuts
Thumb joint	=	1 teaspoon (tsp) Used to measure fats
3 Thumb joints	=	1 tablespoon (T) or ½ ounce (oz)

2. Using "common items" measurements

Soda can	=	12 ounces (oz)
Baseball (not softball)	=	Average fruit or 1 cup of anything
Yogurt container	=	6 ounces (oz)
Tennis ball	=	Medium/small fruit ½ cup of anything (ice cream, yogurt, pudding, vegetable)
Card deck	=	3 ounces (oz) (meat servings such as chicken breast or beef patty)
Checkbook	=	3 ounces (oz) (grilled fish, pasta)
Ice cream scoop	=	1/3 cup if rounded (rice serving)
Golf ball	=	¼ cup (2 ounces)

(*Continued*)

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Complex carbohydrates are preferred and can be consumed by choosing whole-grain breads, cereals, grains, pasta, legumes (dried beans, peas, and lentils), and starchy vegetables such as peas, potatoes, and corn.

Recommended Fiber Intake Fiber is a carbohydrate that is not digested or absorbed by humans, so it contributes few if any kcalories. The Institute of Medicine recommends fiber intakes of 25 grams per day for healthy women and 38 grams per day for healthy men.

Fiber recommendations for children and elderly are 14 grams of fiber for every 1,000 kcalories consumed. The average U.S. intake of only 16 grams of dietary fiber per day falls short of these goals (7). Good food sources of fiber are listed in Chapters 13, 14, 16, and 20 (vegetables, fruits, grains, and bread products, respectively). One of the ways to increase both complex carbohydrates and fiber is by offering a vegetarian menu option, which, as restaurateurs are now realizing, is no longer just a passing fad (5).

Sugar Tax Governments sometimes implement a "sugar tax." For example, a sugar-sweetened beverage tax in Mexico decreased sales of these beverages by 7%, while plain water intakes increased by 5% (2).

Fat Foods high in saturated fat, trans fat, and/or cholesterol should be minimized (8). Specifically, saturated fat should be reduced to less than 10% of kcalories by replacing it with monounsaturated or polyunsaturated fats, and oils should be used to replace solid fats. The trend toward healthier eating has even led to the World Health Organization recommending that governments consider taxes to promote healthy eating. A Danish saturated "fat tax" resulted in a 4% reduction in saturated fat intake (15).

Fat Sources The main sources of fat in the diet, according to the *Choose Your Foods* guide, are primarily animal foods such as whole milk (8 grams per cup), high-fat meat (8 grams per ounce), and fat itself (5 grams/teaspoon). Plant sources of fat include coconut, avocado, and vegetable oils. Saturated fat is derived primarily from animal sources—milk and meat food products. The only plant products high in saturated fat are coconut and oils derived from coconut or palm.

Cholesterol Although cholesterol is technically not a fat, the American Heart Association has concluded that there is not enough research evidence available to advise limiting dietary cholesterol for heart health (13). Sources high in dietary cholesterol include eggs (213 mg per large egg yolk), shrimp, caviar, and organ meats such as liver, heart, kidney, and sweetbreads (thymus or pancreas of a young animal, especially calf and lamb). (*Note:* Dietary cholesterol is different from blood cholesterol, which is measured in mg/dL. Only animal foods can contain cholesterol, which is made by a liver. Plants do not have livers, so even "oily" foods such as corn oil or peanut butter contain zero cholesterol.)

Protein Sources The primary sources of protein in the diet are milk/dairy foods (8 grams per cup), meat and meat substitutes (7 grams per ounce), and eggs (7 grams each). Small amounts of protein are available from starch (3 grams per serving) and vegetables (2 grams per serving). Little to no protein is found in fruits or fats.

Recommended Protein Intake The Institute of Medicine recommends a daily intake of 0.8 gram of protein per kilogram body weight (or 0.36 gram per pound) in healthy adults. In practical terms, that equals about 46 grams a day for women (19+ years) and 56 grams for men (19+ years) (8).

Micronutrients
Vitamins and minerals are obtained from various foods, with the most common sources (especially for vitamins A and C) being certain vegetables and fruits (Chapters 13 and 14). Approximately 80% of dietary calcium is derived from dairy ingredients (Chapter 10). Iron, zinc, and many B vitamins are found primarily in meats (Chapter 7).

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(labor cost). Thus, budget limitations help determine both the types and amounts of food to be purchased. Food and labor costs are primary concerns for any food-service manager who knows that the bottom line is of paramount importance (10).

Buyers

Larger food-service operations usually have a buyer, a purchasing department, or a cooperative arrangement with other institutions to purchase foods according to the **forecasted** menu requirements. The buyer or purchasing department determines food needs, selects vendors, bargains for price, and negotiates contracts.

Food-service purchasing may be formal or informal. Informal purchasing, or open-market buying, consists of ordering food supplies from vendors on a daily, weekly, or monthly basis. Formal purchasing, or competitive-bid buying, occurs when the buyer sends vendors an invitation to quote prices on a needed food item (13). **Specifications** describe in detail the food items to be purchased and may be developed by either the buyer or the seller (12). Deadlines are provided in formal purchasing, bids are submitted, and the lowest bid is awarded the purchasing contract.

Food Stores and Vendors/Suppliers

The cost of anything, including food, depends in part on where it is purchased. Understanding the differences among the types of retail and wholesale food supply sources allows buyers to select the sources that will give them the most for their money. The variety of food stores available to consumers includes supermarkets; warehouse stores, co-ops, farmers' markets, convenience stores, specialty stores, and health food stores. Food-service establishments rely on large food distribution centers to obtain their supplies.

Forecast The amount of food that a food-service operation is predicted to require within a given time period.

Specifications Descriptive information used in food purchasing that defines the minimum and maximum levels of acceptable quality or quantity (i.e., U.S. grade, weight, size, and fresh or frozen).

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Supermarkets

A century or so ago, consumers went to the local grocery store, gave a storekeeper or clerk a list of what they wanted to purchase, and then waited while all the products on the list were collected for them. Although this was an accepted part of life in the community, it could be tedious and time-consuming, and it prevented customers from browsing and selecting items at their leisure.

In the early 1900s, large city grocery stores began allowing retailers of individual products to sell from booths inside the stores. This opened up the market for different kinds of foods, increased consumer choices, and made shopping faster and more convenient. Eventually, this arrangement developed into the modern supermarket, where the major departments include meats, produce, dairy, bakery, frozen, canned, and otherwise processed foods, as well as nonfood items such as cleaning, beauty, and even car care supplies.

Warehouse Stores

Warehouse stores, another popular avenue for purchasing food, are less expensive than supermarkets because they offer the basic foods with little glitz. Food is often found on the shelves in the original shipping containers, and shoppers may find themselves bagging their own purchases.

Co-ops

The food cooperative (co-op) is a membership arrangement that cuts out the middle retail level by purchasing foods in bulk at wholesale prices to sell to members and, in some instances, the public. Any profits are divided among the co-op members. Some co-ops expect the members to put in several hours per week helping with the operation of the co-op, whereas others hire the necessary help.

Smaller Outlets

The smaller food outlets include convenience stores, specialty stores, health food stores, and farmers' markets. Convenience stores are a mini version of the supermarket. Specialty stores include bakeries, delicatessens, butcher shops, and ethnic food, cookie, candy, and ice cream stores. Although specialty stores are usually more expensive, they offer unique items that may not be found at the supermarket. Health or natural food stores offer a wide selection of foods, many of which have been produced without chemical pesticides, herbicides, fertilizers, hormones, or antibiotics. Finally, farmers' markets and roadside stands offer fresh produce straight from the growers' fields.

Food-Service Vendors

Food-service distribution centers and vendors supply the food for food-service establishments. These large food warehouses obtain food directly from the food companies and deliver it to various private and public food-service organizations. Vendors, the purveyors or food suppliers, usually specialize in a given product or category of products, such as produce, meat, or dairy.

Cost Control

Although the budget is certainly not the only consideration in making a purchase, it is a vital factor, and there are several methods for keeping food costs down.

Meats

The biggest expense in the food budget is meat. A money-saving and nutrition-conscious step would be to reduce daily meat intake to no more than 5 ounces per person. The less tender cuts of meat are just as nutritious, often less fatty, and less expensive than the tender cuts. In addition, it is generally more economical to buy a large piece of meat and cut it up than it is to buy meat already cut up.

Many nonmeat substitutes are available to provide inexpensive protein options. Some examples include a grain called quinoa (pronounced "keen-wah") and legumes such as dried beans (including soybeans and the tofu made from them), peas, and lentils. These foods are high in complex carbohydrates and fiber, and the best sources of plant protein. Eggs are another nutritious and inexpensive protein source.

Fish

Frozen or canned fish is often less expensive than fresh fish. Lobster, crab, and jumbo shrimp are usually more costly than other protein sources.

Dairy

The least expensive form of milk is nonfat dried milk. If the taste and texture are unacceptable, it can be mixed with fluid milk, or a teaspoon of vanilla flavoring can be added for each gallon of reconstituted nonfat dried milk. Cheese varies widely in cost, with presliced or shredded cheeses tending to be more expensive than those sold in block form.

Bread/Grains

Creating a diet based on pasta and grains subjects the budget to automatic belt-tightening. The more processing that is involved in a product, the higher the cost will be. A wide variety of grains are sold in bulk at very reasonable prices.

Fruits and Vegetables

Seasonal availability, brand, grade, and added ingredients all factor into the equation when comparing the price of fresh, dried, canned, or frozen fruits and vegetables.

Price Comparisons

A price comparison is accomplished by calculating the cost per serving for each option. This is easily done when the price per unit (ounce, pound, count, etc.) is given by the supplier. It pays to check this price and not be deceived by a product's packaging, shape, or size.

Prices differ not only among brands but also among forms—fresh, dried, canned, or frozen. Convenience foods are almost guaranteed to be more costly, as shown in Figure 6-8.

FIGURE 6-8 Price comparison.



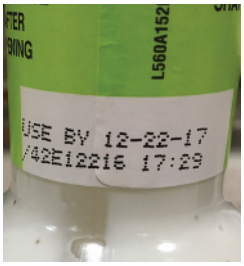
Instant oatmeal: .40 per oz
Old Fashioned Oatmeal: .17 per oz

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FIGURE 6-9 Dates on labels and what they mean.



Use By or Best By Freshness or quality assurance date—The last day the product will be of optimum quality. It is not a safety date.



Sell By Date (Pull date)—The suggested date for retailers to remove the product from the shelf. It is not a safety date. The last day a store will sell an item, even though the food may be safe for consumption for a little while longer. Dairy and other perishable and semi-perishable items have a pull date that indicates the last day a store should sell the item. Such items are often priced very low and are a good buy if used within a short period of time.



Expiration date—The last day a food should be consumed. Certain products that will "expire," such as baking powders, yeast packages, and refrigerated doughs, need to show expiration dates to let consumers know whether they are still capable of making baked products rise.



Pack date—The date the food was packed at the processing plant. Canned, bottled, or frozen goods have pack dates that inform consumers how old the food is when purchased. It is often used by stores, which need to know when to rotate stock.

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Reading Label Product Codes

Familiarity with the various types of dating on some packaged items helps consumers select the freshest available products (Figure 6-9). Code dates (not shown) are useful in the event of a recall because they identify the manufacturer and/or packer of the food. With the exception of infant formula and baby food, the FDA does not require food companies to date their food products.

Reducing Waste Saves Costs

Careful purchasing avoids waste that can commonly occur in the following areas (1):

- Overpurchasing perishable produce or other foods. Fresh produce losses can be avoided by following the "3-Day Rule": never buy more than what can be consumed in 3 days.
- Losses resulting from food preparation (peeling, coring, trimming of fat, deboning).
- Losses from shrinkage during cooking.
- Losses from *plate waste,* that is, food left on the plate because of too-large portion sizes or poor food quality.

As Purchased vs. Edible Portion

There can be a great disparity between the amount of food purchased and what ends up on the table. These different quantities are termed **as purchased (AP)** and **edible portion (EP).** Extra quantities of food must sometimes be purchased to make up for losses incurred during preparation, especially when buying meats, fruits, and vegetables.

Percentage Yield

The **percentage yield** gives an estimate of how much edible food will remain after peeling, trimming, and, sometimes, cooking (Table 6-2). To calculate how much food to purchase using the percentage yield, follow these steps:

1. Determine the edible portion by multiplying the number of servings by the serving size.
2. Determine the amount to purchase by dividing the edible portion by the percentage yield for that particular food (Table 6-2).

For example, a meal of boneless, skinless chicken breasts for five people, each having a 3-ounce serving, calls for a total edible portion of 15 ounces (step 1). The percentage yield for chicken breast with ribs and skin is 66%, so 15 ounces divided by 0.66 results in 22.7, or approximately 23 ounces (step 2). Thus, for each guest to receive 3 ounces of edible chicken breast, a total of 23 ounces of chicken breast with ribs and skin will need to be purchased.

Portion Control

One of the most important aspects of controlling the food budget of a food-service organization is portion control. Because food cost is a major expense, it is crucial to adhere to set serving sizes. If 300 people are served 4 ounces of roast beef instead of the planned 3 ounces, this results in the consumption of almost 19 pounds of roast beef beyond what was calculated into the budget. It may also leave customer number 301 without any meat and dissatisfied.

Portions may be measured in three ways:

1. By weight (ounce, pound) or volume (cup, pint)
2. By number (five olives, one ear of corn, two dinner rolls)
3. By size (1.8-inch slice of cake, 2-by-2-inch brownie)

Careless measuring is ultimately reflected in the final yield of the food for the diner and the cost to the establishment. Portion guides are

As purchased (AP) Refers to the total amount of food purchased prior to any preparation.

Edible portion (EP) Food in its raw state, minus that which is discarded—bones, fat, skin, and/or seeds.

Percentage yield The ratio of edible food to food as purchased. Edible food = food as purchased minus losses due to waste, inedible portions, and/or cooking (if applicable).

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TABLE 6-2 Percentage Yield: Approximate Edible Portion (EP) Yield per Pound of Selected Foods As Purchased (AP)

Food Items	% Yield Pounds of EP
Meat, Poultry, Fish (Cooked)	
Beef, ground (no more than 30% fat)	40
Beef, chuck roast (boneless)	60
Beef, round (boneless)*	60
Beef, stew meat*	55
Lamb, leg (boneless)*	60
Lamb, stew*	65
Pork, loin chops*	40
Pork, loin roast (boneless)*	55
Pork, spareribs	45
Ham (boneless)*	65
Chicken, breast (rib and skin)	66
Chicken, drumstick (skin)	50
Turkey, whole (skin)	55
Turkey, frozen rolls	65
Fish, frozen portions (raw breaded)†	60
Fish, frozen sticks (raw breaded)†	60
Fruits (Raw)	
Apples	75
Apricots	94
Avocados	75
Berries	95
Bananas, with peel	65
Cantaloupe	50
Coconut	50
Grapefruit	50
Grapes	90
Kiwi	80
Lemons	45
Mangoes	75
Oranges	65
Papayas	65
Peaches	75
Pears, pared	80
Pineapple	55
Plums	95
Watermelon	55
Vegetables (Cooked)	
Beans, green	88
Carrots	60
Corn on the cob	55
Potato, baked with skin	80
Sweet potato, baked with skin	60
Vegetables (Raw)	
Asparagus	55
Beets	45
Broccoli	80
Cabbage	90
Carrots	70
Cauliflower	55
Celery	75
Leeks	50
Lettuce, head	75
Mushrooms	95
Onions	90
Parsley	85
Peppers	82
Radishes	90
Spinach	80
Squash (summer)	90
Squash (winter)	75
Tomato	99
Turnips	80

*Lean meat

†75% fish

available to help keep food costs under control (Table 6-3).

TIME MANAGEMENT

Quality meals rely on timing. Food is usually best when it is prepared as soon as possible after purchase and served immediately after preparation. Different foods are prepared at different rates, so coordination is key to an organization's capability to provide timely meal service.

Estimating Time

The preparer gains control by beginning with a realistic assessment of available time and energy. The stress of planning a meal can be minimized by logging how long it will take for each menu item to be prepared, estimating the time at which the meal will be served, and working backward to determine at what time the preparation should be started in order to serve the meal on time. Meal items are usually prepared in descending order of time required.

How & Why?

How many pounds of carrots should you buy if you need 4 ounces per serving of carrot salad for 50 people?

First, multiply 4 ounces per serving by 50 servings, for a total of 200 ounces. You know that carrots are sold by the pound, so you have to convert ounces to pounds. Divide the 200 ounces by 16 ounces per pound to get 12.5 pounds. However, 12.5 pounds of carrots would not be enough because Table 6-2 shows that the percent yield for raw carrots is 70%. This means that you have to divide 12.5 pounds of carrots by 0.70 to obtain the amount you need to buy, which is 17.86 pounds. A buyer would probably round that off to a 20-pound purchase of carrots because vendors often do not sell by the half pound or even under 5- or 10-pound increments.

Efficient Meal Preparation

Effective management of time can improve the efficiency of all the steps of meal preparation, which include the following:

1. Planning the menu
2. Developing a purchase list
3. Purchasing the food
4. Storing the food
5. Planning the order in which the menu items will be prepared
6. Preparing the food
7. Preparing the table
8. Serving
9. Cleaning up

The preparer can increase efficiency through menu planning and wise purchasing, as described previously, as well as through recipe consultation.

Recipes

There are four styles (or forms) of recipe writing: descriptive, standard, action, and narrative (Figure 6-10). In the descriptive method, the ingredients are listed in the sequence in which they are used. A *descriptive* recipe displays the ingredients, amounts, and directions

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TABLE 6-3 Portion Guide: Common Food Service Serving Sizes*

Breakfast		
Eggs	2–4 oz (1–2 eggs)	50–125 g
Meat	2–4 oz	50–125 g
Fruit	½ C	125 mL
Cereal	¾ C	175 mL
Juice	½–¾ C	125–175 mL
Bread	1–2 slices (1–2 oz)	30–60 g
Lunch		
Soup	4–6 oz	125–175 mL
Salad	4–8 oz	125–250 g
Salad dressing	1–2 oz	25–50 mL
Main dish	4–6 oz	125–175 g
Starch	2–3 oz	50–100 g
Vegetable	2–3 oz	50–100 g
Sauce	1–2 oz	25–50 mL
Bread	1–2 oz	30–60 g
Dessert	2–4 oz	50–125 g
Dinner		
Soup	6–8 oz	175–250 mL
Salad	4–8 oz	125–250 g
Salad dressing	1–2 oz	25–50 mL
Main dish	6–8 oz	175–250 g
Sauce	1–2 oz	25–50 mL
Starch	2–3 oz	50–75 g
Vegetable	2–3 oz	50–75 g
Bread	1–2 oz	30–60 g
Dessert	2–4 oz	50–125 g

Hors d'ouevres and Canapes†	
Lunch, with meal	2–4 per person
Lunchtime, without meal	4–6 per person
Dinner, with meal	4–6 per person
Before-dinner reception	6–8 per person
After-dinner reception	4–6 per person

*Quantities given reflect general practice. Specific needs will vary.

†Average size is 1 oz (30 g). Total number reflects combined hot and cold items.

Source: Based on Mizer DA, M Porter, B Sonnier, and KE Drummond. *Food Preparation for the Professional*, 3rd ed. Wiley, New York, 1999.

in three columns, which makes it easy to read. The *standard* recipe style lists all ingredients and amounts with the instructions in numerical order. A modification of that form is the *action* recipe, which gives the instruction followed by the ingredients for that step only. Probably the most tedious to decipher is the *narrative* form, which reads like an essay, explaining ingredients, amounts, and preparation methods in text form.

Food-service establishments rely on **standardized recipes** for serving a large number of people (48 to 500 servings) that are repeatedly tested and adapted to suit a particular food-service operation. Standardized recipes, which frequently follow the descriptive style, record ingredients, proportions, and procedures so the number of servings can easily be increased or decreased. When standardized recipes are stored in a computer, changing the number of servings automatically changes the amount of each ingredient needed.

TYPES OF MEAL SERVICE

There are six basic types of meal service in North America. In descending order of formality they are Russian, French, English, American, family, and buffet. Not only do the table settings for each differ, but the manner in which the food and beverages are placed on and removed from the table differs as well (9). No matter which type of service is employed, dessert is served only after the table has been cleared of all extraneous items, including salt and pepper shakers, all condiments, and unnecessary flatware.

Russian Service

The most formal type of meal service is Russian, also known as European, Continental, or formal service. The entire meal is served by well-trained waiters. Normally, the waitstaff serves and clears food items from the left with the left hand, whereas beverages are always served and removed from the right. The guest to the right, or the host or hostess, is served first, with the rest of the diners being served in a counterclockwise direction. Service plates, or place plates, sometimes made of or embossed with silver or gold, are part of each place setting and serve as underliners; the food is never placed directly on them.

The meal is served in courses, starting with the appetizer and then the soup. Each of these courses has its own underliner plates, which go on top of the place plates. A fish course may follow the soup. Prior to the introduction of the main entrée, a miniature serving of chilled sorbet is provided to clear the taste buds of any lingering flavors. The place plate is then removed, and the main entrée is served from a platter or on plates placed before guests. Salad is served and consumed before or after the main entrée has been removed. After the diners have finished their salads, the waiters remove all flatware, tableware, glassware, and condiments, and then finish clearing the table with a procedure known as **crumbing.** Filling all glasses and/or coffee cups or teacups before serving dessert is a common policy, regardless of the type of meal service. After the dessert is finished and removed, a finger bowl containing cool water and, usually, a lemon slice is

Standardized recipe A food-service recipe; that is, a set of instructions describing how a particular dish is prepared by a specific establishment. It ensures consistent food quality and quantity, the latter of which provides portion/cost control.

Crumbing A ceremonious procedure of Russian service in which a waiter, using a napkin or silver crumber, brushes crumbs off the tablecloth into a small container resembling a tiny dustpan.

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FIGURE 6-10 The four different styles of recipes: descriptive, standard, action, and narrative.

DESCRIPTIVE

Texas Chocolate Cake

Desserts: C-33
Portion: 16 servings
Oven Temperature: 350°F
Time: 20 minutes

Ingredients	Amount	Procedure
All-purpose flour Sugar	1 C 1 C	Sift flour and sugar together into large mixing bowl.
Water Margarine Cocoa	1 C 2 sticks 4 Tbsp	Melt margarine in sauce pan and add water and cocoa. Bring it to a boil while stirring constantly. Take off heat and pour into flour/sugar mixture.
Eggs Sour milk* Baking soda Cinnamon Vanilla	2 ½ C 1 tsp 1 tsp 1 tsp	In a separate bowl, beat eggs slightly and add to milk, baking soda, and flavorings. Add gradually to creamed mixture and mix with spoon until just blended smooth. Pour batter into a 13 × 9 greased baking pan. Immediately place on center rack of preheated oven. Bake until toothpick comes out clean. Cool briefly in pan on rack.

*or ½ C milk + 1 Tbsp lemon juice or vinegar

ACTION

Texas Chocolate Cake

Preheat oven to 350°F and grease sides and bottom of 13 × 9 pan.

Sift together flour and sugar into large mixing bowl.
1 C All-purpose flour
1 C Sugar

Melt margarine in sauce pan and add water and cocoa. Bring it to a boil while stirring constantly. Take off heat and pour into flour/sugar mixture.
2 Sticks Margarine
1 C Water
4 Tbsp Cocoa

In a separate bowl, blend ingredients below, add gradually to creamed mixture, and mix with spoon until just blended smooth.
2 Eggs (slightly beaten)
½ C Sour milk
or ½ C milk + 1 Tbsp lemon juice or vinegar
1 tsp Baking soda
1 tsp Cinnamon
1 tsp Vanilla

Pour batter into greased baking pan. Immediately place on center rack of preheated 350°F oven. Bake until toothpick comes out clean. Cool briefly in pan on rack.

STANDARD

Texas Chocolate Cake

Preparation Time: 15 minutes
Cooking Time: 20 minutes
Yield: 16 servings

Ingredients:
1 C All-purpose flour
1 C Sugar
1 C Water
2 Sticks margarine
4 Tbsp Cocoa
2 Eggs
½ C Sour milk
or ½ milk + 1 Tbsp lemon juice or vinegar
1 tsp Baking soda
1 tsp Cinnamon
1 tsp Vanilla

Directions:
(1) Preheat oven to 350°F and grease sides and bottom of 13 × 9 pan.
(2) Sift together flour and sugar into large mixing bowl.
(3) Melt margarine in sauce pan and add water and cocoa. Bring it to a boil while stirring constantly. Take off heat and pour into flour/sugar mixture.
(4) In a separate bowl, beat eggs slightly and add to milk, baking soda, and flavorings. Add gradually to creamed mixture with spoon until just blended smooth.
(5) Pour batter into greased baking pan. Immediately place on center rack of preheated oven.
(6) Bake until toothpick comes out clean. Cool briefly in pan on rack.

NARRATIVE

Texas Chocolate Cake

Cake. Preheat oven to 350°F and grease sides/bottom of 13 × 9 pan. Sift together 1 C all-purpose flour and 1 C sugar into large mixing bowl. Melt 2 sticks of margarine in sauce pan and add 1 C water and 4 Tbsp cocoa. Bring to boil, stir stirring constantly, and pour liquid over the flour/sugar mixture. In a separate bowl, blend together 2 eggs (slightly beaten), ½ C sour milk (or ½ C milk + 1 Tbsp lemon juice or vinegar), 1 tsp baking soda (more soda results in a more cake-like cake, less produces a more brownie-like product), 1 tsp cinnamon, and 1 tsp vanilla. Add this gradually to the creamed mixture and mix with spoon until just blended smooth. Pour batter into greased baking pan. Immediately place on center rack of preheated oven and bake for 20 minutes or until toothpick comes out clean. Cool briefly in pan on rack.

Icing. Bring to boil ½ C margarine and 4 Tbsp cocoa. Stir constantly until mixed and remove from heat. Pour into mixing bowl and add 1 box of powdered sugar; blend with mixer on medium speed. If not blending smoothly, then add 1 Tbsp of milk at a time until it does. Too much milk makes runny icing, which is corrected by adding more powdered sugar. Cakes are usually cooled completely on racks before frosting; however, frosting only 5–10 minutes later makes the cake more moist. Covering the sheet pan with aluminum foil further traps in moisture.

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provided to each guest. The fingertips only are dipped into the water and dried on a napkin.

French Service

Another very formal type of meal service is French, or cart, service. The food is brought out on a cart (*guerdon*) to the table, where it is cooked or has its cooking completed in a small heater (*rechaud*) by the *chef de rang* (chief or experienced waiter) and *commis de rang* (assistant waiter). The French method is expensive, requires skilled personnel, and results in slower service. It tends to be reserved for elegant French restaurants or those found in Europe.

English Service

In English service, waiters bring in the various courses, clear the table at the appropriate times, and may take servings dished out by the host and hostess to the individual guests. Frequently, when it is a family or small gathering, the host serves the meat to the guests, who pass their warmed plates to the hostess, who serves the vegetables. The necessary maneuvering of dishes between host or hostess and guests makes this type of service appropriate for no more than about six or eight people.

American Service

American service is that in which the meal is placed on the plates in the kitchen and then brought out to the table. This type of service is useful in smaller spaces, allowing for faster service, hotter food, and fewer dishes to wash.

Family Service

Family service allows the guests to serve themselves from serving platters and bowls brought to the table and passed counterclockwise among the diners. The main meal-serving dishes, condiment containers, and all accompanying flatware, dinnerware, and glassware are removed after completion of the main entrée. Dessert is served at the table by the hostess or brought to the table in individual portions.

Buffet Service

The buffet service allows guests to walk to a separate buffet table, from which they serve themselves. If the group of people is large, it is preferable to set the table up in such a way that guests can pass down both sides simultaneously. To avoid "the line," people can be divided alphabetically (A–O, P–Z) or by any other method and sent to the buffet in 10-minute intervals.

The sequence of items on a buffet table varies considerably, but it usually starts with the plates and is followed by the vegetables, salad, bread, main entrée, condiments, beverages, flatware, and napkins. Hot items are usually kept warm in a chafing dish with a burner underneath, whereas chilled foods are placed on a bed of ice.

TABLE SETTINGS

A well-prepared meal deserves to be enhanced by aesthetically pleasing table settings and surroundings. This section focuses on the correct presentation of the cover and linens, flatware, dinnerware, glassware, and accessories.

Cover and Linens

The table arrangement focuses on a **cover,** or table setting, for each individual. Each place setting should occupy from 20 to 24 inches to give diners elbow room. The table linen can be a tablecloth, place mats, or a combination of the two, along with a napkin. For formal service, the most common choice is a white damask cloth with a felt cloth or other **silence cloth** placed underneath.

When a tablecloth is used, it should be centered on the table with an 8- to 12-inch overhang. Most people do not like to sit at a table at which the tablecloth is any longer than lap length. Place mats, either alone or in addition to a tablecloth, are arranged so that each table setting is clearly distanced from the one(s) next to it. The napkin is placed to the left of the fork with the open edge facing the plate and its open corner at its own lower left. This makes it easy to grasp with the fingers of the right hand so it can be brought across the lap with a single motion. For formal service, the napkins are often folded attractively and placed in the center of the service plate or in the glassware. Napkins may be of linen or paper and vary in size—large for dinner, medium for lunch, and small for tea or cocktails. Paper napkins are acceptable for most meals, but linen or other cloth napkins are preferred for more formal occasions.

Flatware/ Dinnerware/ Glassware

By convention, **flatware** pieces are assigned specific positions within the table setting, depending on the type of meal being served. A standard placement of flatware is shown in Figure 6-11, but most everyday and restaurant meals do not include two sets of forks, knives, and spoons. Most restaurants position their flatware according to the general rules shown in Figure 6-11, but creativity or necessity can influence the final arrangement.

Convention also dictates the general arrangement of plates, saucers, bowls, and other dinnerware, as shown in Figure 6-12. Dinnerware does not have to match, but patterns should harmonize. It should also be in balance with the position of the glassware.

Accessories

Accessory items that can be distributed attractively on the table include the salt and pepper shakers, sugar bowl with spoon, cream pitcher, butter dish with butter knife, bread baskets, any

Cover The table setting, including the place mat, flatware, dishes, and glasses.

Silence cloth A piece of fabric placed between the table and the tablecloth to protect the table, quiet the placement of dishes and utensils, and keep the tablecloth from slipping.

Flatware Eating and serving utensils (e.g., knives, forks, and spoons).

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FIGURE 6-11 Standard placement of flatware at the start of service.

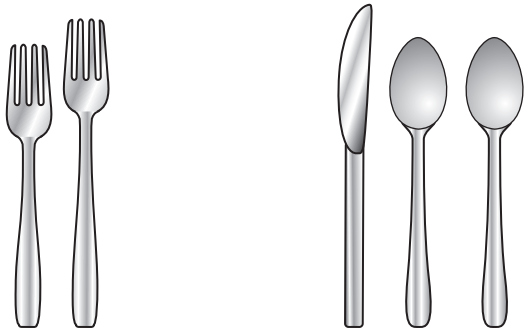
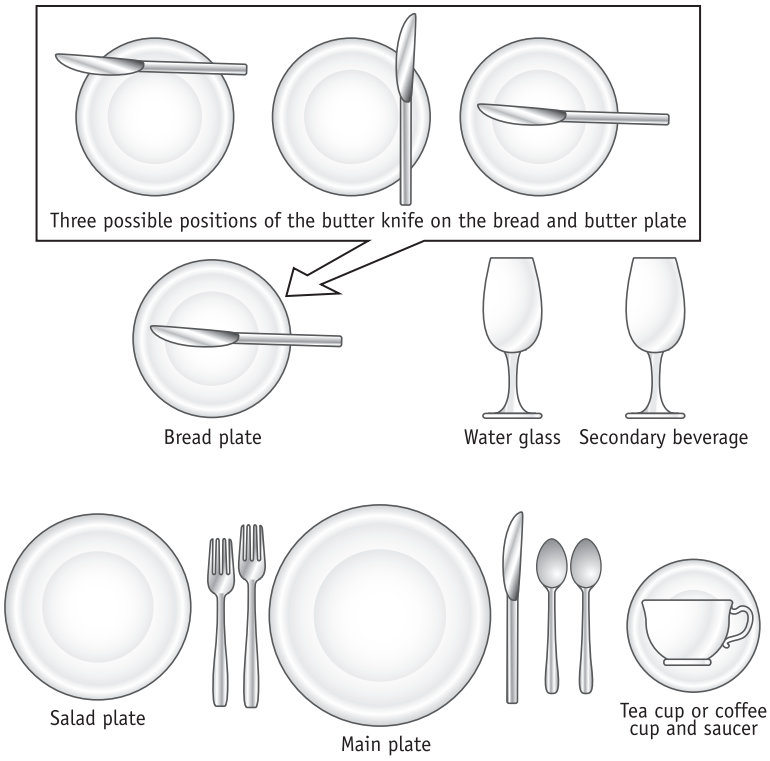


FIGURE 6-12 Standard placement of dinnerware and glassware.



decorations, and condiments removed from their containers and displayed in attractive serving dishes. Items with the potential to drip are always placed on underliners. Saltshakers and pepper shakers are usually placed near the center of the table, with the salt placed to the right of the pepper. Individual containers of salt and pepper are placed just above or slightly to the left of each cover. Depending on the type of service, serving dishes and serving utensils may or may not be placed on the table.

Centerpieces

Simple elegance is the goal in choosing centerpieces and other table decorations. Centerpieces should match the table in scale, should not be overpowering, and should allow guests to see each other across the table. Candle flames should be kept below eye level so that diners need not bend right or left to talk to someone across the table. Many a host or hostess failing to observe these guidelines ends up removing a centerpiece after guests are seated.

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PICTORIAL SUMMARY / 6: Meal Management

Planning meals that are both psychologically and physiologically satisfying requires a basic knowledge of food preparation, nutrition, and presentation strategies. Effective meal management, whether for a household, an institution, or a restaurant, involves efficient management of resources such as money, time, and energy.

FOOD-SERVICE ORGANIZATION

Food-service management must set goals, determine what is needed to achieve them, and mobilize people toward these goals. Division of labor is central to good organization. *Brigade de cuisine* is a system of dividing a kitchen into stations supervised by chefs with expertise in specific areas:

- Sauce
- Fish
- Vegetable
- Soup
- Roast
- Pantry
- Pastry
- Relief



MEAL PLANNING

Planning menus and setting up cycle menus helps control costs as well as balance nutrition. Some points to consider:

- Kilocalorie and nutrient recommendations, including correct serving sizes
- Individual preferences and needs based on age and religious, cultural, ethnic, and regional differences
- **Costs:** Planning nutritious, flavorful, and appealing meals within the available budget.
- **Food-preparation methods:** Alternating oven-baked, boiled, and fried foods for optimal nutrition and to avoid monotony.
- **Seasonal factors:** Availability of fresh food products, method of preparation, and temperature at which food is served.

PURCHASING

Budget limitations determine both the types of food to be purchased and the amounts. Careful control of foods and labor costs is critical in food-service establishments, and waste must be avoided. Food bills can be reduced through organized purchasing, comparison pricing, and portion control.



TIME MANAGEMENT

Food is usually best when it is prepared as soon as possible after purchase and served immediately after preparation.

Coordinating the preparation of different foods to be served at the same time is crucial, but equally important is an awareness of the time involved in menu planning, purchasing, preparing the table, serving, and cleaning up.

Efficiency is increased with careful menu planning and recipe consultation.



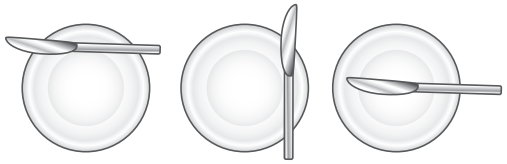
TYPES OF MEAL SERVICE

The six basic types of meal service differ in the manner in which the table is set and the food served. They include the following, in descending order of formality:

- **Russian:** Most formal; entire meal is served by waiters.
- **French:** Food is served and/or prepared from a cart brought to the table by specially trained chefs/staff.
- **English:** Host participates in serving guests; waiters assist.
- **American:** Served on plates in kitchen and brought to table.
- **Family:** Guests serve themselves from platters brought to table and passed counterclockwise among the diners.
- **Buffet:** Guests serve themselves from a central buffet table.

TABLE SETTINGS

A cover or place setting should be laid for each individual. There are specific customs for the placement of linens (tablecloth and/or place mat, napkin), flatware, dinnerware, glassware, and accessories such as decorations and condiments.





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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Both 1 ounce of meat and one egg contain about _____ grams of protein.
   a. 3
   b. 5
   c. 7
   d. 9

2. What is the number one position in a commercial food-service organization?
   a. Executive chef
   b. Production manager
   c. Chef garde manger
   d. Sous-chef

3. AP stands for _____, and EP stands for _____.
   a. as planned, eating plan
   b. amount purchased, edible product
   c. as purchased, edible portion
   d. as planned, eating production

4. The last day a food product will be of optimal quality is referred to as the _____.
   a. freshness/quality assurance date
   b. pull date
   c. expiration date
   d. code date

5. The table setting, including the place mat, flatware, dishes, and glasses, is referred to as the _____.
   a. placement
   b. coding
   c. coverage
   d. cover

6. The second-highest chef position in the kitchen after the executive chef is the _____ chef.
   a. sauce
   b. pantry
   c. pastry
   d. *sous*

7. Which of the following basic types of meal service is the most formal?
   a. French
   b. Russian
   c. Family
   d. American

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe the *Choose Your Foods: Food Lists for Diabetes* guide, and list how many grams of carbohydrate, fat, and protein are in each Food List. Include the primary food sources for carbohydrate, protein, and fat.
2. Explain the basic serving sizes for and kcalories provided by each Food List and why it is easy to exceed recommended energy intakes.
3. Discuss the difference between AP and EP.
4. How many ounces of roast beef do you need to purchase if the roast weighs 5 pounds, the percentage yield is 60%, there are 100 people to serve, and the portion size is 3 ounces?
5. Define each of the following label dates: freshness/quality assurance date, pull date, expiration date, pack date, and code date.
6. Define what standardized recipes are, and explain their function.
7. Briefly outline the *brigade de cuisine* organization of commercial kitchens.
8. Diagram and label a standard lunch cover, including flatware, dinnerware, and glassware.
9. Diagram three positions for the butter knife on the bread and butter plate.
10. Briefly describe the most formal type of meal service and how food is served in French service.

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7



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Meat

Types of Meats 131
Composition of Meats . . 132
Purchasing Meats 137
Preparation of Meats . . . 153
Storage of Meats 159

In North America and Europe, meat from herbivores such as beef cattle, sheep, and swine serves as an important source of complete protein. Meat from other animals, such as goat, rabbit, deer, elk, moose, horse, possum, and squirrel, is less commonly eaten. Sources of meat in other countries include the llama in Peru, the kangaroo in Australia, and the dog in some parts of Asia. This chapter addresses only the meat from cattle, sheep, and swine.

The focus of this chapter is to briefly describe these different types of meat (beef, lamb, mutton, and pork); their composition (muscle, connective, and fatty tissues; bone; pigments; and extractives); the various considerations involved in purchasing meat (inspection, grading, tenderness, fresh cuts, and processed meats); their preparation (heating changes, determining doneness, dry and moist preparation, carving); and their storage.

How & Why?

Why are poultry and fish not considered "meat"?

Meat is generally defined as the muscles of mammals but is used more broadly to include their organs and glands as well. The word *meat* technically excludes the flesh of nonmammals such as poultry and fish, so these foods are not referred to as "meat" in this book and are covered separately in the next two chapters.

TYPES OF MEATS

Beef

The ancestor of beef cattle was a type of wild ox domesticated in ancient Greece and Turkey during the Stone Age (around 10,000 BC). Since that time, hundreds of breeding lines have been specially developed to provide cattle that serve as abundant sources of good quality beef. Beef originates from cattle that are classified according to age and sex:

- ***Steers.*** Male cattle that are castrated while young so that they will gain weight quickly.
- ***Bulls.*** Consumers are rarely offered the tougher meat from bulls. These older uncastrated males that provide *stag meat* are usually used for breeding and then later for processed meats and pet foods.
- ***Heifers and cows.*** Heifers, females that have not borne a calf, are also used for meat. The meat from cows,

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female cattle that have borne calves, is less desirable than that from steers or heifers.

- ***Calves.*** Calves 3 to 8 months old are too old for veal and too young for beef. If they go to market between 8 and 12 months, their meat is referred to as *baby beef*.

Veal

Veal comes from the young calves of beef cattle, either male or female, between the ages of 3 weeks and 3 months. These very young animals are fed a milk-based diet or formula and have their movements greatly restricted, resulting in meat with an exceptionally milky flavor, pale color, and tender texture. Some retailers have stopped selling veal, however, because of possible consumer objections over what is perceived as the inhumane treatment of these animals. The meat from calves allowed to roam in a pasture is called *free-range veal* and it is slightly less tender than traditionally fed veal. Chop and roast cuts are derived from the rib and loin sections of the calf. Roasts come from the hind legs. Cuts from the neck, shoulder, breast, chuck, and shanks are less tender and may require moist-heat preparation.

Lamb and Mutton

Lamb and mutton are the meat of sheep. The primary difference between the two is the age of the animal from which they come: in general, lamb comes from sheep less than 14 months old and mutton from those over 14 months. One can confirm whether one is dealing with lamb or mutton by checking the position where the lower leg of a carcass will snap. Lamb breaks off above the joint, whereas mutton will break in the joint. Mutton is also darker and tougher than lamb and has a stronger flavor, which grows even more pronounced as the animal matures.

Pork

Most pork is derived from young swine of either sex, slaughtered at between 5½ and 7 months of age. Technically, pigs are less than 4 months old, whereas hogs are older than 4 months, although the terms are often used interchangeably. In recent times, pork has been bred to be leaner and more tender. About one third of all pork is sold fresh, whereas the rest is cured and provided to consumers as ham, sausage, luncheon meats, and bacon. Salt pork and fat back are cuts of fatty tissue from pigs that are used as flavoring agents, for example, in Boston baked beans or to wrap cuts of meat prior to cooking.

COMPOSITION OF MEATS

Structure of Meat

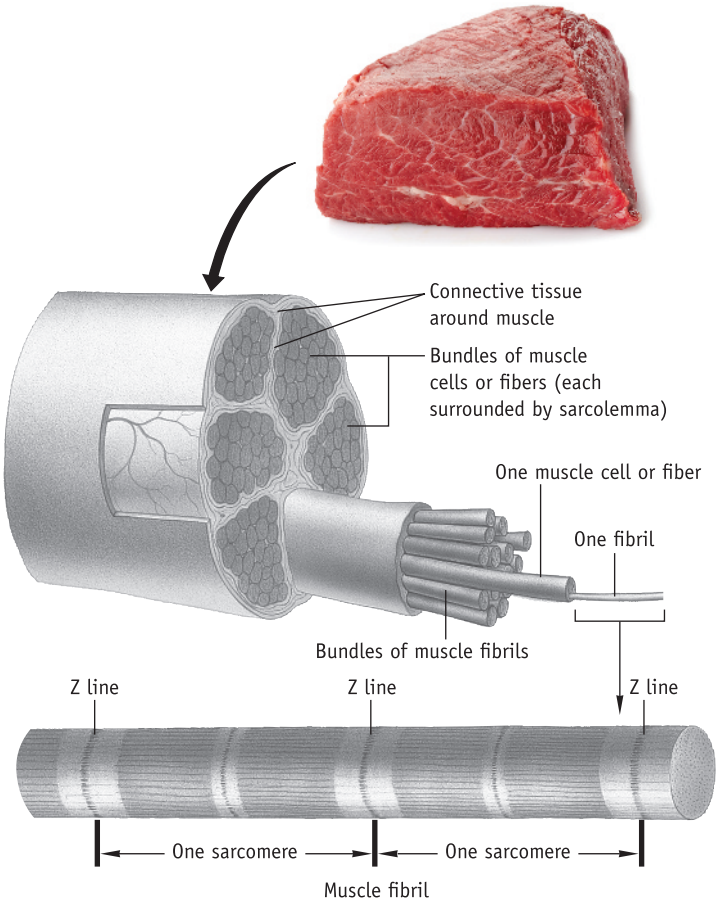
Meats are composed of a combination of water, muscle, connective tissue, adipose (fatty) tissue, and often bone. The proportions of these elements vary according to the animal and the part of its anatomy represented by the cut of meat.

Muscle Tissue

Most of the protein in animals is found in their muscles, which serve as the main sources of dietary meat. The characteristics of muscles are an important consideration in deciding how a cut of meat should be prepared.

Muscles are made up of a collection of individual muscle cells, called "muscle fibers," that are each surrounded by an outer membrane called the sarcolemma (Figure 7-1). Each muscle fiber is in turn filled with cellular fluid (sarcoplasm) containing about 2,000 smaller muscle fibrils that serve as the contractile components of the muscle fiber. If the muscle fibrils are small, the result is finer muscle bundles, which give the meat a very delicate, velvety consistency.

FIGURE 7-1 Muscles are composed of bundles of muscle cells (fibers). Each of these muscle cells (fibers) is a bundle of fibrils. The individual fibrils are responsible for muscle contraction and relaxation.



Source: Adapted from Starr C. *Human Biology.* Wadsworth Publishing, Belmont, CA, 1997.

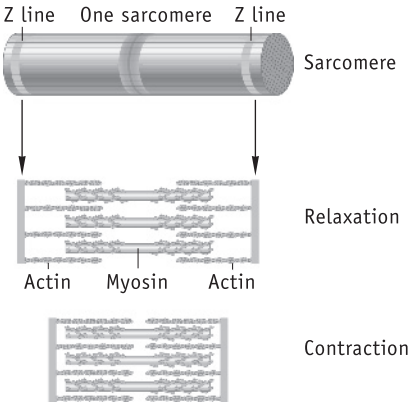
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FIGURE 7-2 Muscle contraction and relaxation. The sliding filament theory states that sarcomere units consist of two protein filaments, actin (thin) and myosin (thick), that interact with each other to form actinomyosin, which shortens (contracts) the sarcomere.



Muscle Contraction and Relaxation

Muscle fibrils play an important role in muscle contraction and relaxation. The muscle fibril is separated into segments called sarcomeres, which are bordered by dark bands called Z lines. The sarcomeres contain two proteins, actin (thin) and myosin (thick), that are alternately aligned. When muscle contraction occurs, actin and myosin react repeatedly at specific sites to form actomyosin cross-links, and the sarcomeres shorten (Figure 7-2). When the muscle relaxes, the actomyosin cross-links are broken, and the sarcomeres return to their original length. The energy for muscle contraction is provided by **Adenosine triphosphate (ATP)**.

Connective Tissue

Connective tissue is a part of ligaments and tendons, and it also acts as the "glue" that holds muscle cells together. It is composed primarily of a mixture of proteins and mucopolysaccharides (a type of polysaccharide). The most abundant protein in connective tissue is **collagen** (Chemist's Corner 7-1). It is tough and fibrous but converts to a gel when exposed to moist heat. The other two main types of connective-tissue proteins are elastin and reticulin. Elastin, as the name implies, has elastic qualities, and reticulin consists of very small fibers of connective tissue that form a delicate interlace around muscle cells. Reticulin fibers create a fine meshwork that supports in bone marrow, liver, and lymphatic system tissues.

How & Why?

How do muscles contract?

Within live muscle cells, nerve impulses initiate the complex sequence of events that results in muscle contraction. Calcium ions are released into the sarcoplasm surrounding the thin and thick filaments, and this allows exposure of "active sites" on the actin molecules. Actin then reacts with protruding "heads" on the myosin molecules (thick filaments), forming actomyosin cross-links. The myosin heads then contract, pulling the actin filaments toward the center of the sarcomeres. Then the actomyosin complex breaks, and the myosin heads form cross-links with different actin molecules. The cycle continues, resulting in overlap of the actin and myosin filaments and shortening of the sarcomeres (refer to Figure 7-2). When the nerve impulse ceases, calcium is pumped out of the sarcoplasm, the actomyosin cross-links are broken, the muscle relaxes, and the sarcomeres return to their original length.

Effect of Collagen on Tenderness

The type and amount of connective tissue found in a meat cut determines its tenderness or toughness and the best type of cooking method. Cuts high in connective tissue are naturally tough and need to be properly prepared using techniques that increase tenderness. Muscles used for movement, such as those found in the neck, shoulders, legs, and flank, contain more collagen and tend to be tougher than muscles from the loin, or lower back, and rib areas, which get less exercise.

Effect of Age on Tenderness

Collagen concentration also increases as animals age, which is why meat from older animals is tougher. These usually less expensive, tougher cuts require slow, moist heating at low temperatures to convert, or hydrolyze, the tough connective tissue to softer gelatin. Conversely, the tougher cuts have more flavor than the more tender ones.

Effect of Elastin on Tenderness

The other two components of connective tissue have less effect on meats when they are cooked. Elastin, which is yellowish, rubbery, and often referred to as *silver skin*, does not soften with heating, so it should be removed before preparation if possible. There is very little elastin in meats, except in cuts from the neck and shoulder, so it is less likely to affect tenderness.

Adipose (Fatty) Tissue

Adipose tissue is fat, which serves as insulation under the skin (subcutaneous) and as padding in the abdominal cavity for sensitive internal organs. When it appears on the outside of meat, this fat is known as cover fat.

Cover fat helps retain the moisture of meats, but this separable fat is often trimmed from meats prior to preparation. Fat found within muscles is called intramuscular fat or **marbling**. Fat content varies widely among meats and is dependent on the source animal's genetics, age, diet, and exercise, as well as the cut of the meat.

Well-marbled beef fetches a higher price, so many cattle ranchers, in an attempt to improve marbling, feed cattle richer grain during the last weeks or months before slaughter. Paradoxically, however, because of the recent consumer trend away from fatty meats,

Adenosine triphosphate (ATP) A universal energy compound in cells obtained from the metabolism of carbohydrate, fat, or protein. The energy of ATP, which is located in high-energy phosphate bonds, fuels chemical work at the cellular level.

Connective tissue A protein structure that surrounds living cells, giving them structure and adhesiveness within themselves and to adjacent tissues.

Collagen A pearly white, tough, and fibrous protein that provides support to muscle and prevents it from overstretching. It is the primary protein in connective tissue.

Marbling Fat deposited in the muscle that can be seen as little white streaks or drops.

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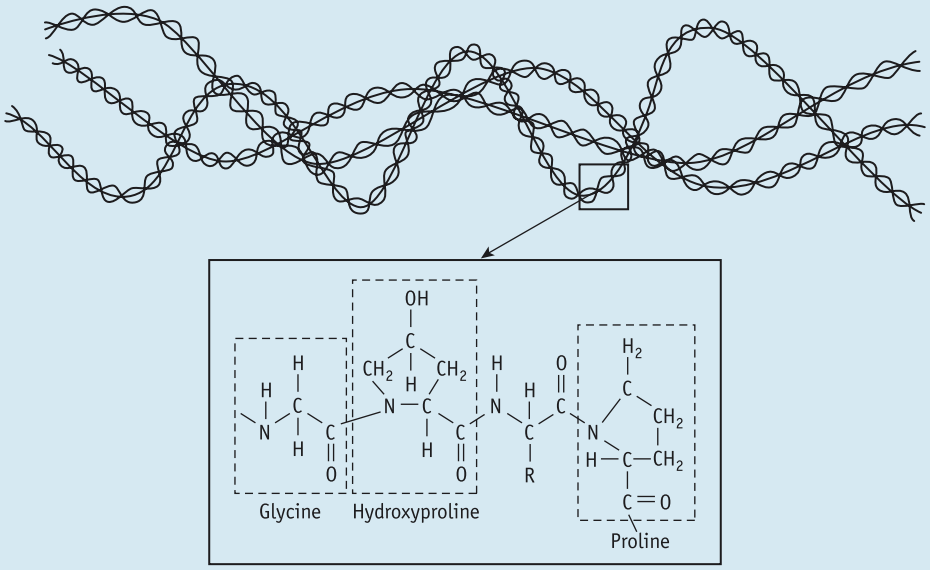
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CHEMIST'S CORNER 7-1

Collagen

Collagen's molecular structure consists of three polypeptide strands twisted together (Figure 7-3). These strands, rich in proline, hydroxyproline, and glycine, are held together by hydrogen and covalent bonds. Older meat is less tender for two reasons: the collagen content of meat increases with an animal's age, and more covalent cross-links are formed between the collagen strands (36).

FIGURE 7-3 Collagen molecule.



some ranchers are raising lower-fat beef to meet these consumer demands. Similarly, a recent technique in swine livestock management is the use of a growth hormone, somatotropin, which results in a leaner animal (35). Conversely, certain hormones (medroxyprogesterone acetate) are sometimes given to animals to speed up fattening (14).

Fat Color and Texture

The animal's age, diet, and species affect the color and texture of fat. It is white in younger animals, and turns progressively more yellow as the animals age due to the presence of carotenoid pigments in the feed. Feeding-lot practices that provide swine with fats that are primarily saturated will yield pork fat that is more saturated and hard (Figure 7-4). Conversely, including more polyunsaturated fatty acids in the animal's diet will make its fat softer. The species and breed of the animal also influence the softness of fat; beef fat, for example, is very different from the hard, more brittle and dense fat observed in lamb.

How & Why?

Why is marbling desirable in meat?

When meat is cooked, the intramuscular fat deposits melt and contribute to perceived flavor and juiciness. For this reason, the more marbling in a cut of beef, the higher the grade (see the "Purchasing Meats" section).

Bone

Bones are used as landmarks for identifying the various meat cuts from a carcass (Figure 7-5). When buying meat, keep in mind that bone weighs more than meat and that the higher the proportion of bone there is to meat, the less the meat yield and the more the cost of the edible portion will be.

Marrow

Marrow is the soft, fatty material in the center of most large bones. The marrow found within the bone will generally be of two different types: (1) yellow marrow, found in the long bones, and (2) red marrow—red because it is supplied with many blood vessels—in the spongy center of other bones. Marrow is a valued food in many cultures and can provide much of the flavor in soups. (See Chapter 15 for more on how bones are used in soups.)

Antibiotics and Hormones

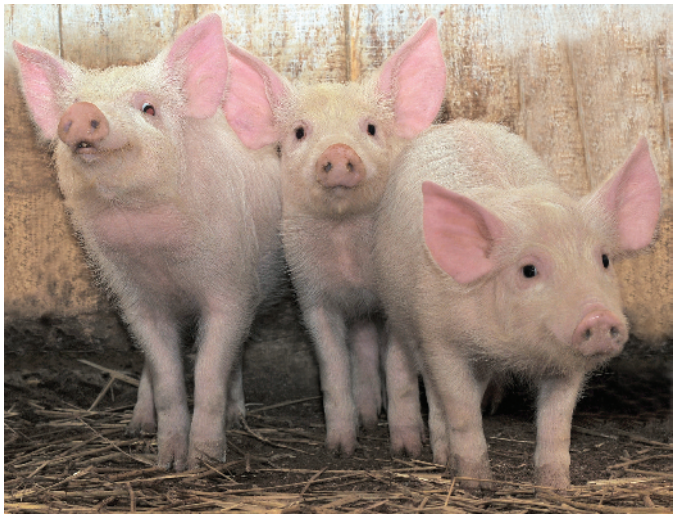
Each year, about 7 million pounds of antibiotics are given to humans. In contrast, approximately 30 million pounds of antibiotics are given to animals raised for meat to shield them from disease and promote growth. Regulations require that the drugs be withheld in the period prior to slaughter so that any remaining residues fall below federal limits. Because large-scale use of antibiotics in livestock production is believed to contribute to the emergence of antibiotic-resistant bacteria known as "superbugs"

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FIGURE 7-4 A polyunsaturated diet will yield pork that is higher in polyunsaturated fat.



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(23), the World Health Organization (WHO) recommends that nations phase out the use of antibiotic growth promoters in animal feed in order to preserve the effectiveness of medicinal antibiotics (see Chemist's Corner 7-2 and 7-3). In 2015, the FDA issued the Veterinary Feed Directive final rule mandating that antibiotics be administered to food-producing animals only with a veterinarian's approval and only when necessary to ensure health (18). The use of antibiotics as growth promoters in livestock has been banned in the European Union since 2006 (23).

CHEMIST'S CORNER 7-2

Antibiotic Resistance

Bacteria and other microorganisms can develop antibiotic resistance—the ability to survive in the presence of a medication that once killed them. Antibiotic resistance can develop sporadically because of a genetic mutation, or it can be a process of adaptation to the constant presence of an antibiotic or disinfectants (23). In both humans and animals, long-term or frequent use of antibiotics and disinfectants has resulted in resistant bacteria that can cause infections with the potential to be unresponsive to these antibiotic medications.

CHEMIST'S CORNER 7-3

Superbugs in Food

Clostridium difficile, commonly called *C. diff.*, is the bacterium most commonly associated with diarrhea in hospitalized patients. *C. diff.* causes only mild diarrhea in some patients, whereas in others, recurring, severe diarrhea develops, requiring the use of powerful antibiotics. Infection with *C. diff.* is often attributed to antibiotic use—antibiotics kill off the normal bacteria in the gut, allowing overgrowth of *C. diff.* Recently, *C. diff.* has been identified in commercial meat (25, 28). It is still unknown whether *C. diff.* can be transmitted from animals to humans and whether the infection can be contracted by eating tainted meat.

FIGURE 7-5 Bones identify retail cuts of meat.

Cut	Bone
Shoulder arm	Arm bone
Shoulder blade	Blade bone (near neck); Blade bone (center cuts); Blade bone (near rib)
Rib	Back bone and rib bone
Short loin	Back bone (T-shape) T-bone
Hip (sirloin)	Pin bone (near short loin); Flat bone (center cuts); Wedge bone (near round)
Leg or round	Leg or round bone
Breast or brisket	Breast and rib bones

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The U.S. Department of Agriculture (USDA) has allowed cattle and sheep (but not swine or poultry) to be treated with hormones for almost half a century. Hormones are given to livestock to encourage rapid weight gain (increase production by 15%), help them reach market weight sooner, and reduce the production cost (hormone-treated animals gain more on less feed) (29). The hormones are delivered to the animal through its feed or an ear implant (removed at slaughter). Not all countries approve of this practice, however. Since 1988, the European Union has banned meat imported from countries that permit hormone use in livestock.

Critics voice concerns that hormone trace residues in the meat may have serious human-health consequences. They also question the effect on the environment of those hormones eliminated through the feces, especially as these hormones may enter the water supply. Some have attributed changes in the reproductive cycle of fish to water runoff from feedlots and slaughterhouses (7). Adverse effects of these hormones in humans remain controversial, with the exception of antibiotic resistant bacterial strains that kill more than 23,000 people a year through bacterial infections that are resistant to any treatment (59).

Over three-fourths of North American cattle are treated with hormones. Although much more expensive, organic beef is raised without hormones or antibiotics (60) and is sometimes labeled "no hormones administered." However, the word "natural" on a meat label does not mean that hormones were not used. Any meat without added ingredients can be called "natural."

Pigments

Many people evaluate a meat's color when deciding whether to purchase a particular cut. In fact, a meat's color is the number-one factor influencing consumers when they are purchasing meats (30). The color of meat is derived from pigment-containing proteins, chiefly myoglobin and, to a lesser extent, hemoglobin. The so-called red meats—beef, pork, sheep, and lamb—have more of these pigments than poultry or fish do. Myoglobin receives oxygen from the blood and stores it in the muscles, whereas hemoglobin transports oxygen throughout the body and is found primarily in the bloodstream.

The higher the concentration of myoglobin in raw meat, the more intense is its bright red color (see Chemist's Corner 7-4). Several factors influence the concentration of myoglobin. Heavily exercised muscle has a higher demand for oxygen, so it is higher in myoglobin and therefore redder than the less exercised muscles. The red color of meat also increases as the animal ages, which is why beef is redder than veal, and mutton is darker than the pink hue of lamb. Meat color also varies from species to species. Beef is darker than lamb, which, in turn, is darker than pork, a meat that is on the pink side with no visible red.

Effect of Oxygen on Color

Exposure of meat to oxygen changes the color of myoglobin and, therefore, of the meat. After slaughter, meat undergoes several changes in color over time due to modifications in the molecular structure of myoglobin and/or hemoglobin (Chemist's Corners 7-4, 7-5, and 7-7). Myoglobin within the meat is purplish-red, but once exposed to oxygen (when meat is cut), it becomes bright red—a color that indicates freshness and is therefore desired by consumers. After

CHEMIST'S CORNER 7-4

Meat Pigments

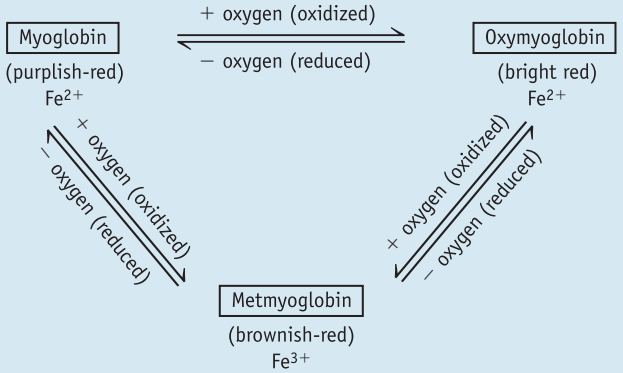
Each pigment-containing compound in meat consists of two parts: a protein (globin) and a nonprotein pigment (heme). The heme is an atom of iron surrounded by four connecting pyrrole rings. The difference between myoglobin and hemoglobin is that the simpler myoglobin molecule consists of one protein polymer strand and one heme (molecular weight = about 17,000), whereas the larger hemoglobin molecule is made of four protein polymer strands and four hemes (molecular weight = about 68,000) (36).

CHEMIST'S CORNER 7-5

Color Changes in Meat

The molecular changes in the pigment-containing proteins determine the color of meat from slaughter to consumption. Color changes are dependent on the oxidation or reduction of the iron in the heme. Initially, the internal color of meat is purplish-red because slaughter depletes oxygen concentrations in the meat. As soon as meat is cut from the carcass and exposed to the oxygen in the air, a bright red compound known as oxymyoglobin forms (Figure 7-6). Over time, the bright red oxymyoglobin is further oxidized to metmyoglobin, which is a brownish-red color (61). Older meat cuts look browner because myoglobin or oxymyoglobin is converted to metmyoglobin as the iron in the pigment is oxidized from its ferrous (2^+) to ferric (3^+) state. This usually occurs during storage, when the meat undergoes continued exposure to bacteria, oxygen, or light (fluorescent and incandescent). The brownish-red color resulting from metmyoglobin is undesirable to retailers (41).

FIGURE 7-6 Color changes in meats.



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a while, meats left in storage may be exposed to bacteria or less oxygen, and/or kept under fluorescent or incandescent lights, all of which turn the meat brownish-red (31). Using plastic wrap that is permeable to oxygen allows meat retailers to maintain the bright red color for a longer period of time, whereas vacuum wrap, which eliminates the oxygen, causes the meat to appear purplish-red.

Effect of Heat on Color

Cooking meat initially converts the color of raw meat to bright red, but then the denaturing of the pigment-containing proteins yields the classic color of well-done meat—grayish brown. Storing cooked meat too long causes the denatured protein to break down further, causing the meat to turn yellow, green, or faded.

Extractives

Meat derives some of its flavor from nitrogen compounds called **extractives**. The most common extractives are creatine and creatinine, but urea, uric acid, and other compounds also contribute to the flavor of meat. The meat from older animals contains more connective tissue and extractives, and therefore yields more flavor than that from younger livestock. Extractives are water-soluble, so some of the flavor of boiled or simmered beef may be lost in the cooking water; the flavor can be recaptured by using the cooking liquids in the preparation of soup or gravy.

NUTRIENT CONTENT

Meat consists primarily of **water (75%), protein (20%), and fat (varies), with a few minerals and some B vitamins** (41). It contains very **little to no carbohydrates** (liver is the richest source), **no fiber, and no vitamin C**.

Protein. According to the Exchange Lists, meat delivers **7 grams of protein per ounce**. Current recommendations suggest a protein foods intake of **4 to 6 ounces a day**, so when chosen as the protein source, meat provides a majority of the recommended daily protein intake—28 to 42 grams. The Dietary Reference Intake **(DRI) for protein for adults is approximately 50 grams per day** (46 grams for women and 56 grams for men), and meat is an excellent source of this nutrient. The remaining protein need is usually met by consuming foods from other food groups—especially dairy (milk, cheese, etc.), which provides **8 grams for each cup of milk or ounce of cheese.**

Fat. Fat content can **vary widely** according to the grade of meat and its cut. Several cuts of beef are lower in fat than an equal amount of some poultry choices, yet consumers often select poultry over beef, thinking it is lower in fat (57). See the Calorie Control box for more information on how to choose lower-fat meats.

Carbohydrate. Meat contains **very little carbohydrate**. Glycogen, found in liver and muscle tissue, is present when the animal is alive, but the glucose that makes up the glycogen is broken down to lactic acid during and after slaughter.

Vitamins. Meat is an **excellent source of certain B vitamins**—thiamine (B_1), riboflavin (B_2), pyridoxine (B_6), vitamin B_{12}, and niacin—and contains some folate. Niacin is obtained from tryptophan, an amino acid plentiful in meats and milk. Vitamin B_{12} and fat-soluble vitamins, especially vitamin A, are found in liver. Vitamin loss during meat preparation depends on the temperature, the time exposed to the heat source, and the cooking method. Thiamine (B_1) is especially sensitive to heat, so levels of this vitamin are somewhat reduced in canned meats, which have undergone high-heat processing (27). Water-soluble B vitamins can be leached from meat into cooking liquid, but it can be recaptured by making gravy or soup from that liquid.

Minerals. Meat is an excellent source of **iron, zinc, copper, phosphorus,** and a few other trace minerals; liver is especially rich in iron. Minerals are stable when heated, and although they can be lost in cooking water, retention of most minerals in cooked meat ranges from 80 to 100%.

PURCHASING MEATS

To ensure that consumers are purchasing meat that is safe, federal laws require the inspection of animal carcasses. In addition to this mandatory inspection for safety, meat may also be assigned yield grades and then later quality grades to assist consumers in selection. Grading is voluntary.

Inspection

The Federal Meat Inspection Act of 1906 made inspection mandatory for all meat crossing state lines or entering the United States through foreign commerce. Inspections are the responsibility of the USDA Food Safety and Inspection Service. This inspection is a guarantee of only wholesomeness and does not ensure the quality or tenderness of the meat itself. A meat inspection is conducted by licensed veterinarians or by specially trained, supervised inspectors.

The inspectors or veterinarians examine live animals prior to slaughter as well as animal carcasses, observe the meat at various processing stages, monitor temperatures and additives, review packaging materials and labels, determine employee and facility hygiene, and check imported meat. Meat that passes this federal inspection is marked with an inspection stamp (Figure 7-7) to distinguish it from meats that are diseased or slaughtered in unsanitary conditions. Note, however, that this visual inspection does not ensure the absence of the small parasite *Trichinella spiralis* (see Chapter 4 for information on this and other diseases).

FIGURE 7-7 USDA meat inspection stamp. The number is assigned to the meat-processing plant. Consumers rarely see the stamp, which is placed on larger wholesale cuts.



Extractives Flavor compounds consisting of nonprotein, nitrogen-containing substances that are end products of protein metabolism.

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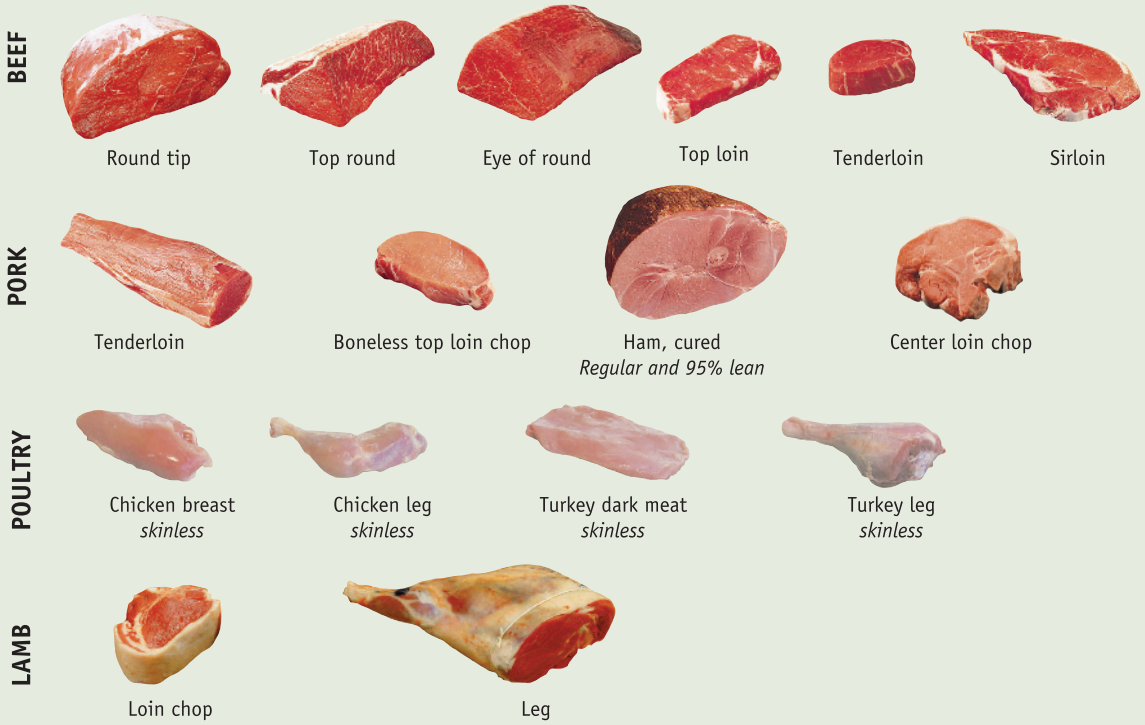
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CALORIE CONTROL
Choosing Meats and Meat Substitutes

Portion control starts with recognizing how many kcalories are being consumed for each meal, which may average 400 kcalories for women and 600 kcalories for men (see Chapters 1 and 6). Choosing lean meat cuts and following the tips for reduced-fat cooking. Listed below are some of the steps that can be taken toward achieving a healthy, balanced diet. Kilocalories from meats are controlled by (1) limiting the number of ounces and (2) leaning more toward the lean meats.

FIGURE 7-8 Lower-fat meats.



TIPS FOR REDUCED-FAT COOKING

- ☑ Choose 3-ounce servings (for a total of 6 ounces per day). Start with 4 ounces of raw meat to end up with a 3-ounce cooked serving. This will account for cooking losses.
- ☑ Look for beef labeled with the "USDA Select" grade. It's lower in fat and kcalories than "Choice" or "Prime." Marbling (the flecks of fat in the lean) makes the difference.
- ☑ Use the "loin/round" rule of thumb for beef and "loin/leg" for pork, lamb, and veal. Cuts with these words on the label will be lean choices.
- ☑ Tenderize lean cuts of meat by cooking them slowly in liquid or marinating them before cooking. Pounding, grinding, and slicing across the grain can also help.
- ☑ Keep your meat selections lean. Trim all visible fat and let the remainder drip off during cooking. When you prepare meat, broil, grill, bake, roast on a rack, or microwave. Buy skinless poultry or remove skin before cooking and you will reduce fat content by about half.
- ☑ Remove fat from stews, soups, and casseroles by chilling them and skimming the hardened fat from the top. If you're pressed for time, use a baster to remove it.
- ☑ Don't fry. The batter or breading on fried chicken, for example, acts like a sponge—soaking up fat. And after frying, you're less likely to remove the coating and skin before you eat the meat. Also skip the heavy gravies and rich sauces. Even the butter or margarine you use on broiled food makes the fat add up fast.

Source: USDA

(*Continued*)

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Limit meat to 5 to 6 ounces a day. ChooseMyPlate.gov and the Exchange Lists recommend 5 to 6 ounces of protein foods per day, depending on the person's sex and age group. Visually, 3 ounces of meat is about the size of a deck of cards or the palm of an average hand. In terms of the Exchange Lists, a serving size for meat is 1 ounce, so if the average meat portion on the plate weighs 3 ounces, that means it provides about 250 kcalories (75 kcalories/ounce × 3 ounces = 225 kcalories, rounded to the nearest 50).

Choose lean meats. The less fat, the fewer kcalories.

- The general rule of thumb is that beef cuts from the loin or round and veal and lamb cuts from the loin or leg are the leanest choices. Examples of lean beef cuts include sirloin, tenderloin, top loin, top round, and eye round (Figure 7-8).
- Avoid processed meats such as hot dogs, bologna, and sausage, as they average 30 to 50% fat (exceptions are the lower-fat alternatives).
- Wild game tends to be lower in fat as compared with beef, as shown in Table 7-1.

Approximate kcalories (from low to high) and fat content in meat and other protein foods can be found at http://ndb.nal.usda.gov (click on "Start your search here"). Animal-derived protein foods also include poultry, fish, cheese, and eggs, but these are listed under their respective chapters.

TABLE 7-1 Fat Content of Wild Game as Compared with Beef*

Species	Fat (grams)	Kilocalories
Beef, T-bone, USDA choice	10	214
Antelope	4	165
Bison (buffalo)	2	143
Deer (venison)	3	158
Duck (skinless)	11	201
Elk	2	146
Moose	1	134
Pheasant, breast without skin	3	133
Rabbit	8	197
Rabbit (wild)	4	173
Squirrel	5	173

*All values shown are for a 100-gram (about 3 oz) cooked portion, with visible fat removed, unless noted.

Courtesy of USDA; © 2010 Amy Brown

Other laws passed since 1906 further protect the meat supply. The USDA can oversee only meats that are transported between states, so the Wholesale Meat Act of 1967 was passed to require that meat sold within the states meet requirements equal to the federal standards. The USDA inspection regulations incorporating hazard analysis and critical control points (HACCP) within meat and poultry slaughterhouses, along with mandatory testing for *E. coli*, were implemented in 1997 (40).

Grading

The grading of meat is not under government mandate or control and is a strictly voluntary procedure that the meat packer or distributor may have performed under contract with the USDA (58). For purposes of grading, a cut is made between the twelfth and thirteenth rib in order to expose the rib muscle.

Quality

The **quality grades** for the different types of meat are shown in Table 7-2. Factors considered in grading are color, grain, surface texture, and fat distribution. Unfortunately, this system is not used uniformly by retailers. Instead of Prime, Choice, Select, and Standard, retailers frequently designate the quality of their meat with a descriptive word or phrase such as 5 Star, Blue Ribbon, or Supreme. This is purely a marketing strategy and leaves it up to the consumer to determine the validity, or lack thereof, of the designation. Although a large percentage of meat sold is graded, the term *no roll* is used to indicate ungraded meat.

Any judgment of quality must be somewhat subjective, but several identifiable factors separate a poor cut of meat from an excellent one. Top cuts of meat have the optimum color for their type and fine-grained, smooth surfaces that are velvety, silky, or satiny to the touch. They contain fat that is evenly distributed, white or creamy-white rather than yellow, and firm instead

Quality grades The USDA standards for beef, veal, lamb, and mutton.

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TABLE 7-2 USDA Quality Grades for Beef, Veal, Lamb, and Mutton from Highest to Lowest*

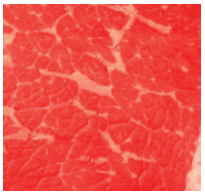
Beef	Veal	Lamb	Mutton
Prime	Prime	Prime	Choice
Choice	Choice	Choice	Select
Select	Select	Select	Commercial
Standard	Standard	Commercial	Utility
Commercial	Commercial	Utility	Cull
Utility	Utility	Cull	
Cutter	Cull		
Canner			

*There are no quality grades for pork.

FIGURE 7-9 USDA grades related to marbling.



USDA Prime: Very heavy marbling that looks like snowflakes and is evenly distributed.



USDA Choice: Moderate marbling in delicate lacy streaks that is less evenly distributed than in Prime.



USDA Select: Spotty marbling scattered like rice grains.







7th Son Studio/Shutterstock.com; BW Folsom/Shutterstock.com; ND700/Shutterstock.com

of brittle or runny. These factors contribute to tenderness, which is never directly measured in grading, although it remains a top concern among both retailers and restaurateurs (8).

Influence of Fat Content on Grading

Fat, especially in the form of marbling, melts during heating, thereby increasing the flavor and perceived tenderness of the meat. USDA quality grades of beef reflect the degree of marbling. Prime, the top USDA grade, contains the most marbling and is the most expensive (Figure 7-9). The marbling and any fat trim of a beef steak being examined for possible purchase should be cream colored. If the fat is yellowish, the meat may be from an older animal and therefore may be tough. However, when retailers trim the fat to 1/8 inch around the meat, it makes it difficult to judge the fat's actual color and texture. The differences in USDA quality grades for beef are described here.

Yield grade A standard representing the amount of lean meat on the carcass in proportion to fat, bone, and other inedible parts.

USDA Beef Quality Grades

There are eight USDA quality grades for beef, with the top three—Prime, Choice, and Select—being of most concern to consumers (Table 7-3). Prime accounts for less than one-fifth of the beef marketed. It is usually sold to restaurants because the price is not competitive enough for the average supermarket consumer. Choice and Select are the grades most commonly purchased by consumers in the supermarket. Select cuts contain 5 to 20% less fat than Choice cuts, and 40% less fat than Prime. Standard and Commercial USDA grades are not sold at the retail level because they are usually from older, more mature, and therefore less tender cattle. The USDA grades identified as Utility, Cutter, and Canner are usually used in processed foods such as canned meats, sausages, and pet foods.

Yield

Yield grade is the other key characteristic of a meat cut (Figure 7-10). The evaluation for yield does not occur at the consumer level but rather at the slaughterhouse, often referred to as a "rendering plant." Carcasses of beef, lamb, and mutton are rated at yields of 1 to 5, with 1 providing the highest yield and 5 the lowest (Table 7-4). Pork is yield-graded from 1 to 4. Veal is not yield-graded because it contains so little fat. Although 4 ounces of raw meat with little or no bone generally constitutes one serving, ¾ to 1 pound of meat per serving may be needed if the meat contains high amounts of refuse.

TABLE 7-3 Top Three USDA Quality Grades for Beef

USDA Grade	What the Grade Means
	Very tender, juicy; flavorful; the greatest degree of marbling. The most expensive of the grades, Prime is sold to finer restaurants and some meat stores.
	Quite tender and juicy, good flavor; slightly less marbling than Prime. The grade most frequently found in retail stores.
	Fairly tender; not as juicy and flavorful as Prime and Choice; has least marbling of the three, and is generally lower in price.

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FIGURE 7-10 USDA yield grades. The amount of lean muscle is compared in a ratio to the nonmeat portion—fat, bone, and inedible material.

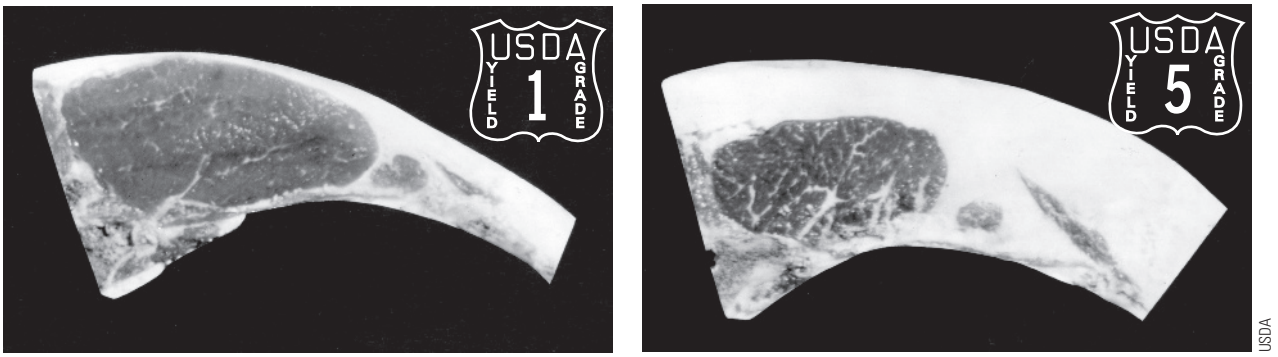


TABLE 7-4 Percentage of Lean Meat Required for USDA Yield Grades

Yield Grade	Usable Carcass Meat*
1	74% or more
2	71%
3	68%
4	64%
5	61% or less

*Percentages vary depending on the range within each yield grade and the way the carcass is cut.

Tenderness of Meats

Tender meat generally is preferred by consumers. In fact, tenderness and flavor are the two most important factors affecting consumer acceptance of cooked beef (13). It's difficult to select tender meat because a top-quality grade does not guarantee its tenderness. The only real test is how easily the meat gives way to the teeth. Extreme variations of tenderness exist in beef, even within different areas of a single meat cut; however, overall, natural meat tenderness is due to factors such as the cut, age, and fat content. Meats can also be treated to make them more tender by adding enzymes, salts, and acids, or by subjecting them to mechanical or electrical treatments. Preparation temperatures and times also have an influence on tenderness.

Natural Tenderizing

The particular cut of the meat, the animal's age at slaughter (connective-tissue concentration), the animal's heredity and diet, the meat's marbling, slaughtering conditions, and aging all play a part in determining tenderness (53).

Cut

The most important influence on the tenderness of meat is the location, on the animal's body, of the muscle from which it came. Muscles that are exercised are tougher than those that are not because of higher concentrations of connective tissue (6). Meat cuts such as chuck and round from the shoulder and hindquarters come from muscles that are used for locomotion and are therefore tougher than those from the loin (lower back) and rib areas of the animal. The least tender cuts are flank steak, short plate, shank, short ribs, rump roast, and brisket from the legs and underside of the animal. The most tender cuts of the carcass, such as sirloin, tenderloin, and rib eye, are found in the loin and rib areas, where the muscles are used less and thus develop less connective tissue. Other tender cuts of meat include strip steak, strip loin, T-bone steak, and standing rib roast. Cuts of beef with intermediate degrees of tenderness include flank, chuck, top blade, and skirt steaks (6).

Animal's Age

An animal's age at the time of slaughter contributes to tenderness, and top USDA grades usually come from relatively young animals. As muscles age, the diameter of the muscle fibers increases and more connective tissue develops, resulting in toughening of the meat (50).

Heredity

Cuts of meat will vary in tenderness because of genetic factors. For example, beef from Black Angus cattle, which are bred to be heavily muscled and marbled, will be very different from meat obtained from dairy cattle or from one of the other, larger breeds of cattle.

Diet

The type of diet fed to the animal directly influences its fat accumulation, which is one of the factors affecting the tenderness and flavor of its meat.

Marbling

Fattening animals before slaughter is thought to increase tenderness by increasing marbling and the development of subcutaneous fat. The amount of subcutaneous fat on the carcass contributes to tenderness by delaying the speed at which the carcass chills when refrigerated. When choosing meat cuts, consumers seem to prefer lean-looking meats over more marbled ones, but usually reverse their choices in a taste test after those same cuts are prepared.

Rigor Mortis

Within 6 to 24 hours after slaughter, the muscles of livestock enter the state of **rigor mortis**. This condition reverses naturally 1 or 2 days after slaughter.

Rigor mortis From the Latin for "stiffness of death," the temporary stiff state following death as muscles contract.

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How & Why?

Why does a carcass stiffen?

Rigor mortis is caused by a cascade of events that take place at the cellular level:

1. Death interrupts the blood flow and prevents oxygen from reaching the cells.
2. Anaerobic conditions prevail, glycogen is converted to lactic acid, and the pH drops, ultimately to around 5.5.
3. At this pH, the enzymes required for glycolysis are denatured, so ATP production ceases.
4. ATP is necessary for muscles to contract and relax; without it, actin and myosin bind irreversibly (because the calcium ions cannot be pumped out of the sarcoplasm), and the muscle becomes stiff.

The extent of overlap of actin and myosin when the muscle goes into rigor is important because the greater the overlap, the more actomyosin cross-links are formed, which can make meat tough. Therefore, the animal's carcass is hung after slaughter to stretch the muscles and minimize actomyosin formation.

The way that meat is handled during this period is important because it can affect pH, which influences meat quality. The perception of a meat's juiciness or dryness depends on the binding of water to muscle proteins, and this is influenced by pH. Water-holding capacity is best in meats with a pH of 5.8 (39). A pH that is too low or too high results in less than desirable meat.

Meat pH changes during rigor mortis because the oxygen-deprived cells switch to glycogen as an energy source. Glycogen is converted to lactic acid, and the increase in acidity causes the pH to fall from approximately 7.0 to 5.8, which is a desirable pH for meat quality.

Aging Holding meat after slaughter to improve texture and tenderness. A ripening that occurs when carcasses are hung in refrigeration units for a longer period than that required for the reversal of rigor mortis.

Slaughtering Conditions

Both the conditions preceding slaughter and the handling of the carcass immediately afterward can result in several problems affecting the meat's quality: dark-cutting condition; pale, soft, and exudative (PSE) pork; thaw rigor; cold shortening; and green meat. The first two problems are related to pH. Under ideal conditions, the process of rigor mortis results in meat with a pH of 5.5 to 5.8; however, the pH can drop either too much or not enough depending on the timing and duration of stress to the animal.

- ***Dark-cutting meat (dark, firm, dry condition).*** If glycogen stores are depleted before death because the animal is exercised or stressed, insufficient lactic acid will be produced during rigor mortis. The resulting higher pH (above 5.8) of the meat will result in a deep-purple meat known as dark-cutting meat, which has a dry or sticky texture that is unacceptable to consumers (36).
- ***PSE condition.*** The PSE condition most commonly affects pork but may also affect beef, lamb, and poultry. It results when the pH drops too quickly after slaughter, which causes the meat to become very dry when cooked. A low pH—under 5.1, or even up to 5.4—can cause the meat to become extremely pale, mushy, slimy, flavorless, and full of excess drip (5). Japanese export buyers evaluate pork based on its pH (4). Because a low pH can damage meat proteins and alter color to a pale tan, they watch for this color change and select darker-colored meats with a higher pH, and thus better flavor. Some meatpacking companies likewise measure the pH of their meat products.
- ***Thaw rigor.*** Freezing meat before it undergoes rigor mortis can cause thaw rigor, a phenomenon in which the meat shrinks violently by almost 50% when thawed.
- ***Cold shortening.*** Cold shortening is a less severe form of thaw rigor that occurs when meat has been chilled too rapidly before rigor mortis sets in. In both cases, the meat will be tougher. Neither thaw rigor nor cold shortening meat may be sold at the consumer level.
- ***Green meat.*** Meat cooked while in a state of rigor mortis (before the muscles have had time to relax) will be tough and tasteless. However, it can be quite tender if prepared before stiffening begins.

Aging

Aging meats improves their juiciness, tenderness, flavor, color, and ability to brown during heating. This treatment pertains primarily to beef (11). All fresh beef is aged for at least a few days and may be aged up to several weeks. Enzymes naturally found in the meat break down the muscle tissue, improving its texture and flavor (Chemist's Corner 7-6). Hanging the carcass also aids in the aging process by stretching the muscles. The animal's species, size, age, and activity before slaughter influence how long rigor mortis lasts. Beef takes about 10 days to age, which is about the same amount of time it takes for meat to be transported, packaged, and sold to the consumer. Top-quality beef is often aged longer, up to 6 weeks. Mutton is sometimes aged, but pork and veal come from such young animals that aging is not required to increase tenderness. The fat in pork tends to go rancid quickly, and veal's lack of protective fat covering causes it to dry out quickly—further reasons these meats are not routinely aged.

Meats are aged in one of several ways. The time required for aging depends on the method used.

- ***Dry aging.*** Carcasses are hung in refrigeration units at 34 to 38°F (1 to 3°C) with low (70 to 75%) or high (85 to 90%) humidity for 1½ to 6 weeks. Specialty steak houses and fine restaurants usually purchase

CHEMIST'S CORNER 7-6

Passing of Rigor Mortis

Rigor mortis passes when the muscles gradually become soft and pliable again. This is facilitated by proteases that hydrolyze the thin filaments at the Z bands, or ends of the sarcomeres. Actomyosin cross-links between the thin and thick filaments within the sarcomeres are not broken down, however (34).

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dry-aged meat. The meat is more expensive than other types of aged beef because the exposure to air can cause it to lose up to 20% of its original weight. The carcass weight is further reduced because the dry exterior layer must then be trimmed. The advantage of dry aging is that the dehydration concentrates the meat's flavor, making it more succulent and mellow (32).

- ***Fast or wet aging.*** Most beef is aged in plastic shrink-wrap. Warmer temperatures of 70°F (21°C) with a high humidity of 85 to 90% lower the aging time to 2 days, but additional aging will occur during the 10 or so days it takes the meat to reach the consumer. Ultraviolet lights are used to inhibit microbial growth. Most retail meat is fast aged.
- ***Vacuum-packed aging.*** Less weight loss and spoilage occur in meats that are aged by vacuum packing (cryovacing). During this process, meat carcasses are divided into smaller cuts, vacuum packed in moisture- and vapor-proof plastic bags, and then aged under refrigeration.

Artificial Tenderizing

External treatments, including enzymes, salts, acids, and mechanical methods such as grinding or pounding can be applied to meats to increase their tenderness.

Enzymes

One of the reasons that contracted muscles begin to "relax" toward the end of rigor mortis is that proteolytic enzymes work internally to break down the proteins within the muscle fibrils (34). Commercial meat tenderizers containing enzymes are available for consumers to use, but they are effective only on fairly thin cuts of meat because they penetrate to a depth of only 1/2 to 2 millimeters. They are ineffective on larger cuts, such as roasts. Tenderizers are sold as a salt or liquid mixture and differ in the proteolytic enzymes they contain: papain from papayas, bromelin from pineapples, ficin from figs, trypsin from the pancreases of animals, and rhozyme P-11 from fungi (mushrooms).

The enzymes are not active at room temperature. The optimal activity temperature (with the highest rate of activity) for papain, the most common tenderizing enzyme, is about 131 to 170°F (55 to76°C), which is reached only during heating. Exceeding 185°F (85°C) denatures the enzyme, thus inhibiting its activity. Uniform distribution is hard to achieve with the use of commercial tenderizers, and any attempt to get more of the enzyme to penetrate by adding excessive amounts of it can cause the meat to have an unappetizing, mealy, mushy texture.

How & Why?

How do meat tenderizers work?

Meat tenderizers contain enzymes that break down muscle proteins. They are sprinkled on meat, which is then pierced with a fork to drive the enzymes below the surface, where they hydrolyze muscle cell proteins and connective tissue when activated by the heat of preparation.

Salts

Tenderness can also be increased by the addition of salts in the form of potassium, calcium, or magnesium chlorides. These salts retain moisture and break down the component that surrounds the muscle fibers, resulting in the release of proteins. Polyphosphates are sometimes added to the salts to improve the meat's juiciness through increased water retention, and, if added to processed meats, they also increase firmness, emulsion stability, and antimicrobial activity (46). However, this increased water-retention capacity is accompanied by an increase in sodium concentration.

Acids

Meats can be made more tender and/or flavorful by applying **marinades**. Their acidic ingredients—such as vinegar, wine, lemon juice, tomato juice, and fruit juice—break down the outside surface of the meat (19). Fermented dairy products such as buttermilk or yogurt are also acidic and may be used similarly in preparation. Not only do marinades tenderize the meat, but they also increase flavor and contribute to color. Extra flavor can be added by including herbs, spices, peppers, onion, garlic, and ginger. Oil can serve as the delivery system to hold the acid and flavor substances against the food. The maximum benefit of a marinade can be obtained by increasing the surface area of the meat. This may be done by cutting the meat into small pieces, such as teriyaki strips or kabob cubes. Marinades penetrate only one eighth of the meat's muscle surface (if skin or fat is not present) so they are not effective in tenderizing large cuts of meat or poultry. Generally, the acid in a marinade is responsible for tenderizing, although some marinades rely on added enzymes from certain tropical fruits such as papayas and pineapples. The meat is allowed to soak in the marinade, in the refrigerator, from half an hour to overnight, or for several days for sauerbraten. If marinated too long, the meat can become mushy yet still be tough.

Mechanically Tenderized Beef (MTB)

Meat can be tenderized mechanically by several methods, including grinding, cubing, needling, and pounding. These actions physically break down the muscle cells and connective tissue, making the meat easier to chew. Grinding and cubing meat simply increases the surface-area-to-volume ratio, causing the teeth to have less work to do.

Another method of mechanical tenderization more suitable for home kitchens is simply pounding the meat with a special hammer that breaks apart its surface tissue.

How & Why?

How is needling done?

Needling uses a special piece of equipment to send numerous needle-like blades into the meat, separating the tissues. Commercial equipment can be used to tenderize meat, and consumers can use handheld tenderizers.

Marinades A liquid containing acids, aromatics, and/or oil in which meat, fish, or vegetables are soaked to enrich their flavor or tenderize them.

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FIGURE 7-11 How retail cuts are obtained from a hindquarter wholesale cut.

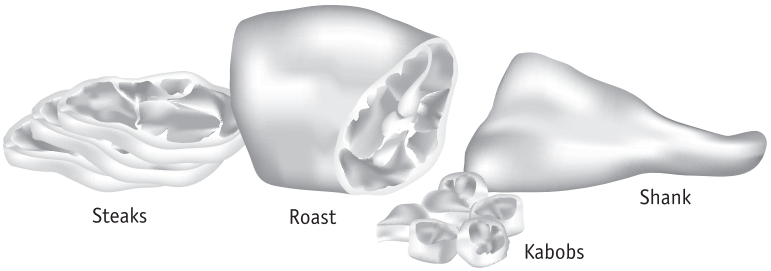
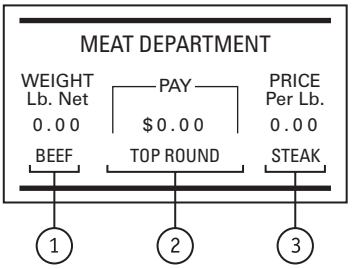


FIGURE 7-12 Meat labeling.



1. **The kind of meat**
   BEEF, VEAL, PORK or LAMB. It is listed first on every label.
2. **The primal (wholesale) cut**
   CHUCK, RIB, LOIN or ROUND. Tells where the meat comes from on the animal.
3. **The retail cut**
   BLADE ROAST, SPARERIBS, LOIN CHOPS, etc. Tells from what part of the primal cut the meat comes.

Electrical Stimulation

The meat of beef cattle and sheep, but not swine, becomes more tender when a current of electricity is passed through the carcass after slaughter and before the onset of rigor mortis. Electrical stimulation speeds up rigor mortis by accelerating glycogen breakdown and enzyme activity, which disrupts protein structure, making the meat more tender (8). In this way, the meat can be immediately cut up without any loss of quality.

Cuts of Meat

Consumer confusion abounds when it comes to deciphering the various meat cuts. Part of this confusion stems from the fact that there are two major types of meat cuts, wholesale and retail. Prior to reaching the supermarket and the consumer, a carcass is divided into about seven **wholesale** or **primal cuts** (nine in the case of beef). Although the carcasses of each species are sectioned slightly differently, the basic wholesale cuts are similar to each other and are identified by the major muscles and by bone "landmarks" (see Figures 1 to 5 in the color insert). These wholesale cuts are then divided into the **retail cuts** purchased by consumers. Figure 7-11 shows how common retail cuts are obtained from the wholesale cut of a hindquarter.

Wholesale (primal) cuts The large cuts of an animal carcass, which are further divided into retail cuts.

Retail cuts Smaller cuts of meat obtained from wholesale cuts and sold to the consumer.

Terminology of Retail Cuts

The use of the standard system of naming retail cuts is not mandatory, so consumers often face additional confusion at the market. The same cut of meat may be called by different names, depending on the retailer or the part of the country in which it is sold. For example, beef chuck cross-rib pot roast is also known as Boston cut, bread and butter cut, cross-rib roast, English cut roast, and thick rib roast. Lack of a single title for each cut prevents the sheer repetition that would help consumers catch on to a standardized nomenclature.

Of necessity, commercial establishments do have a system of standardized names. The names and specifications for more than 300 cuts of beef, veal, pork, and lamb are known as Institutional Meat Purchases Specifications (IMPS). The IMPS are listed in *The Meat Buyer's Guide*, which can be purchased online. It serves as an industry reference for those responsible for the preconsumer purchase and the sale of meat. Most retail meat markets adhere to *The Meat Buyer's Guide*. Under this system, meat labels include the species (beef, veal, pork, or lamb), primal cut, and retail cut (Figure 7-12). Hence, rib eye steak would be labeled "Beef, rib, rib eye steak."

Beef Retail Cuts

Rib, short loin, and sirloin wholesale cuts lie along the back of the animal and are usually the most tender and expensive cuts of beef (Figure 7-13). Rib roasts are the most tender roasts, and tenderloin is the most tender steak. Filet mignon is the small end of the tenderloin, but some retailers incorrectly, perhaps deliberately, label any cut from the tenderloin as filet mignon. Although less tender, chuck (shoulder area) and round (rump area) wholesale cuts provide many popular retail cuts. The least tender wholesale cuts are flank, short plate, brisket, and foreshank (Table 7-5).

Ground Beef

About 44% of all fresh beef is sold in the form of ground beef, used extensively in fast-food restaurants, schools, military programs, and homes (9). The terms *ground beef* and *hamburger* are often used interchangeably, but there is a difference. The USDA classifies ground beef as beef that has been ground. Hamburger is ground beef that is often combined with ground fat; seasonings may also be added. Neither ground beef nor hamburger may exceed 30% fat by weight. Regular ground beef contains 30% fat, lean ground beef about 23%, and extra lean ground beef no more than 15% fat. Draining the fat off hamburger or ground beef during and after cooking lowers the fat content appreciably. Consumer preference studies have shown that ground beef containing 15 to 20% fat is preferred. Reducing the fat content below 20% decreases the flavor, tenderness, and juiciness of the product (12).

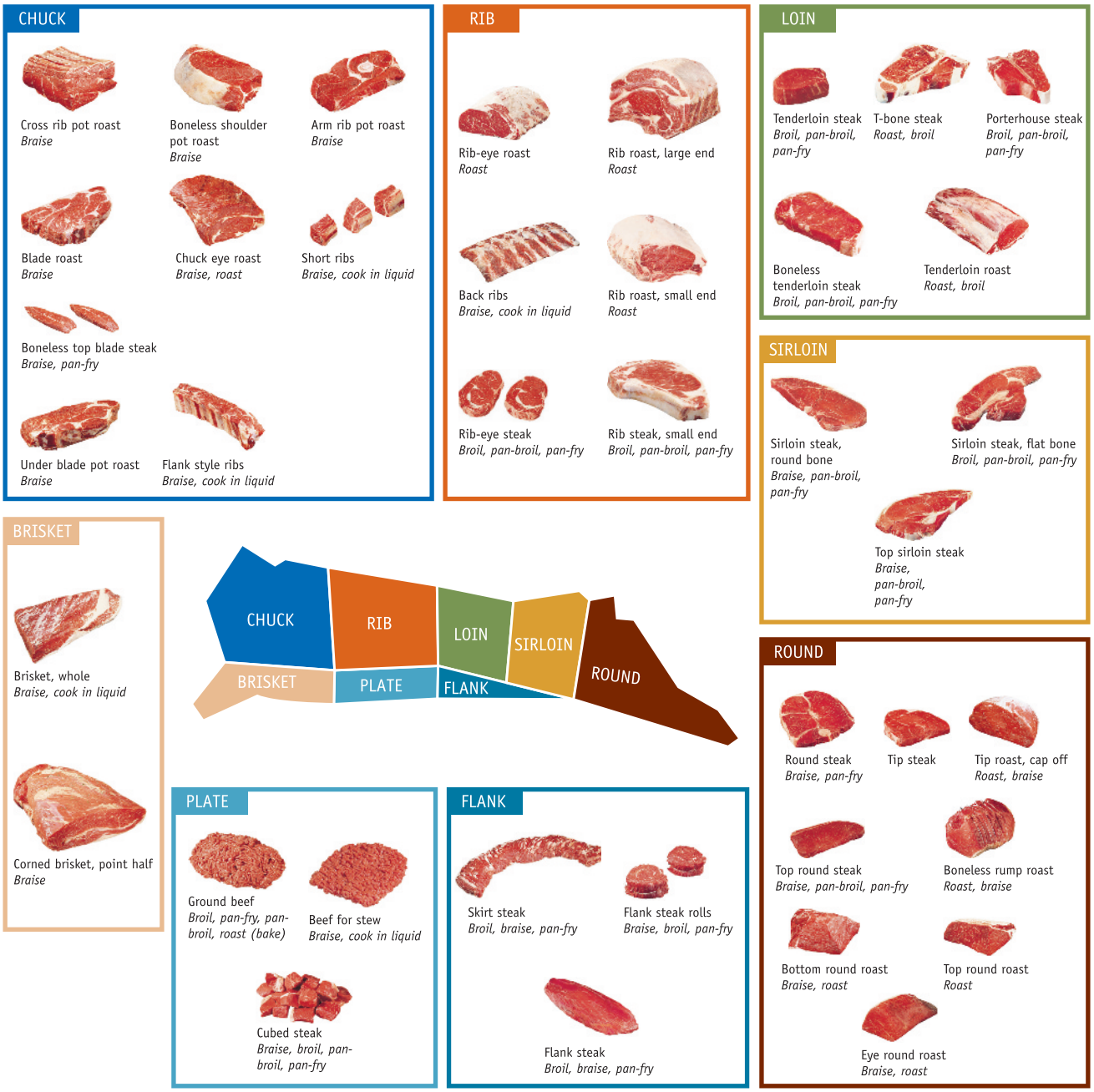
The fat in ground beef can be reduced by adding extenders such as nonfat dry milk solids, texturized vegetable protein (TVP), plant starches, soy proteins, oat bran or fiber, modified food starches, maltodextrins (starches), and vegetable gums (carrageenan) (15). Many of these extenders enhance the flavor as well as lower the fat content.

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FIGURE 7-13 Wholesale and retail cuts of beef.



- **Broiling:** filet mignon steak, strip loin steak, Delmonico steak, rib eye steak, top butt sirloin steak, chuck tender steak, and top round steak.
- **Pan-frying:** top round steak, top sirloin steak, shoulder steak, chicken steak, bottom round steak, eye round steak, and flank steak.
- **Roasting:** center-cut chuck, chuck shoulder, rump roast, bottom round, top rib, brisket, and plate.
- **Stewing:** boneless chuck (center and rib), heel of round, flank steak, top rib, shin of beef, and plate.
- **Braising:** top round, top sirloin, chuck shoulder, bottom round, chuck blade steak, flank steak, and short ribs.

Courtesy of the USDA

Lean Finely Textured Beef (LFTB)

During beef processing, muscle connected to bone and fat is trimmed to produce a ground beef filler called lean finely textured beef (LFTB). First, the beef trimmings are heated to about 100°F (38°C) until the fat is liquefied; then the fat is separated from the muscle tissue by spinning the meat trimmings in a centrifuge. For food safety purposes, ammonium hydroxide or citric acid is applied to the resulting LFTB to destroy any bacteria. Approximately 5 to 15%, but no more, of this 95% lean protein can be added to raw ground beef to produce beef more cheaply (38). Public outcry over the use of LFTB—popularly known as "pink slime"—as a filler resulted in many supermarkets pulling this type of ground beef off the market.

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TABLE 7-5 Retail Cuts Obtained from the Primal Cuts of Beef

Some of the more tender retail cuts

Rib	*Short Loin*	*Sirloin*
Rib eye (Spencer)	Tenderloin	Sirloin steak (Delmonico)
Rib roast	Porterhouse steak	Top loin steak
Rib steak	T-bone steak	Sirloin tip roast
		Tenderloin steak

Less tender, but still popular, retail cuts

Chuck	*Round*
Chuck roast	Top round steak or roast
Cross-rib roast	Eye of round steak or roast
Boneless chuck eye roast	Bottom round or roast
Blade roast or steak	Rump roast
Arm pot roast or steak	Heel of round
Boneless shoulder pot roast or steak	Cubed steak
Chuck short ribs	Ground beef
Stew meat	
Ground chuck	

The least tender cuts

Flank	*Short Plate*	*Brisket*	*Foreshank*
Flank steak	Skirt steak rolls	Brisket	Crosscut shank
	Short ribs	Corned beef	Stew meat
	Stew meat	Stew meat	

Veal Retail Cuts

The retail cuts of veal, like those of pork and lamb described below, are fewer in number than those of beef because the carcasses are smaller (Figure 7-14). The hind legs of these animals are suitable for roasts, but veal roasts are usually tender regardless of their wholesale cut origin.

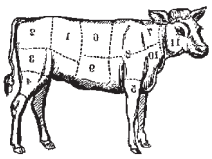
Pork Retail Cuts

Pork is usually tender, regardless of the cut because it comes from animals under 1 year of age. When compared to beef, veal, or lamb wholesale cuts, the wholesale loin and spare rib cuts of pork are much longer because there is no separation of the rib and sirloin as in other carcasses (Figure 7-15). In addition, modern breeders have developed an even longer swine with fourteen ribs (as compared with thirteen in beef and lamb). The leg is the largest primal cut, representing about one-fourth of the carcass weight. The following wholesale cuts provide the majority of fresh pork retail cuts:

- ***Loin.*** Pork loin chop or roast, Canadian-style bacon, pork loin tenderloin
- ***Spare rib.*** Spare ribs, bacon, salt pork

Baby back ribs are cut from the backbone, close to where tenderloin

FIGURE 7-14 Cuts of veal and the preferred method of cooking them.



The rib and loin sections of a calf are divided into chop and roast cuts, while the hind legs are tender enough for roasts. Cuts from the neck, shoulder, breast, chuck, and shanks are less tender and may require moist-heat preparation.



Arm steak
Braise, pan-fry



Riblet
Braise, cook in liquid



Leg cutlet
Braise, pan-fry, broil



Loin chop
Braise, pan-fry, broil



Rib chop
Braise, pan-fry, broil



Blade steak
Braise, pan-fry

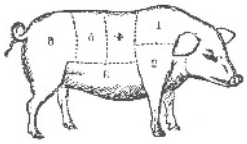
Source: USDA

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FIGURE 7-15 Cuts of pork and the preferred method of cooking them.



Preferred pork steaks and chops suitable for **pan-frying** are center-cut loin chop, center-cut rib chop, loin end chop, fresh ham steak, shoulder arm steak, and blade pork steak.

Chops: one of the most familiar pork cuts, chops can be prepared by pan-broiling, grilling, broiling, roasting, sautéing, or braising. Thin chops (3/8-inch) are best quickly sautéed. Thicker chops (3/4-inch to 1 1/2 inches) can be grilled, roasted, braised, or pan-broiled.



Sirloin chop



Center-cut loin chop



Pork rib chop



Pork loin chop



Boneless pork sirloin chop



Blade steak

Pork tenderloins: among the leanest cuts of pork, a tenderloin has only 4.1 grams of fat and 141 kcalories per 3-ounce roasted, trimmed serving.



Ribs: commonly used for barbecue meals; slow-roasting or braising yields tender, flavorful results.



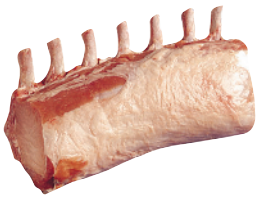
Roasts: large cuts of pork from the loin, leg, shoulder, or tenderloin. They can be roasted in the oven, barbecued over indirect heat, or braised in the oven.



Bone-in blade roast



Boneless blade roast



Center rib roast (rack of pork leg)

Source: USDA

and pork chops are cut (42). These ribs, also called "top loin" or "loin back ribs," are smaller and more expensive than spareribs. Spareribs are cut from the belly, in a location similar to that for bacon. Spareribs are fattier and meatier, but they are also cheaper.

Thicker cuts of pork, up to 1½ inch, are juicier because they have a lower surface-area-to-weight ratio, which results in better retention of their natural juices (49).

Lamb Retail Cuts

Lambs are smaller than either cattle or swine, so the leg wholesale cuts are usually cut into roasts, with leg of lamb being the most common (Figure 7-16). A rack of lamb consists of seven or eight rib chops; the backbone is usually removed to make carving easier. A fancier cut is crown roast of lamb, which consists of two rib sections or racks attached to the backbone, a circle or crown. It can be stuffed and is often decorated just before serving by covering the bone tips with paper frills, making a very handsome main dish for any table. Lamb chops are frequently cut from the loin, rack (rib), or shoulder. Loin chops are the most tender.

Variety Meats

Variety meats, also known as organ, offal, sundry, or specialty meats, can be divided into two categories: organ meats and muscle meats (Figure 7-17). Organ meats such as liver, kidneys, and brains from young animals are generally very soft, are extremely tender, and require only very short heating times. Sweetbreads can be obtained only from calves or young beef because the thymus gland disappears as the animal matures.

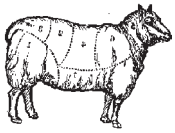
Variety meats The liver, sweetbreads (thymus), brain, kidneys, heart, tongue, tripe (stomach lining), and oxtail (tail of cattle).

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FIGURE 7-16 Lamb cuts and how to cook them.



Did you know: Lamb is traditional in Middle Eastern and Navajo cuisine. In North America, it is often served with mint sauce or jelly.

PAN-FRYING (if cut thin enough)



Loin chops



Ground lamb



Rib chop



Sirloin chops

ROASTING



Boneless lamb shoulder



Boneless loin roast

BRAISING, STEWING, AND MOIST COOKING



Shanks



Center leg



Shoulder chops



Half of leg

Source: USDA

FIGURE 7-17 Variety meats.



Oxtail



Tongue



Heart



Kidney



Sweetbreads



Brains



Liver



Tripe

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The meat of heavily exercised muscles such as the tongue and heart is quite tough and requires long, slow cooking. Tripe, the inner lining of the stomach, can be smooth or honeycombed. Smooth tripe originates from the first stomach, and honeycombed tripe, which is more popular, comes from the second stomach. Both types are extremely tough and strong in flavor. As with the tongue and heart, they require long, slow cooking.

Kosher Meats

Kosher meats come from certain animals (cattle, sheep, and goats, but not swine) designated as clean that have been slaughtered according to Jewish religious practices dating back more than 3,000 years (see Chapter 1). The animal must be slaughtered in the presence of a rabbi or other approved individual with a single stroke of a knife, be completely bled, and have all its arteries and veins removed. Blood must not be consumed because in the Jewish tradition it is synonymous with life. The hindquarter is rarely used for kosher meats because it is so difficult to remove the blood vessels in this area.

Halal Meats

As discussed in Chapter 1, *halal* is an Arabic term defined as "permitted," and it often refers to meat. Most meat is allowed except pork and carnivorous animals with fangs (lions, wolves, tigers, dogs, etc.). Acceptable animals need to be sacrificed according to Muslim guidelines.

Organic Meats

The demand for the more expensive organic meats is increasing. Organic beef standards were established in 2002 by the U.S. government. Organic meat is defined as being derived from cattle fed only milk, grasses, and grains from birth to slaughter.

Processed Meats

About one-third of all meat is processed, meaning it has been changed from its original fresh cut (Table 7-6). Ham, sausage, and bacon are the most popular processed meat products. Other examples of processed meats include salami, bologna, bratwurst, and pastrami.

TABLE 7-6 Examples of Processed Meats

The meats are grouped according to their major meat ingredient. Differences within each group are based on added ingredients and processing techniques.

Beef	Pork/Ham	Beef and Pork	Veal and Pork	Liver
Beef bologna	Blood sausage	Club bologna	Bockwurst	Braunschweiger
Beef salami	Bratwurst	Cervelat	Bratwurst	Liverwurst (pork)
Pastrami	Capicola	Frankfurters*	Veal loaf	
	Chorizo	Honey loaf	Weisswurst	
	Frizzies	Hot dog*		
	Ham	Knockwurst		
	Ham bologna	Luncheon meat		
	Linguiça	Mettwurst		
	Lola/Lolita	Mortadella		
	Luncheon meat	Olive loaf		
	Lyons	Peppered loaf		
	New England-style sausage	Pimento loaf		
		Salami		
	Old-fashioned loaf	Smokies		
	Pork sausage	Weiner*		
	Prosciutto	Vienna sausage*		
	Salsiccia			
	Scrapple			
	Thuringer			

*Terms used interchangeably.

Processing Methods

Before the advent of refrigeration, meat was preserved by such processing methods as curing, smoking, canning, and drying.

Curing

Commonly cured meat products include ham, bacon, sausages, frankfurters, corned beef, and luncheon meats. Meat once was cured by saturating it with salt. Corned beef, a cured beef brisket, was so named because in the sixteenth century, the word *corn* was used interchangeably with *grain*, so meat rubbed with coarse grains of salt was called *corned* (17). Today, the term *cure* is generally used to mean the addition of synthetic nitrates or nitrites, salt, and other preservatives (3). The curing mixture often includes sodium or potassium nitrate, sugar, spices, phosphates, dextrose, corn syrup, lactates, and seasonings (3). Nevertheless, salt remains one of the major flavoring agents of cured meat. The different proportions and combinations of ingredients used for curing contribute to the varying flavors of cured meats, which often garner additional flavor from being smoked.

There are several ways to cure meat. Dry curing consists of mixing the ingredients together and rubbing them into the surface of the meat, so that

How & Why?

How does nitrite cure meat?

Nitrite or nitrate salts are used in most cured meat products. When added to meat, the nitrite molecule ($-NO^2$) chemically reacts with the meat to create nitric oxide, which is the agent responsible for curing the meat (3). Nitrate ($-NO^3$) will not cure meat until it is converted to nitrite; this can be accomplished before or after it is added to the meat.

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they can penetrate their way to the center. Another method involves brining the meat (soaking it in a salt solution) or immersing it in a pickling solution. Salt and other flavors migrating into the meat not only makes it more flavorful but also changes the muscle protein. Through the mechanism of osmosis, fluids diffuse through cells into the meat to equalize the increased salt (ion) concentration. That is, the greater salt concentration in the meat causes it to absorb some of the water of the brining solution (6 to 8% of the meat's original weight), resulting in a moister meat (2). Whole turkey carcasses are commonly brined; however, this process can be applied to any meat.

The most common commercial curing technique is one in which the curing solution is mechanically pumped or injected into the meat using a machine lined with needles. These injected curing solutions increase the meat's weight. If the meats are not shrunk back to their original weight through heating and/or smoking, and if they contain up to 10% added moisture, they must be labeled "Water Added."

Although the original purpose of salting foods was to keep them from spoiling, now that refrigeration is widely available, meats are no longer cured solely for preservation. The high sodium content of many cured meat products now serves several purposes: to provide flavor, to improve texture by facilitating the binding of proteins, and to increase the proteins' water-binding capacity, which reduces fluid loss within the packages. Nevertheless, lower-sodium processed meats are becoming increasingly available in the retail market.

Smoking

Most cured meats are also smoked and cooked. Smoke imparts flavor, aroma, and color to foods. Meats are placed in smokers, where they are exposed to the smoke of burning wood. In smoke houses, the intensity of the smoke, the humidity, and the temperature are all carefully regulated, and the type of sawdust or wood used to produce the smoke determines the product's resulting flavor. Sawdust is the most economical fuel and is often used by commercial processors, but other woods available for smoking include mesquite, hickory, oak, apple, and various combinations of them. In the late 1800s, a technique was developed to distill the smoke from burning wood to create liquid smoke, which could be spread on cured meats to achieve the flavor of meat smoked in a smoke house (37). Today, the use of liquid smoke is more common, and it saves time and minimizes air pollution. Although the additional flavor provided by smoked meats is preferred by some consumers, there is some concern about its posing a possible cancer risk regardless of the type of smoking used (33).

Canning

Canned meats are processed through either pasteurization or sterilization. Pasteurized canned meats require refrigeration and are labeled "Perishable—Keep Refrigerated," whereas those that are sterilized do not need refrigeration as long as the can remains sealed.

Drying

Drying is not widely used for meats, but it has some applications for them. Certain types of sausage, including pepperoni, salami, and cervelat, are dried. They are cooked, sometimes smoked, and dried under specific conditions of humidity and temperature. Beef jerky, usually dried to a water activity of 0.7 to 0.85, is convenient, is ready to eat, and requires no refrigeration (60).

Food Additives in Processed Meats

A variety of food additives are added to processed meats, as shown in Figure 7-18. Nitrite is a common food additive used by the food industry to keep processed meat from turning brown (Chemist's Corner 7-7). Nitrite and salts of nitrate are used as preservatives in approximately 7% of foods, particularly processed meats such as ham, hot dogs, bacon, sausage, bologna, salami, and other cold cuts (51). These food additives are responsible for keeping many packaged processed meats permanently pink, while simultaneously reducing the risk of botulism and creating a distinctive flavor.

The safety of foods containing nitrites became an issue after the discovery that carcinogenic nitrosamines can form when nitrites combine with secondary amines in the stomach acid (16). This concern resulted in the lowering of nitrite levels used in processing, but not in their elimination because of their role in preventing botulism poisoning. In fact, nitrites are also formed in the body and are found naturally in such foods as cabbage, cauliflower, carrots, celery, lettuce, radishes, beets, and spinach. Nevertheless, antioxidants such as ascorbic acid (vitamin C) or vitamin E are now often added to cured meats to help reduce nitrite reactions.

Other additives used as preservatives in processed meats include BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene), citric acid, potassium nitrite, propyl gallate, and EDTA (ethylenediaminetetraacetic acid). Potassium sorbate and propylparaben are used as preservatives to prevent mold growth on sausage casings. Flavoring additives include sucrose, sodium, sorbitol, corn syrup, glucose (dextrose), hydrolyzed vegetable (plant) protein, and MSG (monosodium glutamate). Papain is sometimes added as a meat tenderizer. Annatto, saffron, and turmeric are coloring agents used in sausage casings. Cochineal, derived from the dried female insect, *Coccus cacti*, generates a red color in some meat products.

"Natural" additives are sometimes used to accomplish the same goal as chemical additives. While "natural curing" is not a term recognized by the USDA, meats have been cured naturally for centuries in a wide variety of cultures, including those of ancient Egypt and Rome (3). Natural curing is sometimes used to refer to the use of microbes (typically bacteria) to convert nitrates in the environment to nitrites, which then react with meat to cure it. For example, the addition of harmless food-grade microorganisms and sea salt to meat can result in a natural curing process. Examples of other additives considered as natural curing agents include carrageenan (seaweed), sodium bicarbonate (baking soda), vegetable and fruit juices, vinegar, honey, sugar, food start cultures, and spices. Flavoring additives that are considered natural include celery, onion, garlic powder, and fruit or vegetable juices.

When meat is packaged and labeled as "natural," this term refers to the additives in the product, not the meat itself. This is because all meat is considered natural, irrespective of the antibiotics or hormones used in raising the animals (3).

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FIGURE 7-18 Selected additives used in processed meat and poultry products.

Butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), tocopherols (vitamin E)—Antioxidants that help maintain the appeal and wholesome qualities of food by retarding rancidity in fats, sausages, and dried meats.

Carrageenan—Seaweed is the source of this additive that may be used as a binder in meat products.

Citric acid—Widely distributed in nature in both plants and animals. It can be used as an additive to protect the fresh color of meat cuts during storage. Citric acid also helps protect flavor and increases the effectiveness of antioxidants.

Corn syrup—Sugar derived from the hydrolysis of cornstarch. Uses include flavoring agent and sweetener in meat and poultry products.

Emulsifier—Substance added to products, such as meat spreads, to prevent separation of product components to ensure consistency. Examples of these types of additives include lecithin, monoglycerides, and diglycerides.

Gelatin—Thickener from collagen that is derived from the skin, tendons, ligaments, or bones of livestock. It may be used in canned hams or jellied meat products.

Humectant—Substance added to foods to help retain moisture and soft texture. An example is glycerin, which may be used in dried meat snacks.

Monosodium glutamate (MSG)—A flavor enhancer. MSG comes from a common amino acid, glutamic acid, and must be declared as monosodium glutamate on meat and poultry labels.

Phosphates—The two beneficial effects of phosphates in meat and poultry products are moisture retention and flavor protection. An example is the use of phosphates in the curing of ham in which approved additives are sodium or potassium salts of tripolyphosphate, hexametaphosphate, acid pyrophosphate, or orthophosphates, declared as phosphates on labels.

Propyl gallate—Used as an antioxidant to prevent rancidity in products such as rendered fats or pork sausage. It can be used in combination with antioxidants such as BHA and BHT.

Sodium caseinate—Used as a binder in products such as frankfurters and stews.

Sodium erythorbate—The sodium salt of erythorbic acid, a highly refined food-grade chemical closely related to vitamin C, synthesized from sugar, and used as a color fixative in preparing cured meats.

Sodium nitrite—Used alone or in conjunction with sodium nitrate as a color fixative in cured meat and poultry products (bologna, hot dogs, bacon). Helps prevent growth of *Clostridium botulinum*, which can cause botulism in humans.

Whey, dried—The dried form of a component of milk that remains after cheese making. Can be used as a binder or extender in various meat products, such as sausage and stews.

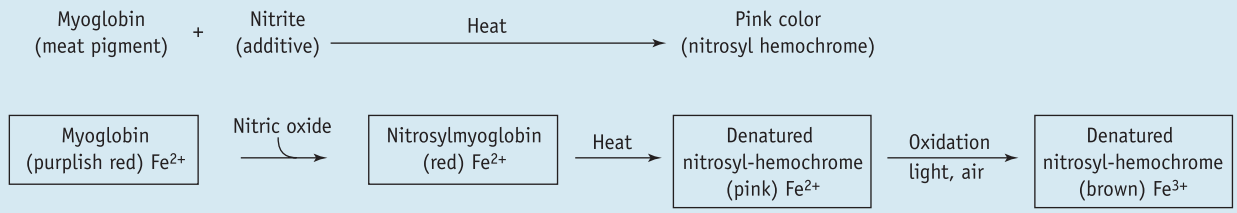
See Chapter 3 for more information about food additives in processed meats.

Source: Food Safety and Inspection Service, U.S. Department of Agriculture.

CHEMIST'S CORNER 7-7

Color Changes in Cooked Meats: Nitrites

Nitrite, a conjugate base of a weak acid named nitrous acid, provides color to processed meats by combining with the myoglobin pigment to produce nitrosyl myoglobin. This resulting compound denatures during the cooking phase of the curing process to form a pink-colored compound called nitrosyl hemochrome. One of the major problems of storing nitrite-cured meats is that continued exposure to oxygen and light oxidizes the iron from the ferrous (2^+) to the ferric form (3^+), which results in a brown discoloration. Additional oxidation of the pigment-containing protein's porphyrin ring, instead of the iron, results in a very undesirable yellow or greenish color, making the meat unappealing to consumers (41).



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Types of Processed Meat

Three types of meats are commonly processed: ham, bacon, and sausage. In addition, lower-fat processed meats are becoming popular with consumers.

Ham

Ham is cured pork, and according to USDA standards, only meat from the hind leg of a hog can be labeled ham. Several types of cooked ham products are available for purchase:

- ***Canned ham***. Boneless, fully cooked ham that can be served cold or heated. Most are cooked only to pasteurization temperatures, so they must be refrigerated. Sterilized hams are usually available only in cans of under 3 pounds. Gelatin is often added in dry form to absorb the natural juices of the ham as it cooks.
- ***Water-added ham***. Contains no more than 10% by weight of water added. The added moisture contributes to a moist, juicy, and tender texture.
- ***Imitation ham***. Ham that retains more than 10% moisture after curing.
- ***Country ham***. Ham cured by the dry salt method and usually hickory smoked to develop a distinctive flavor.
- ***Picnic ham***. Cured pork that comes from the front leg instead of back leg of the hog, and therefore cannot be labeled simply *ham*. This cut is less tender and higher in fat than regular ham.

Bacon

Bacon is cured and smoked meat from the side of a hog. It should be balanced in its proportion of fat to lean. When cooked, bacon with too much lean will be less tender, whereas bacon with too high a proportion of fat will shrink too much.

Sausage

Sausage originated in the Mediterranean (26). It is meat that has been finely chopped or ground and blended with various ingredients, seasonings, and spices. The seasonings usually include a curing salt, which is partly responsible for the distinctive flavor (56). It is then stuffed into casings or skins. Traditionally, the casings were made of the intestines of pigs or sheep, but now they are often manufactured from cellulose or collagen. The usual main ingredient is beef or pork, or a combination of the two. Other meats and meat combinations may be used, including veal, chicken, turkey, lamb, duck, rabbit, venison, and liver from any of several animals. Other ingredients that may be added include eggs, cream, oatmeal, breadcrumbs, potato flour, tripe, wine, and beer. Pork and/or beef fat are often added to boost the moisture content and enhance the texture. There are four major classifications of sausage:

- ***Uncooked.*** Made from ground, uncooked meat. Fresh pork sausage, bratwurst, mettwurst, and bockwurst are examples. New combinations of chicken, turkey, apple, and other lower-fat alternatives are available. Uncooked, fresh sausage has the highest moisture content, approximately 50 to 60% (56). Fresh sausage can be stored for several days, and requires cooking before ingestion.
- ***Raw fermented.*** Raw fermented sausage is kept at high temperatures, allowing the growth of bacteria. These bacteria produce lactic acid, which lowers the pH of the sausage (56). Examples of this type of sausage include merguez and Lebanon bologna, which is smoked. Raw fermented sausage must be cooked before eating.
- ***Cooked.*** Made from cured meat, which may be slightly smoked before being stuffed into the casings. Examples include hot dogs, bologna, and knockwurst. Chorizo, a spicy pork sausage native to Spain, may be sold fully cured and ready to eat or may require cooking at home.
- ***Dry/semidry.*** Made of cured meat that has been dried. Dry fermented sausage is thought to have originated in Italy in the early eighteenth century (56). Several decades later, the practice was adopted in Germany, where sausage became a major component of the local diet. Examples are pepperoni, salami, thuringer, and cervelat. Dried, cured sausage undergoes a ripening period during which the texture changes from a soft, pliable mass into a hard, sliceable, distinctly flavored sausage. The unique flavors of dry cured sausage result from the enzymatic breakdown of proteins, carbohydrates, and lipids to smaller compounds that exhibit intense aromas (20). Sausage is considered semidry when the weight decreases by 20%; these sausages have a moisture content of 35 to 50%. The pH of semidry sausage is around 5.0, and the water activity is above 0.86. Summer sausage is an example of semidry sausage. Dry sausage loses greater than 30% of its weight during the drying process, and generally has a moisture content below 35% (56). Italian Turista, salami, Spanish Salchichon, pepperoni, and French saucisson are types of dry sausage. Dry and semidry sausages can be fermented for various amounts of time. A fermentation process of 7 days or less is considered rapid, 3 weeks is considered regular, and greater than 3 to 4 months is considered slow (56).

Lower-Fat Processed Meats

Many processed meats contain 30 to 50% fat. Consumers have challenged processed meat product manufacturers by demanding foods that are lower in fat and cholesterol. Many processed meats are available in versions that are 95% or more fat-free.

Lower-fat processed meat products are produced by using leaner cuts of meat, adding more water, and/or including ingredients such as fiber, gums, modified starches, and whey protein concentrate (47). Water can be substituted for fat in processed meats as long as the total amount of fat and water does not exceed 40%, with a maximum fat content of 30%. Less fatty ingredients, including fat replacers (see Chapter 22 on fats and oils), may also take the place of more fatty ones.

The federal government used to define certain processed products by a minimum amount of fat, but these regulations have been changed in light of dietary recommendations. For example, cooked frankfurters had been required to contain about 30% fat, but a 1998 change in regulations lowered it to 20%. Sausages used to average 43% fat, but sausages are now available that do not exceed 15% fat (10).

Mechanically Deboned Meat

The traces of meat that are left on the bones after butchering can be collected and sold as mechanically deboned meat. This is accomplished by grinding the remaining meat and bones together, and

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removing the bone by putting the mixture through a sieve. The resulting meat contains ground bone, bone marrow, and soft tissue and is most commonly used in meat products that are undergoing further processing. The presence of the bone increases the calcium and trace mineral content of the meat. Processed meat products containing up to, but no more than, 20% mechanically deboned meat must include the designation "mechanically separated meat" on the food product's ingredient list.

Restructured Meat

Restructured or fabricated meat is made from meat trimmings and/or lower-grade carcasses. It is similar to real meat in texture, flavor, and appearance, but is less expensive. The meat trimmings are broken down to particle size by flaking, shredding, grinding, or chopping and are then bound together into uniform shapes and sizes. Some natural binding between the meat's proteins occurs, but binding is further accomplished by adding non-meat ingredients such as egg albumen, gelatin, textured soy protein, and wheat or milk proteins (55). The uniformity in shape and weight of the types of products made possible with restructured meat makes it ideal for the fast-food industry and food-service establishments.

PREPARATION OF MEATS

Meat is usually the most expensive portion of a meal; therefore, its preparation is usually given extra consideration. It's important to observe the changes in the meat during heating, to look for signs of doneness, and to realize the differences between dry-heat and moist-heat preparations. The meat cut selected partially determines how the meat will be prepared. Some cuts are naturally tender, whereas others are tough, so preparation methods must vary accordingly. Tender cuts lend themselves to dry-heat methods such as roasting, broiling, grilling, and frying, whereas tougher cuts are better for long, slow, moist processes such as braising, stewing, or steaming.

Whether meat is prepared by dry-heat methods or by any of the various moist-heat methods, it should first be wiped with a paper towel to remove any surface moisture. Leaving water on the meat or washing it will result in a faded color and the loss of some water-soluble nutrients and flavor compounds. After it is wiped, the meat can be trimmed of any visible fat or connective tissue to reduce kcalories and increase tenderness. If the meat is a tougher cut, it can be tenderized according to the techniques discussed earlier.

For best results when preparing frozen meats, thaw them thoroughly in the refrigerator or microwave before cooking. Cuts prepared from the frozen state take longer to heat and are less energy- and cost-efficient. A frozen roast may take up to three times longer to prepare than a thawed roast. Frozen cuts are more difficult to heat evenly, and the center may remain frozen even though the outside looks perfectly done.

Changes during Heating

Tenderness and Juiciness

Cooking meats at the correct temperature for the right amount of time will maximize their tenderness, juiciness, and flavor. Although heat makes meat more palatable, exposing it to high temperatures for too long will toughen, shrink, and harden meat because such exposure shortens muscle fibers, denatures proteins, and causes the meat to dehydrate (1). Even with proper cooking, it is not unusual for a 4-ounce piece of meat to be cooked to 3 ounces. During heating, the collagen molecule begins to denature at 102°F (39°C) and collapses at 149°F (65°C), resulting in a considerable loss of volume and length in the meat (see Chemist's Corner 7-8). Another factor contributing to meat shrinkage is the freeing of some water as the meat's other proteins denature and lose their water-binding capacity. Tenderness starts to decrease as temperatures reach 104°F (40°C). Longer cooking at lower temperatures makes meat, especially the tougher cuts, more tender by breaking down the collagen, which often gelatinizes during cooling (41).

As has been mentioned, any fat in the meat melts as it is cooked, which increases tenderness, juiciness, and flavor. When meat is very lean, it may be desirable to add fat to it. Fat may be added by two older techniques known as **larding** and **barding**.

CHEMIST'S CORNER 7-8

Effect of Temperature on Meat Components

Meat becomes tender when cooked because of the breakdown of its protein, fat, and connective tissue with increasing temperatures (6). From a biochemical standpoint, specific components of meat are affected at different temperatures:

- 100°F (38°C): Proteins begin to unfold; the meat appears red, soft, and slippery.
- 120°F (49°C): Proteins coagulate (clump together) and lose water; the meat appears very firm and pink.
- 140°F (60°C): Connective tissue shrinks, and more moisture is lost; the meat appears pinkish-brown and visibly loses juices.
- 150°F (66°C): Connective tissue begins dissolving into a gelatin-like substance, and proteins are densely packed; meat appears brown and shrunken, and starts to taste tough.
- 170°F (77°C): Proteins are entirely coagulated, and most of the moisture is lost; meat tastes hard and dry.

Searing

It was once thought that **searing** would help to keep the juices inside a piece of meat as it cooked. It is now known that roasts heated at low temperatures for the entire cooking time retain more juices than those that are seared.

Larding Inserting strips of bacon, salt pork, or other fat into slits in the meat with a large needle.

Barding Tying thin sheets of fat or bacon over lean meat to keep the meat moist during roasting. The sheets of fat are often removed before serving.

Searing Cooking that exposes a meat cut to very high initial temperatures; this is intended to seal the pores, increase flavor, and enhance color by browning.

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How & Why?

Does heating tenderize or toughen meat?

When meat is heated, the muscle fiber proteins denature, unfold, coagulate, and toughen, beginning at around 100°F (38°C). However, heat causes hydrogen bonds in collagen to be broken, some collagen is converted to gelatin, and as a result the connective tissue softens and becomes more tender. This process is negligible at 140°F (60°C) but occurs more rapidly as the temperature is increased. Consequently, there is tension between these opposing effects; softening of connective tissue occurs at temperatures that cause toughening of the muscle proteins. This explains why the recommended cooking method depends on the amount of collagen present. Cuts of meat with little or no collagen are inherently tender and should not be overcooked, or they will become tough. On the other hand, meat with considerable amounts of collagen will be tough unless the collagen is softened during the cooking process. Tough cuts of meat are therefore cooked slowly and preferably using moist heat to solubilize the collagen and produce tender meat.

Searing still remains a valuable technique for increasing the flavor and color of meat, however, because it caramelizes the outside, sealing in the flavor. To sear a piece of meat, place the meat in a pan that is already extremely hot, and leave it in the pan long enough for it to form a rich, brown crust. Trying to move the meat too early in the searing process will destroy the crust formation (45).

Flavor Changes

Natural compounds in meat yield that characteristic meat flavor, but other factors contribute to flavor as well, including protein coagulation, melting and breakdown of fats, organic acids, and nitrogen-containing compounds. The trace amount of carbohydrates in meat contributes to the special flavor of browned meat surfaces as these sugars react with proteins in the Maillard reaction, producing the desirable brown color. Storing meat for more than 2 days in the refrigerator or heating leftover meat can result in an unfavorable warmed-over flavor (WOF), which is best avoided by reheating the meat in a microwave oven (Chemist's Corner 7-9) (21).

CHEMIST'S CORNER 7-9

Warmed-Over Meat Flavor

The WOF in reheated meat is a major contributor to quality deterioration. It is thought to be caused by the oxidation of the meat's unsaturated fatty acids, which results in various off-flavor substances (e.g., hexanal) (24).

Flavor Enhancements

The flavor of baked or broiled meat can be enhanced by basting and seasoning. If the seasoning includes salt, however, some professional chefs recommend adding it only after the meat has been slightly browned because salt draws out juices and retards browning. Meat is basted by brushing the meat drippings or fat-based marinade over its surface to help it retain moisture and flavor. Self-basting can be achieved by barding. Seasoning prior to heating may improve flavor if the seasoning becomes part of the crust. Marinating meat is a flavorful way to preseason it, whereas prepared sauces may be served with the meat (Figure 7-19). Sauces and their preparation are discussed further in Chapter 18. In addition to sauces, condiments can also be used to add flavor to meats. Those frequently served with meat include steak sauces, ketchup, seasoned butters, salsas, and chutneys and fruit sauces, such as mint sauce for lamb cuts.

FIGURE 7-19 Sauces for beef.

Aujus—Natural beef juices

Béarnaise—Thick sauce of egg yolks, white wine, tarragon vinegar, and herbs

Béchamel—Seasoned white sauce

Bercy butter—Shallots cooked in white wine mixed with creamed butter and parsley

Beurre noir—Clarified butter with vinegar or lemon juice

Bordelaise—Brown sauce with red wine, shallots or green onions, herbs, and lemon juice

Brown (sauce espagnole)—Flavorful beef sauce used as a base for others sauces

Chasseur—Brown sauce with mushrooms, tomato sauce, and tarragon

Chili salsa—Chopped tomato, onion, and green chili pepper

Choron—Béarnaise sauce and tomato

Colbert—Béarnaise sauce and meat glaze

Hollandaise—Thick sauce of egg yolks, melted butter, and lemon juice

Madeira—Brown sauce and Madeira wine

Maître d'hôtel sauce—Béchamel sauce with butter, lemon juice, parsley, and tarragon

Marchand de vin—Red wine, parsley, green onions, and lemon juice

Meunière—Browned butter with lemon juice and parsley

Mornay—Creamy cheese sauce

Périgueux—Wine sauce with diced truffles

Robert—Brown sauce with mustard, onion, tomato, and pickle

Determining Doneness

Several changes occur in meat during cooking, and a multitude of factors affect the cooking times of meats: the effects of carryover cooking; differences in the type, size, and cut of meat; the presence of bones, which conduct heat faster than flesh, or of fat, which acts as an insulator; the oven temperature; the temperature of the meat before heating; and variations in the degree of doneness preferred by the preparer. Various methods are used to determine doneness, and sometimes more than one method is used. Those discussed below include internal temperature, time/weight charts, color changes, and touch.

Internal Temperature

Using a meat thermometer is the most accurate method of determining

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doneness. Several different styles of meat thermometer are available on the market; some are inserted into meats before heating, and others, such as instant-read thermometers, can be inserted at any time. The thermometer should be inserted into the thickest portion of the meat and in such a way as not to touch any fat or bone. Meat thermometers should be thoroughly sanitized after each use.

The USDA advises that meats should be allowed to reach an internal temperature of at least 145°F (63°C) and then to rest for 3 minutes prior to consumption. Table 7-7 gives the internal cooking temperatures indicating doneness for various meats.

Ground meats are required to reach higher temperatures before serving. In January 1993, following a highly publicized outbreak of *E. coli* in the Northwest, health departments across the United States and the USDA increased the required preparation temperature for hamburgers served by eating establishments from 140°F (60°C) to 160°F (71°C).

How & Why?

Why is it safe to consume rare steaks but not rare hamburgers?

Rare steaks are intact muscles and thus are sterile on the inside unless they have been pierced for some reason. Heating kills the surface bacteria, which is why steaks may be eaten rare. Ground meat, on the other hand, has had its surface tissue (and bacteria) literally ground into its interior, so it must be sufficiently heated to kill any possible pathogens located in the center.

TABLE 7-7 Internal Temperatures Recommended for Cooked Meat

Meat	Description	Color/Appearance	Internal Temperature* °F	°C
Beef	Rare	Rose red in center; pinkish toward outer portion, shading into a dark gray; brown crust; juice bright red	140	60
	Medium	Light pink; brown edge and crust; juice light pink	160	70
	Well done	Brownish gray in center; dark crust	170	77
Veal	Well done	Firm, not crumbly; juice clear, light pink	165	74
Lamb	Rare	Rose-red in center; pinkish toward outer portion; brown crust; juice bright red	140	60
	Medium	Light pink; juice light pink	160	70
	Well done	Center brownish gray; texture firm but not crumbly; juice clear	170	77
Pork				
Ham				
Fully cooked or canned	Heated	Pink	130–140	55–60
Cook before eating	Medium	Pink	140	60
Smoked loin	Medium	Pink	160	70
Fresh rib, loin, picnic shoulder	Well done	Center grayish white	170	77

*The USDA recommends 145°F (63°C) as the minimum temperature for cooked meats; professional chefs may use lower temperatures.

Source: USDA.

When measuring internal temperature, it is important to adjust for **carryover cooking**. This can result in an average temperature increase of 10 to 15°F (6 to 8°C) for average-size roasts. Very large roasts can have as much as a 25°F (14°C) increase in temperature, whereas small cuts may rise only 5°F (3°C) in temperature. To adjust for this carryover cooking, most roasts should be removed from the oven when the internal temperature is 10 to 15°F (6 to 8°C) below the final desired degree of doneness. Meat cooked at a low temperature such as 200 to 250°F (93 to 12°C) will experience only minimal carryover cooking. Depending on their size, roasts should be allowed to stand for 15 to 30 minutes in order to distribute the heat and juices.

Time/Weight Charts

Time/weight charts, such as the one shown in Table 7-8, are useful in estimating roughly how long it will take to cook a piece of meat, but they are unreliable if used alone because of the many factors that can affect doneness. Instead, a combination of criteria is used to determine the doneness of meats: time/weight charts, color changes, internal temperature, and touch.

Color Changes

Meat pigments change color as the meat is cooked. Doneness can be determined by observing the following colors in red meats:

- ***Rare.*** Strong red interior. Rare meat does not reach a final internal temperature considered microbiologically safe.
- ***Medium.*** Rosy pink interior and not quite as juicy as a rare piece of meat.
- ***Well done.*** Brown interior. No traces of red or pink left. Moist, but no longer juicy.

Veal and pork are known as "white meats," in part because they change from a pinkish to a whiter color as they are heated to the well-done stage.

Carryover cooking The phenomenon in which food continues to cook after it has been removed from the heat source as the heat is distributed more evenly from the outer to the inner portion of the food.

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TABLE 7-8 Time/Weight Chart for Roasting Beef

Cut	Approximate Weight (pounds)	Oven Temperature (°F)	Approximate Cooking Time (minutes per pound)		
			Rare	Medium	Well
Rib roast	4–6	300–325	26–32	34–38	40–42
	6–8	300–325	23–25	27–30	32–35
Rib eye roast	4–6	350	18–20	20–22	22–24
Boneless rump roast	4–6	300–325	—	25–27	28–30
Round tip roast	3½–4	300–325	30–35	35–38	38–40
	6–8	300–325	22–25	25–30	30–35
Top round roast	4–6	300–325	20–25	25–28	28–30
Tenderloin roast					
Whole	4–6	425	45–60 (total)		
Half	2–3	425	35–45 (total)		

According to the USDA, pork should be heated at least to an end-point temperature of 145°F (63°C). Color may not be a good indicator for doneness in meat from older swine, which is often grayish-brown rather than pink (22). It is not recommended that color be used to judge the doneness of hamburger, either, because of the risk of *E. coli* O157:H7 contamination.

Touch

Doneness can be determined by the firmness of the meat. Some meat cuts such as steaks and chops can be judged for doneness based on their color and firmness. Pressing lightly on the center of the lean tissue can help to determine whether the meat is rare, medium, or well done (Figure 7-20). This technique takes a fair amount of experience to master and is most often used by professional chefs who frequently prepare steaks.

Dry-Heat Preparation

Tender cuts are usually prepared by one of the dry-heating methods: roasting (baking), broiling, grilling, pan-broiling, and frying.

Roasting

Roasting is the heating of moderate-to-large, tender cuts of meat in the dry, hot air of an oven. A roast will usually be at least 2½ inches thick and provide more than three servings. The meat is placed fat side up (if it has any) on a rack in an open pan. The rack prevents the meat from sitting in its own juices, which would cause the meat to simmer rather than to roast. If a rack is not available, one can be made by lining up carrots and celery stalks lengthwise across the bottom of the pan. Figure 7-21 shows examples of cuts suitable for roasting.

Temperatures from 300 to 350°F (149 to 177°C) are recommended for roasting and should produce an evenly cooked, easy-to-carve, juicy, tender, flavorful roast with a greater yield than roasting at higher temperatures would have produced. Higher temperatures of 350 to 500°F (177 to 260°C) are recommended to produce roasts with deeply seared crusts in less time, but the higher oven temperatures cause greater shrinkage. In general, it usually takes 18 to 30 minutes of roasting time for every pound of meat. As previously mentioned, roasts should be removed from the oven slightly before their final desired temperature is reached and allowed to stand for 15 to 30 minutes in order for carryover cooking to occur. This will also make carving easier and result in a more evenly juicy roast.

Broiling and Grilling

Smaller cuts of tender meat ranging from 1 to 3 inches in thickness can be broiled or grilled. High temperatures and short heating times keep the meat tender. Broiling and grilling times are based primarily on the meat's thickness and its distance from the heat (Table 7-9). Ovens, whether electric or gas, need at least 15 minutes to reach the desired temperature, whereas charcoal or wood fires need at least 25 minutes to burn down to the required heat. Beef retail cuts suitable for broiling include the following steaks

FIGURE 7-20 Touch as a test for doneness.



Rare: Shake, dangle, and relax right hand; pressing the area between thumb and index finger feels similar to rare steak—soft and yielding to slight pressure.



Medium: Stretch out the right hand and tense the fingers; the springy firmness is similar to the resistance felt in medium-cooked meats.



Well done: Harden the right hand into a tight ball; this hard and unyeilding feeling with all the springiness gone is how well-done meat feels.

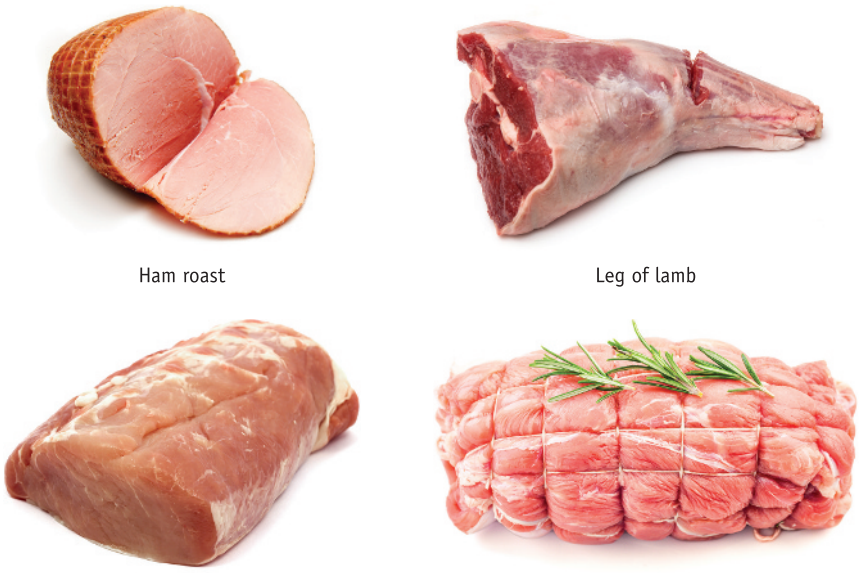
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FIGURE 7-21 Examples of tender roast cuts.



Ham roast

Leg of lamb

Pork center-cut loin

Veal roast

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TABLE 7-9 Time/Weight Chart for Broiling Sirloin Steak

Approximate Thickness (inches)	Approximate Weight (pounds)	Distance from Heat (inches)	Approximate Cooking Time (total minutes)		
			Rare	Medium	Well
¾	1¼ to 1¾	2 to 3	10	15	—
1	1½ to 3	3 to 4	16	21	—
1½	2¼ to 4	4 to 5	21	25	—

in descending order of tenderness: filet mignon, strip loin, Delmonico, rib eye, top butt sirloin, chuck tender, and top round. A very light layer of oil on the meat will keep it from sticking to the grill, whereas using a marinade, spice rub, or adding sauces during basting will yield more flavor.

The goal in either broiling or grilling is to simultaneously heat the inside of the meat while achieving just the right degree of browning on the exterior. The thickness of the cut and the desired level of doneness dictate the intensity of the heat, which is controlled by altering the distance of the meat from the heat source, from 2 inches for cuts less than 1 inch thick to up to 5 inches for thicker cuts. When broiling thicker steaks or those to be well done, the broiler rack in an electric oven should be lowered and the door left open to prevent steam from accumulating, thereby preventing the meat from browning. Gas broiler doors are left closed.

The oven, broiler, or grill should be preheated. Then the meat should be placed under the broiler or over the coals and heated until one side is brown. Tongs should be used to turn the meat, but if a fork is used, it is best inserted into the fat trim to avoid letting the juices escape. The second side is heated to the desired stage of doneness. When heating is complete, remove and serve immediately. One of the benefits of using a grill is that attractive, appetizing grill marks can be made by turning the meat over according to the pattern depicted in Figure 7-22.

Pan-Broiling

Very thin cuts of meat (less than ½ inch) can be pan-broiled to achieve a tasty outside crust without overcooking the meat. In this method, heat is applied directly through the hot surface of a heavy pan or flat grill (Figure 7-23). Thin, tender cuts of beef steaks, lamb chops, and ground-beef patties are perfect for pan-broiling. Place the meat on the hot surface of the preheated pan with no added fat or oil. Any drippings should be drained during heating to prevent frying. The meat can be seasoned before, during, or after placing it in the pan.

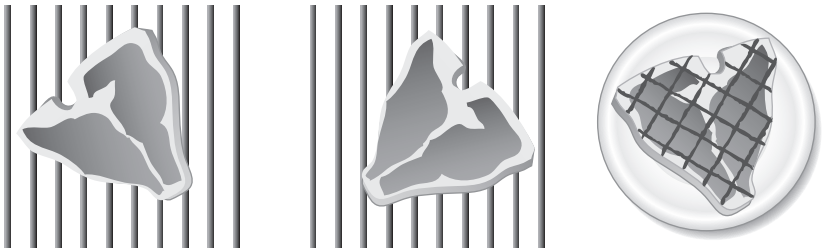
Frying

Sautéing, pan-frying, and deep-frying are suitable for tender, small pieces of meat that are low in fat or that have a breaded coating.

Sautéing

Sautéing is identical to pan-broiling except that a small amount of fat is heated to the sizzling point before the meat is added. Examples of sautéed meat dishes include liver and onions, veal Oscar, veal piccata, and veal cordon bleu. Liver should be salted after it is sautéed, or it will toughen and shrivel. Stir-frying is a type of sautéing that has become increasingly popular. For stir-frying, thin slices of meat are cooked in an oiled wok or other pan with sloping sides. The meat is stirred constantly over high heat for about 3 minutes to promote even heating. When the meat is done, it is moved to the side, and chopped vegetables are added to the pan. As soon as they are barely tender, they are mixed with the meat and any desired sauces or flavorings.

FIGURE 7-22 Technique for making grill marks: Rotate clockwise a quarter of a turn (or point at 10 a.m., and then turn to 2 p.m.).



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FIGURE 7-23 Pan-broiling.



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1. Place beef in preheated frying pan.
2. Do not add oil or water. Do not cover.
3. For cuts 5⁄8 inch to 1 inch thick, cook slowly, turning occasionally. For cuts thicker than ½ inch, use medium to medium-low heat. For thinner cuts, use medium-high heat.
4. Pour off excess drippings as they accumulate.
5. Season if desired.

Pan-Frying

In pan-frying, more fat (but no more than up to ½ inch deep), lower heating temperatures, and longer cooking times are used than what is common in sautéing. Typically, pan-fried meat cuts are larger and include steaks (Figure 7-24), chops, and sliced pieces of liver. Meats are often seasoned and coated with flour or breading before pan-frying. The fat used in sautéing or in pan-frying should be vegetable oil or clarified butter. The low smoking temperatures of whole butter and margarine make them unsuitable for frying. An alternative to frying steaks and chops in oil is to use a nonstick pan or to sprinkle the pan with a thin layer of salt. The pan is heated until a drop of water hisses; the meat is then added, fried, and turned when the underside has reached the desired brownness.

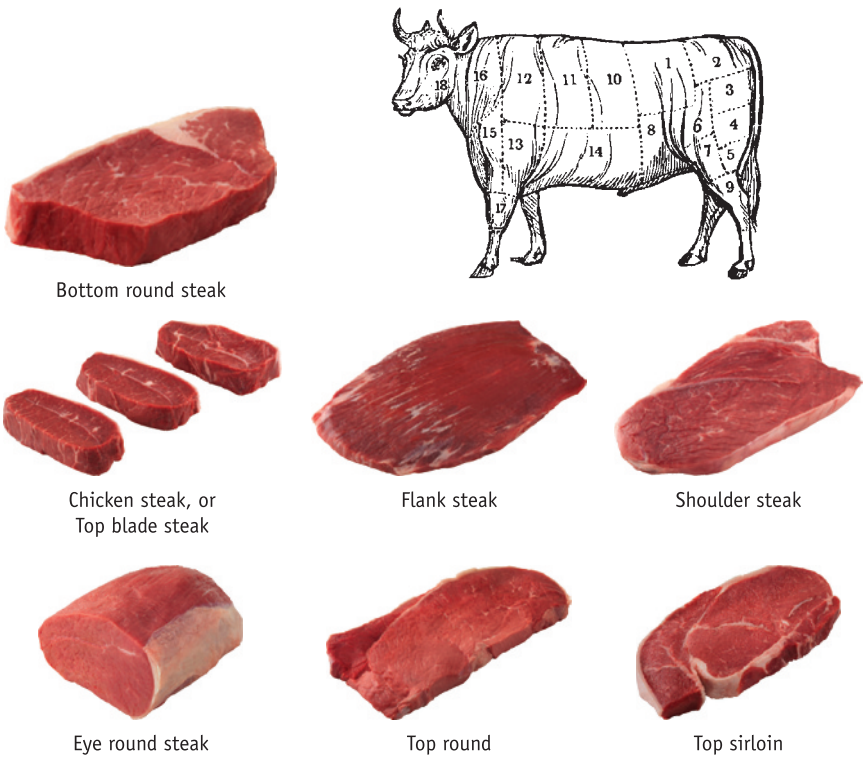
Deep-Frying

Meat, with the exception of chicken-fried steak, is seldom deep-fried. When it is, the meat is usually cut into small pieces and dipped in seasoned flour or cornstarch, placed in a wire basket, submerged in oil preheated to 300 to 360°F (149 to 182°C), and fried until golden brown.

Moist-Heat Preparation

Less tender cuts of meat, which tend to come from more heavily exercised muscles or older animals, are usually prepared by moist-heat methods such as braising, simmering/stewing, or steaming.

FIGURE 7-24 Cuts of steak suitable for pan-frying (if less than ½ inch thick).



Source: USDA

Braising

Braising combines dry and moist heat methods. The meat is first seared or sautéed and then simmered in a covered pan in a small amount of water or other liquid. It is ideal for less tender cuts such as beef chuck, round steak, and flank steak because braising breaks down collagen and tenderizes the meat. Braising can transform a meat's texture from tough to fork-tender (54). Some smaller meat cuts such as round steaks, pork and veal chops, and organ meats are also good candidates for braising. The most common braised meats are pot roasts, which are large cuts of meat cooked whole and served in slices covered with their own cooking liquid. Adding vegetables completes the meal and adds color. Chopped vegetables commonly added to pot roasts include potatoes, carrots, onions, celery, and tomatoes.

Although not necessary, browning the meat prior to adding the liquid improves the final color and flavor. Before browning, the meat should be dried with a paper towel; sometimes, it is dredged with seasoned flour. As with any browning, it is essential not to overcrowd the pan and to brown the meat in batches, if necessary.

After the liquid is added, the pan is covered, and the liquid is brought to a simmer; boiling must be guarded against because it will toughen the meat. The goal is to simmer the meat until it is tender. When braising, doneness is determined by fork tenderness. The flavor of the braising liquid can be enhanced by the addition of wine, soup stock, marinades, seasonings, or tomato products. Only enough liquid to produce steam should be added—no more than 1 inch. If too much liquid is used, it can reduce the flavor by sheer dilution.

Simmering or Stewing

Simmered or stewed meat is usually cooked completely submerged in liquid. The pan is covered, brought to simmering (not boiling), and cooked until the meat is tender. Fricassees are stews in which the meat is first browned in fat. Stews, unlike other simmered meats, are served in their own cooking liquid mixture, thickened or not, as desired, and usually contain vegetables added during the last hour of heating. Cured meats, such as corned beef or tongue

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and fresh beef brisket cuts, are commonly prepared by stewing. They are not browned first, and the cooking liquid, which has very little flavor, is usually discarded.

Steaming

Steaming exposes food directly to moist heat. Meats can be steamed in a pressure cooker or in a tightly covered pan. They can also be wrapped in aluminum foil or placed in a plastic oven bag, which is then placed in a heated oven. Oven bags are heat-resistant nylon bags made to withstand oven temperatures in order to provide steam to foods that are being roasted. They are used to cook a variety of foods but are most often used for cooking large cuts of meat such as turkey, ham, or beef roasts. Because the meat cannot be observed during heating in a pressure cooker, its doneness is determined by timing. Meats also heat very well in a crockery cooker, an electrical appliance that will gently steam meat to extreme tenderness with only a little added liquid. Depending on the size and toughness of the cut, this may take anywhere from 6 to 12 hours. The long heating time and relatively low temperature may pose food safety concerns, however (see Chapter 4).

Microwaving

Microwave ovens are usually not the best option for cooking meats, except for thawing and reheating leftovers. They decrease juiciness, do not brown, and do not heat sufficiently to kill pathogens such as *Trichinella spiralis*. Microwave ovens heat food unevenly causing localized cold spots and allowing some pathogenic bacteria to persist. Microwaved meats do not taste the same as meats cooked by other time-tested methods, primarily because they do not get browned. Brown condiments such as Kitchen Bouquet, Worcestershire sauce, soy sauce, or steak or barbecue sauces can be used to add color to the meat or to cover it up, hiding the fact that the surface appears uncooked. Microwave browning skillets and grills are also available, but the flavor and texture problems remain the same.

Carving

Meat should not be sliced in just any manner because the way it is sliced affects its tenderness. The first step in slicing meat is to determine the direction in which the muscle fibers run, called the *grain*. The grain is visible on the surface of the meat. It may be difficult to find in larger cuts such as roasts because they consist of parts of several different muscles, each with its own grain. When carving meats, it is important to cut across the grain to increase tenderness (Figure 7-25). Cutting across the grain shortens the muscle fibers into smaller segments, making the meat easier to chew.

FIGURE 7-25 Carving across the grain.



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STORAGE OF MEATS

Meat contains high percentages of water and protein, both ideal for the growth of microorganisms. Consequently, meat should be stored in the refrigerator or freezer. Raw meat and poultry are stamped with "use by" dates on the packaging; they should be cooked or frozen by this date. After cooking, ground meat can be stored up to 2 days, and whole cuts of meat can be stored for 3 to 5 days.

Refrigerated

Meats are best refrigerated at just above freezing (32°F [0°C]), between 32°F and 36°F (0 to 2°C). They do not freeze until the temperature drops to below 28°F (−2°C). The best place to store meats in the refrigerator is in the coldest part. Many refrigerators have an area or a compartment reserved for meat storage.

Wrapping Meat

Most retail meats are packaged with plastic wrap and can be refrigerated in their original wrap for up to 2 days. After that time, the store wrapping should be removed and replaced by loosely wrapped plastic wrap, wax paper, or aluminum foil. Leaving the tight store wrapping on meat for more than 2 days creates moist surfaces, which promote bacterial growth and deterioration of the meat. Exceptions to this general storage guideline are hams and other processed meats that are high in salt. They should not be stored in aluminum foil because the salt's corrosive action on aluminum foil will cause discoloration of the meat. Cured meats are also high in fat, which quickly turns rancid when exposed to oxygen and light. For this reason, ham and other processed meats are best stored in the refrigerator in their original wrappings.

Refrigeration Times

General guidelines suggest that fresh meat should not be stored in the refrigerator longer than 3 to 5 days and that ground meats and variety meats should be cooked within 1 or 2 days (see back inside cover of this book) (44). Variety meats are more perishable than regular meat cuts and should be used within a day or two of purchase or

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frozen immediately. Cooked meat can be kept for about 3 to 4 days. If the meat needs to be kept longer than the recommended storage times, it should be frozen.

Packaging

How long meat can be stored depends on its packaging—polystyrene (Styrofoam™) tray, fas-flushed tray, or vacuum packaging (52).

- ***Polystyrene tray***. The most popular packages for fresh meat are polystyrene trays with a soaker pad on the bottom to absorb meat juices. The plastic wrap over the top is not sealed, so juices can leak out. It is also permeable to air, allowing oxygen into the package, which keeps the meat looking red for 2 to 4 days. These packages should be inserted in a plastic bag during transport to avoid contamination. Brown discoloration does not affect the quality or flavor of the meat until several days later. Odors and a sticky texture are better indicators of spoilage than a faded color. The total refrigerated life of these trays is 5 to 7 days, so the sell-by-date is usually 3 days after cutting. After that, they should be cooked or frozen.
- ***Fas-flushed tray***. These thicker polystyrene or more rigid polypropylene trays are easily recognized by higher sides that leave extra space above the meat. The higher vertical sides entrap more oxygen, allowing the meat to stay red longer during dark storage (the meat will become discolored in half the time when exposed to light because of the extra oxygen) and extending the refrigeration time to 10 days for whole meat cuts and 14 days for hamburger. However, this type of packaging is not suitable for freezing because the extra oxygen will dry out the meat, which enhances freezer burn.
- ***Vacuum packaging***. One alternative to storing fresh meats for long periods of time at refrigeration temperatures is a patented, controlled-atmosphere package (CAP) available only to meat wholesalers. It can extend the shelf life of fresh red meat from several days up to 28 days. The CAP process involves placing the meat in a special package that allows the removal of oxygen and its replacement with a mixture of 70% nitrogen and 30% carbon dioxide (48). Precooked meat can also be vacuum packaged in a pouch against a cardboard sleeve, resulting in storage times of up to 90 days.

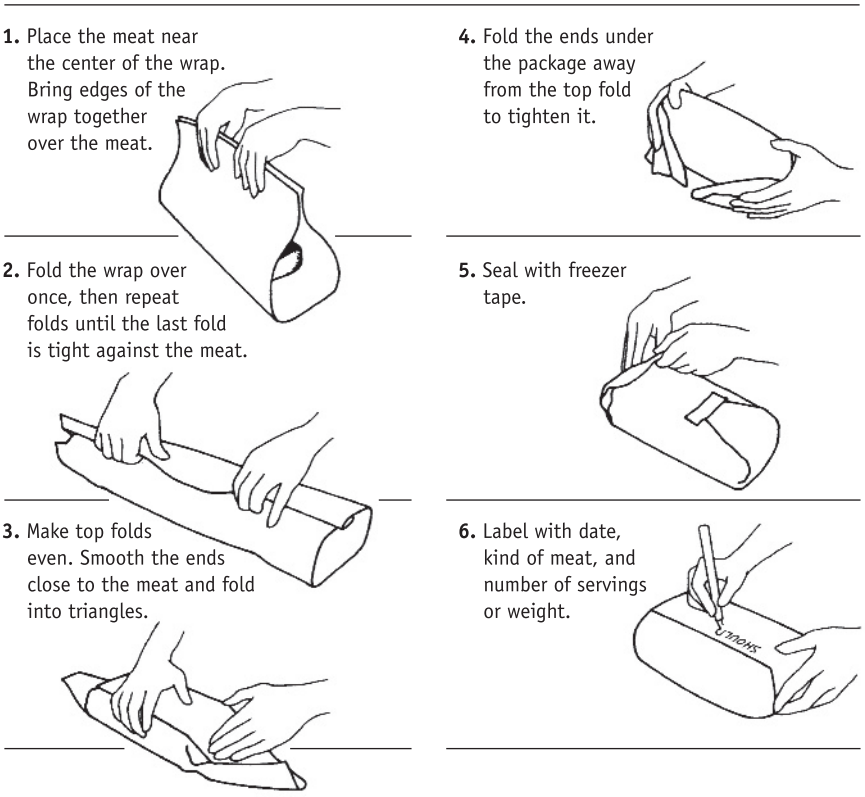
Frozen

Meats to be frozen should be wrapped tightly in aluminum foil, heavy plastic bags, or freezer paper and stored at or below 0°F (−18°C) (Figure 7-26). It is a good idea to first trim meat of bone and fat and to divide it up into individual servings before wrapping and freezing it. Most beef cuts can be kept frozen for 6 to 12 months, but ground beef should be frozen for no longer than about 3 months (see back inside cover of this book). The colder temperatures reached by commercial freezers can kill *T. spiralis* if it is held for at least 20 days at 5°F (−15°C). If not frozen to this degree, pork should always be cooked to the recommended temperature of 145°F (63°C). Wrappers often hide the identity of their contents, so the packages of frozen foods should be labeled and dated. It is better to make more frequent purchases than to freeze meat for extended periods of time, which can reduce its quality.

The texture and flavor of thawed meats will be adversely affected if they are refrozen. Freezer burn, caused by loss of moisture from the frozen food's surface, can result if meat is stored longer than the recommended storage time or wrapped in materials that are not vapor-proof or are punctured. The dehydration of freezer burn causes a discolored surface on the meat that becomes very dry, tough, and somewhat bitter in flavor when cooked.

Although freezing prevents bacterial growth and kills some bacteria, it does not kill them all, and those that are viable will multiply during the thawing process. For this reason, thawing must be carefully controlled to prevent significant growth of any pathogenic bacteria that are present.

FIGURE 7-26 Wrapping meat for freezing (apothecary or drugstore method).



Source: National Livestock and Meat Board.

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PICTORIAL SUMMARY / 7: Meat

Usually the most expensive item on a menu, meat serves as an important source of complete protein. In North America and Europe, the main sources of meat are herbivores, such as beef cattle, sheep, and swine.

TYPES OF MEATS



Beef. Most beef is supplied by steers, male cattle that are castrated while young so that they will gain weight quickly. Heifers, females that have not borne a calf, are also used for meat.



Veal. Veal comes from male and female calves of beef (and dairy) cattle between the ages of 3 weeks and 3 months. These animals are fed a milk-based diet and have their movements restricted for a more flavorful and tender meat.



Lamb. Lamb comes from sheep less than 14 months old; the meat from older animals is sold as mutton.



Pork. Most pork comes from young swine of either sex. In the past 30 years, pork has been bred to be leaner and more tender.

COMPOSITION OF MEATS

Meats consist of muscle, connective tissue, adipose (fatty) tissue, and bone. In meat cuts, the fat deposited in the muscle is visible as white streaks, called "marbling." In terms of nutrient composition, meat is primarily water, high-quality protein, fat, some minerals, and B vitamins. Meat is not a good source of carbohydrates, fiber, or vitamin C.



Source: USDA

PURCHASING MEATS



Meat inspection is mandatory in the United States, but grading is voluntary. There are quality grades for beef, veal, lamb, and mutton. Factors considered in grading are color, grain, surface texture, and fat distribution. Yield grades are ranked from 1 (highest) to 5 (lowest), and they indicate the amount of lean meat in proportion to fat, bone, and other inedible parts.

Tenderness in meats is due in part to natural influences such as the cut, marbling, animal age, heredity, diet, and slaughtering conditions. Meats can be artificially treated to make them more tender by aging; adding enzymes, salts, and acids; or subjecting them to mechanical or electrical treatments.

Kosher meats have met standards set by Jewish religious law.

Variety meats include the liver, sweetbreads (thymus), brain, kidney, heart, tongue, tripe (stomach lining), and oxtail of the animal.

Processed meats such as ham and sausage are preserved by curing, smoking, cooking, canning, or drying.

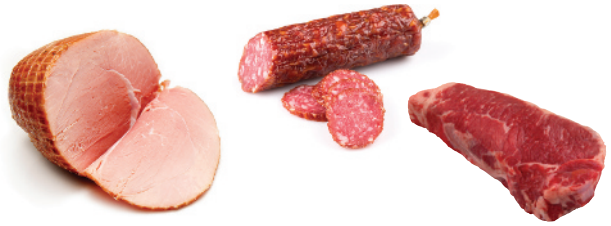
PREPARATION OF MEATS

Meat should be sponged clean of any moisture with paper towels and trimmed of fat before being prepared. Doneness of meats can be determined by a combination of time/weight charts, color changes, internal temperature, and touch. Tender meats are best prepared by dry heat (roasting/baking, broiling, grilling, pan-broiling, and frying), whereas moist-heat methods (braising, simmering, stewing, and steaming) are best for tougher cuts.



STORAGE OF MEATS

All meats should be refrigerated or frozen according to recommended temperatures. They should be held in the refrigerator no longer than the suggested maximum times, usually 3 to 5 days, although ground and variety meats will last only 1 or 2 days. Most meats can be kept frozen for 6 to 12 months if properly wrapped to avoid freezer burn caused by moisture loss.



Source: USDA

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The most important influence on the tenderness of meat is the:
   a. animal's age.
   b. animal's diet.
   c. cut (location on the animal's body).
   d. marbling.

2. What is the most abundant protein in connective tissue?
   a. Cholesterol
   b. ATP
   c. Actin
   d. Collagen

3. Meats are good sources of the mineral _____, but poor sources of the mineral _____.
   a. iron, calcium
   b. chromium, calcium
   c. calcium, zinc
   d. zinc, iron

4. Which of the following retail cuts of beef would be classified as tender?
   a. Top loin steak
   b. Rump roast
   c. Brisket
   d. Chuck roast

5. For meat to be considered kosher, the animal must be:
   a. slaughtered in the presence of a rabbi.
   b. slaughtered with a single stroke of a knife.
   c. completely bled.
   d. All of the above

6. What is the most flavorful and tender USDA grade of meat?
   a. Choice
   b. Select
   c. Prime
   d. Grade 1

7. What term is used to describe tying thin sheets of fat or bacon over lean meat to keep it moist during cooking?
   a. Larding
   b. Barding
   c. Searing
   d. Au jus

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Briefly describe the following components of meat: muscle tissue, connective tissue, adipose tissue, and bone.
2. Meat changes color during storage and preparation. Explain what is happening as meat turns from purplish-red to bright red to brownish-red.
3. List the USDA quality grades for beef. How do these differ from the yield grade?
4. Discuss how the following factors affect meat tenderness: cut, age, heredity, diet, marbling, and slaughtering conditions.
5. What is rigor mortis? Describe the changes that occur in meat during aging.
6. List and briefly describe the various methods for artificially tenderizing meats.
7. Define the following terms: wholesale/primal cuts, IMPS, kosher meats, variety meats, processed meats, mechanically deboned meat, and restructured meat.
8. Briefly describe four methods for determining the doneness of cooked meats.
9. Describe the general process of preparing meats by the following methods: roasting (include an explanation of carry-over cooking), broiling, pan-broiling, braising, and stewing.
10. Discuss the special requirements for the storage of fresh meats, including temperature, packaging, and maximum storage time.

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8



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Poultry

Classification of Poultry 163
Composition of Poultry 163
Purchasing Poultry 163
Preparation of Poultry 168
Storage of Poultry 174

The word *poultry* refers to all the domesticated birds raised for their meat. Although chickens are the most popular poultry consumed, other species include turkeys, ducks, geese, guinea fowls, and pigeons (squabs). Game birds such as pheasant, wild duck, and quail are also consumed, but few of them reach the marketplace. Emus and ostriches, though not yet readily available in all parts of the country, are being bred for their lower-fat meat.

Despite the variety of poultry, chickens have been raised by humans for more than 4,000 years (18) and remain the poultry most commonly consumed. Chickens are especially useful because both their meat and their eggs are consumed. The popularity of chicken and turkey continues to increase at the expense of beef (6). In the past 50 years, annual production of broilers (young chickens) in the United States has increased from about 34 million to more than 8.5 billion (18). The purpose of this chapter is to discuss the classification, composition, purchasing, preparation, and storage of chicken and other poultry.

CLASSIFICATION OF POULTRY

Ready-to-eat poultry is classified according to age and sex, and vary according to species (Table 8-1) (13, 16).

COMPOSITION OF POULTRY

The composition of poultry (muscle tissue, connective tissue, etc.) is similar to that of meat (see Chapter 7). Turkeys and chickens have both white and dark meat, the lightness or darkness depending on the amount of myoglobin present in the muscle.

PURCHASING POULTRY

Inspection

In 1968, the Wholesome Poultry Products Act made inspection of poultry shipped across state lines mandatory. It is also required that poultry sold within a state meet similar regulations, but these vary slightly from state to state. Poultry is inspected for wholesomeness before and after slaughter by a U.S. Department of Agriculture

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TABLE 8-1 Classifications of Poultry*

Chicken Species[1] – younger chickens are classed as broilers/fryers, roasters, capons, and Cornish game hens

							
Class[1]	Poussin[2]	Cornish Hen[3]	Broiler / Fryer[4]	Roaster[5]	Capon[6]	Hen, Fowl, Baking or Stewing Chicken[7]	Cock or Rooster[7]
Sex	Either	Either	Either	Either	Castrated male	Female	Male
Age	< 4 weeks	5 weeks	< 10 weeks	8-12 weeks	< 4 months	> 10 months	> 10 months

Turkey Species – classified as fryer-roasters, hens, and toms

	Class	Fryer-roaster	Young hen	Young tom	Yearling hen	Yearling tom	Mature or Old
	Sex	Either	Female	Male	Female	Male	Either
	Age	< 12 weeks	< 6 months	< 6 months	< 15 months	< 15 months	> 15 months
	Approximate Weight	7 lb	8-15 lb	25-30 lb			

Duck Species[8]

	Class	Duckling	Roaster	Mature or Old
	Sex	Either	Either	Either
	Age	< 8 weeks	< 16 weeks	> 6 months

Goose Species[9]

	Class	Young	Mature or Old
	Sex	Either	Either
	Age	< 6 months	> 6 months

Guinea Species

	Class	Young	Mature or Old
	Sex	Either	Either
	Age	< 3 months	> 3 months

Pigeon Species

	Class	Squab	Pigeon
	Sex	Either	Either
	Age	< 4 weeks	> 4 weeks

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[1] The different species represent "kinds," while class is dependent on the bird's sex and age.

[2] Poussin – a young chicken.

[3] Cornish hen – cross between a Cornish hen (a breed of chicken) with another. The meat is always very tender.

[4] Roaster/broiler – used for broiling and frying, and any other way. Soft skin, tender meat, and a flexible breastbone.

[5] Roaster – older & larger than broilers/fryers. Less flexible breastbone than broilers, having become calcified with age.

[6] Capon – neutered male chickens. The tenderness and juiciness of the meat is comparable to that of broiler/fryers.

[7] Hen or rooster – older chickens that have outlived their breeding capabilities. Their meat is tougher, the skin coarser, and the breastbone less flexible. They are best used in stews, soups, and other slow-cooking dishes. Younger poultry are usually preferred because they are more tender and have less fat than older birds.

[8] Ducks and geese are not as widely consumed as that of chickens or turkeys, and are considered a luxury food item by many people.

[9] Other birds such as guinea fowl, squab (young pigeon), quail, and pheasant are also sometimes consumed. Occasionally these birds may be served in restaurants as delicacies or special entrées.

How & Why?

Why is the breast meat in chicken and turkey whiter than the thigh or drumstick?

Higher amounts of the red-pigmented myoglobin are found in muscles that are used more frequently; for chickens and turkeys, these include the thighs and drumsticks (12). In contrast, their breasts are more white because these types of birds do almost no flying, and their meat (muscles) in these areas thus contains much less myoglobin. Wild birds such as ducks have darker breast meat because they actually use the muscles for flying.

(USDA) inspector, who also ensures that the poultry is processed under sanitary conditions. Processing plants are encouraged to follow a Hazard Analysis and Critical Control Point (HACCP) plan to minimize the risk of foodborne illness among consumers (5). Poultry that passes inspection is stamped with the USDA inspection mark.

Grading

The grading of poultry is voluntary and is paid for by the producer. Three grades are used: A, B, and C. Grade A is the best and refers to a chicken that is full-fleshed and meets standards of appearance (Figure 8-2). The criteria used in grading are the conformation (the shape of the carcass), the fleshing (the amount of meat on the bird), the amount and distribution of fat, and freedom from blemishes such as pinfeathers, skin discoloration, broken bones, and skin cuts and tears (16). Poultry parts may also be graded USDA A, B, or C. In spite of the claims made by some chicken producers, skin color is not reflective of quality, but rather of the amount of xanthophyll and carotene plant pigments in the bird's diet.

The USDA grade shield shown in Figure 8-2 is used only when the poultry has been USDA graded. Because such grading is not mandatory, some poultry may be marketed under the proprietary grades established by individual packing houses, which may or may not match federal standards.

Types and Styles of Poultry

Poultry comes to market in a number of different types and styles. *Type* refers to whether it is fresh, frozen, cooked, sliced, canned, or dehydrated. *Style* describes the degree to which it has been cleaned or processed, that is, live, dressed, ready-to-cook, or convenience categories. Live birds are rarely bought by the average consumer or restaurant. The other styles are far more prevalent.

- **Dressed.** Dressed birds are those that have had only the blood, feathers, and craw removed. The craw or crop is the pouch-like gullet of a bird where food is stored and softened.
- **Ready-to-cook.** Ready-to-cook poultry is **eviscerated** and free of blood, feathers, head, and feet; it is what is typically found in the supermarket and in most food-service facilities. In ready-to-cook poultry, the internal organs such as the heart, liver, neck, and gizzard (part of the bird's stomach) have been cleaned and had the fat removed, and are frequently put back inside the inner cavity, often in their own giblet bag.
- **Convenience.** For convenience, smaller pieces such as halves, breasts, drumsticks, thighs, and wings of both chicken and turkey are available.

Ground turkey and ground chicken products are also becoming increasingly popular, and are used in a variety of foods ranging from sandwich fillings to frozen entrées. Not all ground poultry products are created equal. Labels should be read carefully because fat is sometimes added, which increases the total kcalorie and fat gram counts.

Processed Poultry

Consumers and food manufacturers may also purchase processed poultry products. Processed chicken and turkey are commonly used in canned or dried soups, frozen dinners, pot pies, sausages, hot dogs, burgers, and bologna. In addition, larger pieces of processed poultry meat minus the bone are sold as boneless turkey breast, roll, and ham. These meats are made from mechanically deboned poultry from which the bone fragments have also been removed. The larger cuts are easy to carve and have a characteristic texture due to binders and other compounds that have been added (Chemist's Corner 8-1).

Hormones and Antibiotics

The USDA does not allow the use of hormones in the raising of chickens. Antibiotics may be given to prevent disease and increase feed efficiency. However, a

Eviscerate To remove the entrails from the body cavity of an animal.

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NUTRIENT CONTENT

The protein, carbohydrate, and vitamin contents of poultry are **somewhat similar to those of meats** (see Chapter 7), with the following exceptions.

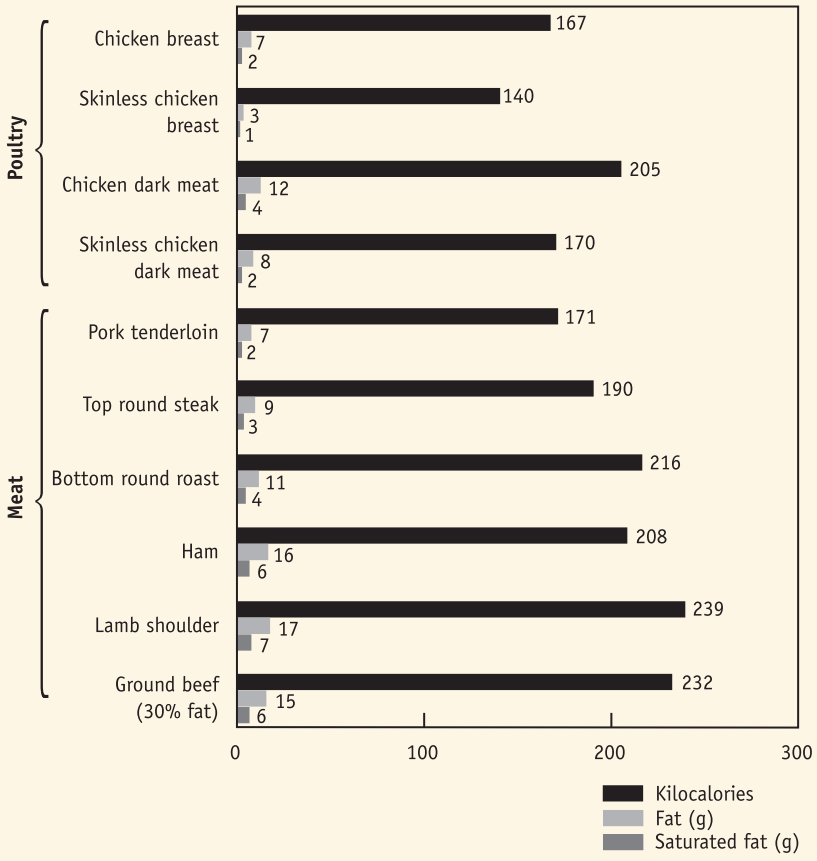
Fat and Cholesterol. Contrary to the popular notion that poultry is always lower in fat and cholesterol, Figure 8-1 shows that, with the exception of a few higher-fat meat cuts, poultry is very similar to other meats in nutritive value.

In both chickens and turkeys, the **dark meat is usually higher in fat, kcalories, and iron than white meat**. It is only after the **skin, about 100 kcalories per ounce**, is removed that there is any significant difference in fat content between poultry and lean cuts of meat. **Ducks and geese have a considerably higher fat content** than chickens or turkeys, which increases their buoyancy in water. Emu and ostrich meat are lower in both kcalories and grams of fat (see Calorie Control box).

Recently, chicken products with favorable fatty acid profiles have been developed through altering the oil content of chicken feed (4).

Minerals. Unless specifically manufactured with less sodium, **any processed poultry product (canned, dried, smoked, or self-basting) is higher in sodium** than nonprocessed poultry. Processed poultry products are sometimes used as a substitute for the meat in foods such as hot dogs, bologna, and hamburgers; in addition, lower-sodium varieties are available for these uses (2, 9).

FIGURE 8-1 Comparing the kcalories and fat grams in poultry versus meat (3 ounces).



CHEMIST'S CORNER 8-1

Processing Poultry

The texture of processed poultry products is influenced by a variety of factors. First, the physical removal of meat from the bone mechanically causes a redistribution of the collagen fibers and myofibril proteins around the fat globules. This creates a more stable meat emulsion (7). Second, a brine mixture containing water, salt, and phosphates is added to improve flavor and cohesiveness. The phosphates in the mixture make the protein more able to absorb water by binding to the calcium and causing the protein fibers to relax. Gums such as carrageenan are then added to absorb water, creating a gel-like texture that prevents water loss during heating and makes slicing easier.

"withdrawal" period is required prior to slaughter to ensure that there are no residues in the bird's system.

Additives

Additives are not allowed in fresh chicken. Processed chicken may contain additives; however, the chicken must be clearly labeled as containing them. Many of the additives used in poultry are also used in meats (see Chapter 7). Common additives used in poultry include salt, monosodium glutamate (MSG), and sodium erythorbate, which keeps processed poultry meat from changing color. Corn endosperm oil and *Tagetes erecta L.* (Aztec marigold flower petals that are dried and ground) are included in chicken feed to enhance the yellow color of chicken skin.

Labeling

The USDA regulates labeling of poultry products, and a partial list of commonly used terms is shown in Table 8-2 (16).

Standardized Poultry Buying

The Poultry Buyer's Guide, a publication similar to *The Meat Buyer's Guide*, provides guidelines for the institutional purchasing of poultry. This guide details the different cuts of chicken, turkey, duck, goose, and game birds.

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FIGURE 8-2 USDA grades for poultry.



tishomir/Shutterstock.com



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USDA A GRADE

Fully fleshed and meaty; uniform fat covering; well formed; good, clean appearance. This grade is most often seen at retail.

USDA B GRADE

Not quite as meaty as A; may occasionally have cuts or tears in skin; not as attractive as A.

The Poultry Buyer's Guide allows standardization among poultry products so that there is some degree of uniformity among companies selling and buying poultry meat.

How Much to Buy

Ready-to-cook poultry contains a good deal of inedible bone and unwanted fat, which must be taken into consideration when deciding how much to buy. A good rule of thumb for most poultry is to buy ½ pound or slightly more per serving. The exceptions are ducks and geese, which have more fat to melt during cooking, resulting in less yield. When purchasing a goose, plan on a bit over ½ pound per serving, and plan on 1 pound for duck. Turkeys under 16 pounds, which have a higher bone-to-meat ratio, are best purchased at about 1 pound per person.

Common broiler-fryer chickens average 3½ pounds and yield 4 servings—two breasts, and two leg and thigh pieces. Chickens under 2½ pounds are not economical. Turkeys, especially full-grown toms weighing 18 pounds

CALORIE CONTROL
Poultry

Avoid fried poultry	Baked		Fried
Chicken (one breast with skin)	187	vs.	364 kcalories
Remove skin from poultry	**No skin**		**With skin**
Chicken (3 oz dark)	170	vs.	205 kcalories
Turkey (3 oz)	159	vs.	188 kcalories

Fried, with-skin poultry is almost double the kcalories of nonfried, no-skin poultry

Daily Cap: Limit meat servings to 5 to 6 ounces daily (two 3-ounce servings; consider kcalories):

Two 150-kcalorie servings = 300 kcalories vs.
Two 300-kcalorie servings = 600 kcalories

Portion Control: One chicken wing with skin (baked) = 100 kcalories
10 chicken wings = 1,000 kcalories and 70 grams of fat

Calorie Crunchers: Chicken nuggets (10 pieces) and duck with skin (3 ounces) average 300 kcalories

Vegetarian Option: 10 vegetarian nuggets (187 kcalories) vs. 10 chicken nuggets (276 kcalories)

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TABLE 8-2 Common labeling terms for poultry products

REQUIRED LABELING

BASTED or SELF BASTED:
Poultry products injected or marinated with a solution (list ingredients that usually consist of butter or other edible fat, broth, stock or water plus spices, flavor enhancers and other approved substances). Maximum added weight is a 3% solution for *bone-in* poultry, and 8% for *boneless*.

MECHANICALLY SEPARATED POULTRY:
A paste-like poultry product produced by forcing bones with attached edible tissue through a sieve-like device under high pressure to separate the two.

OPTIONAL LABELING

FREE RANGE or FREE ROAMING
Poultry allowed access to the outside.

FRESH POULTRY:
Never frozen below 26° F (26° C) (the temperature at which poultry freezes).

NATURAL:
A product containing no artificial ingredient or added color and is only minimally processed.

NO ANTIBIOTICS
"No antibiotics added" may be used on labels if poultry were raised without antibiotics.

NOT ALLOWED

CHEMICAL FREE:
Not allowed to be used on labelling.

NO HORMONES
Hormones are not allowed in raising hogs or poultry. Therefore, the claim "no hormones added" is *not allowed* on the labels for pork or poultry products unless followed by, "Federal regulations prohibit the use of hormones."

Source: https://www.fsis.usda.gov/wps/wcm/connect/e2853601-3edb-45d3-90dc-1befl7b7f277/Meat and Poultry Labeling Terms.pdf?MOD=AJPERES.

or more, provide the greatest yield per pound. One of the most economical ways to buy poultry is in its ready-to-cook whole state. Poultry purchased whole can be cut up following the steps illustrated in Figure 8-3.

PREPARATION OF POULTRY

Throughout the world, chicken is the most widely eaten of all the types of poultry. In Mexico, cooked chicken is shredded to fill tacos, enchiladas, and tamales. The Chinese stir-fry freshly cut up chicken with vegetables and soy sauce. Chicken Kiev is a Russian specialty consisting of boneless breasts that are stuffed, rolled in a seasoned batter, and deep-fried. Paella, a Cuban favorite, is a combination of chicken with rice, tomatoes, sausage, and shellfish in one dish. In Africa, where peanuts are known as groundnuts, groundnut stew is made by simmering chicken with tomatoes and peanuts. In Japan, chicken may be marinated in a mixture of soy sauce, rice wine, and ginger before being grilled or steamed with cooked rice and egg. The resulting dish, called donburi, is very popular in that country. In India, chicken may be spiced and braised in a curry sauce or marinated in yogurt and spices before being roasted. The French are famous for *coq au vin*, or chicken braised in red wine, and the Italians are known for roasting chicken with rosemary. Some chicken dishes commonly consumed in North America include fried chicken, chicken cordon bleu, chicken and dumplings, chicken à la king, chicken divan, and chicken pies, soups, and salads.

Preparation Safety Tips

Raw poultry and meat should not be washed prior to preparation because this increases the danger of cross-contamination. Because most bacteria are on the surface of the meat or the inside cavity, washing may spread them to counter surfaces, utensils, and ready-to-eat foods (17).

Thawing Frozen Poultry

Freezing will largely protect against bacterial growth while the poultry is frozen, but precautions should be taken during and after thawing, when any bacteria that are present may begin to grow. The refrigerator is the best place to thaw frozen birds, and its use requires planning ahead. It takes about a day for a 3½-pound chicken to defrost and 1½ to 5 days for a turkey to defrost, depending on its weight (Table 8-3). When the cavity is sufficiently thawed, the package of internal organs should be removed and the cavity rinsed. Thawing whole poultry at room temperature, in the microwave oven, or under running cold water is not recommended.

Stuffing

For food safety reasons, the USDA recommends that stuffing be prepared and cooked separately or, if not, at least checked with a meat thermometer to confirm that the internal temperature is at least 165°F (74°C) (17). Prestuffed frozen poultry should never be thawed, but should be prepared, according to package directions, directly from the frozen state. The stuffing should be removed from leftover cooked poultry before the bird is refrigerated or frozen. Stuffing turkeys is not recommended as the stuffing may not reach 165°F (74°C).

Brining

Brining is soaking food in salty water (a brine). Applying this method to poultry prior to cooking increases its

TABLE 8-3 Thawing a Turkey

The rule of thumb is about 24 hours of thawing for every 5 pounds of whole turkey.

Weight	Approximate Thawing Time in Refrigerator (40°F [4°C])
8–12 lb	1½–2½ days
12–16 lb	2½–3 days
16–20 lb	3–4 days
20–24 lb	4–5 days

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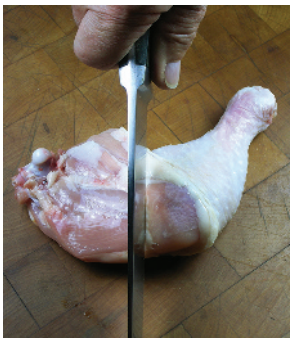
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FIGURE 8-3 Cutting up a chicken.



(1) Separate the leg from the breast. Pull the drumstick toward you. Use the tip of a knife to cut through the skin diagonally. Snap the thigh away from the backbone until the joint pops out of the back. Cut through the remaining skin.



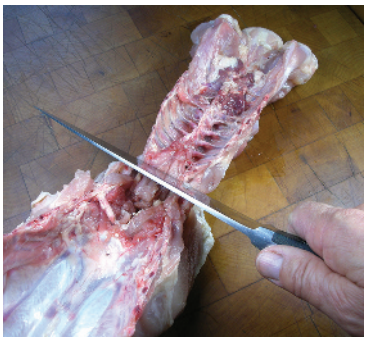
(2) Optional: Cut through the leg joint to create the drumstick and thigh pieces.



(3) Dislocate the wings and then cut them away from the body.



(4) Whack through the ribs with a heavy chef's knife. Holding the chicken with the pointed end of the breast up, use a chopping motion to separate the whole breast from the back.



(5) Snap the backbone away from the breast. Hold the breast in one hand and push down on the backbone with the other. With this action, the wishbone is exposed. Cut along the wishbone to fully remove the back. Aim for the point where the wings join the breast, being careful to leave them attached to the breast. Save the back to use for stock.



(6) Cut the breast in half through the center of the cartilage. Cut off any pieces of wishbone and rib that remain attached to the breast.



(7) A whole chicken cut in nine pieces.

Courtesy of gourmetsleuth.com; Courtesy of Baiada Poultry

water content, resulting in a more juicy, flavorful meat. The poultry (whole or pieces) is placed in a large nonreactive pot and covered with a brine solution. The simplest brine solution is water and salt, but a sweetener, herbs, and spices can also be added. The sweetener (sugar, molasses, honey, or corn syrup) simultaneously contributes to flavor and browning (14). Many formulations for brine solutions exist, but one example consists of water (1 gallon), salt (¾ cup), sugar (⅔ cup), soy sauce (¾ cup), and herbs (one teaspoon each of dried tarragon, thyme, and pepper). The water, salt, sugar, and soy sauce are boiled to dissolve the salt and sugar; the herbs are then added to the solution after it has been removed from the heat source. After the brining solution is cooled, it is important that the chicken be completely submerged in it; do this by placing a heavy object on top of the pot's lid. Food safety is crucial, so the pot containing the submerged chicken in the brining solution should be stored in the refrigerator. The brining process takes about 2 hours for chicken pieces and 4 hours for a whole chicken. The water and salt enter the muscle through diffusion and osmosis. Leaving the chicken for too long a time in the brining solution will cause the meat to become too mushy and salty.

Changes during Preparation

Properly prepared poultry is tender and juicy, but overcooking causes the flesh to become dry, tough, and stringy. The skin of any poultry, which is primarily

How & Why?

Why is there so much concern about food safety in poultry preparation?

Almost three-fourths of all chickens in the United States carry *Salmonella*, and about half carry *Campylobacter jejuni*. Although a national survey showed that only about 5% of broilers tested positive for *Salmonella* before processing, this percentage may rise after the carcasses have been subjected to scalding, defeathering, eviscerating, and chilling (15). For this reason, anything that comes in contact with raw poultry, including hands, cutting boards, sinks, utensils, dishes, and counters, should be cleaned and sanitized afterward.

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fat, can be removed before or after preparation, but if it is left on, it does contribute to flavor and juiciness. Fat that naturally melts off the bird during heating can be used to baste the poultry or to create sauces. Basting adds flavor and helps keep the meat tender and moist. Fat rises to the top of the drippings, so it may be easily removed before the drippings are used for gravy or sauce.

Reheated poultry, especially turkey, has a characteristic warmed-over flavor caused by the breakdown of fat (11). Microwave reheating results in less of this warmed-over flavor than reheating using conventional methods (3). The other changes that occur during preparation closely parallel those found in meats (see Chapter 7).

Determining Doneness

Poultry should always be heated until well done to enhance flavor and to minimize the risk of foodborne bacterial illnesses. Doneness may be determined by internal temperature, color changes, and/or touch and time/weight tables, each of which is discussed below.

Internal Temperature

The best way to check poultry for doneness is to use a meat thermometer. It should be inserted into the thickest part of the breast, although it can also be inserted into the inner thigh. In either case, it should not touch bone or fat. Poultry is sufficiently cooked when the internal temperature reaches a minimum of 165°F (74°C) for at least 15 seconds. The pop-up indicators that some poultry producers place in turkey breasts are not always reliable, so check for other signs of doneness. A thermometer placed in the center of any stuffing must reach a minimum temperature of 165°F (74°C) (Figure 8-4).

Color Change

When the skin on oven-roasted chicken or turkey reaches a golden brown color, it is time to test for doneness. The juices coming out of the bird should have turned from pink to clear, and a bit of bone should be showing on the tip of the legs. When a turkey is roasted breast side up, the breast should be covered with metal foil or a bit of cooking oil to keep the breast from overbrowning or burning. The foil should be removed 45 minutes to an hour before the end of heating to allow for final browning.

Touch

When pressed firmly with one or two fingers, the well-done bird's flesh will feel firm, not soft. White meat may be firmer than dark meat, in part because certain proteins have a higher gel-forming ability in white muscle than they do in dark muscle tissue (20). Another way to tell whether or not the poultry is done through touch is to wiggle the drumstick—it should move easily in its joint.

Time/Weight Charts

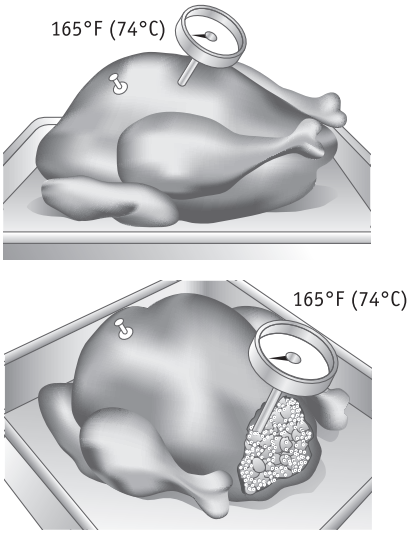
Time/weight charts appear on the packaging of all frozen and many fresh birds. It takes about 1½ hours in a 350°F (177°C) oven to thoroughly cook a 3½ -pound chicken. Preparation times for turkey depend on the weight and are reduced for those roasted in a special oven bag (Table 8-4). Although there are time/weight charts for frozen turkeys, it is not recommended that they be cooked from the solidly frozen state because they may not be heated through enough to destroy microorganisms.

Dry-Heat Preparation

Roasting or Baking

Either whole or individual pieces of poultry can be roasted (baked). A heavy-duty roasting pan is used for the best result. Some people place the bird directly on the pan, either breast up, which promotes the loss of tasty juices to be collected later, or breast down, for more juicy breast meat. Others use a V-shaped rack or a flat rack to keep the bird elevated from the juices. The inside of the cavity of a whole bird is seasoned as desired, and the outside may be coated lightly with vegetable oil to prevent the skin from cracking and the meat from drying out. Moistness is further enhanced by basting the bird every 20 minutes with its own juices. The pan drippings (fat removed) also make an excellent natural sauce to pour over the chicken pieces, further adding to flavor. In fact, without these pan drippings, the meat may seem drier and less tasty. Margarine is not recommended for oiling the skin or for basting because of its low smoking temperature. Seasonings may be added as desired. Although surface seasonings do not add flavor to the flesh, the skin does become more flavorful when it has been browned to a certain crispness (Chemist's Corner 8-2). Salting the skin may dry it out, although sometimes this is done purposely to create crispy skin (1). The outwardly salted bird is left uncovered in the refrigerator (4 hours

FIGURE 8-4 Internal temperatures for a well-cooked turkey.



The safest option is to prepare stuffing in a pan rather than in the bird's cavity.

TABLE 8-4 Time/Weight Chart for Preparing Turkey at 325°F (163°C)*

	Cooked in Open Roasting Pan		Cooked in Oven Cooking Bag	
Weight (pounds)	Unstuffed (hours)	Stuffed† (hours)	Unstuffed (hours)	Stuffed† (hours)
8–12	2¾–3	3–3½	1¾–2½	2¼–2¾
12–16	3–4	3½–4¼	2¼–2¾	2¾–3¼
16–20	4–4½	4¼–4¾	2¾–3¼	3¼–3¾
20–24	4½–5	4¾–5¼	3¼–3¾	3¾–4¼

*These times are approximate, and doneness should always be verified with a properly placed thermometer.
†The safest option is to prepare stuffing in a pan rather than in the bird's cavity.

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to 2 days) to air-dry. Sprinkling a slight amount of sugar on the skin will make it brown even more and perhaps cause darker spots. Salting and seasoning the inner cavity are optional, but the seasonings permeate from the inside out through the meat (via steaming) during baking, which results in a tastier meat.

The bird is then placed in an oven set at between 325°F and 350°F (163°C and 177°C) and baked for the allotted time (up to 1½ to 2 hours for a 3½- to 6-lb chicken):

- 20 to 25 minutes per pound for poultry up to 6 pounds
- 15 to 20 minutes per pound for poultry up to 15 pounds
- 12 to 15 minutes per pound for poultry over 15 pounds

When birds are stuffed, cooking times must be increased by about 5 minutes per pound to make sure the stuffing is heated sufficiently all the way through to kill all microorganisms. A small piece of aluminum foil placed over exposed stuffing in the final stages of baking will prevent it from scorching (Figure 8-5). As stated earlier, it is recommended that turkeys not be stuffed for food safety reasons.

Poultry may be **trussed** before roasting. This is usually done with turkeys because of their long preparation time. Figure 8-6 illustrates one method of trussing a bird. Wire clips, which frequently come with a turkey, will hold the legs in place without trussing. The wire clips should be temporarily removed when cleaning the bird prior to preparation. The wings can be tied up against the breast to prevent their edges from burning.

Birds to be roasted are placed, usually with the breast up, in a heavy-duty roasting pan on the lowest rack of the oven. The pan should have 2 -inch sides; sides higher than 2 inches make basting difficult and prevent browning of the lower portion of the bird. Some cooks claim that the bird is juicier if placed breast down so that it can self-baste. However, eventually it must be turned over to brown the breast, and because this task is not easy, most people find that basting a breast-up bird with accumulated pan juices and/or melted butter is quite satisfactory.

Ducks and geese, because of their high fat content, should be placed breast down after having had their skins thoroughly pricked to release excess fat during the cooking process. They are turned breast up about halfway through the heating time. The skin is pricked again at least once during heating to facilitate fat drainage, and pan drippings are periodically removed during roasting. Duck and goose are sometimes preroasted for about 15 minutes and then prepared in the same manner as chicken. Cornish game hens are roasted the same way as broilers and fryers except that their cooking time is only about half an hour, unless they have been stuffed, in which case, their baking time increases by 15 minutes.

FIGURE 8-5 Protecting stuffing from scorching.

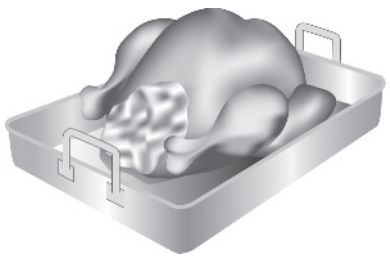
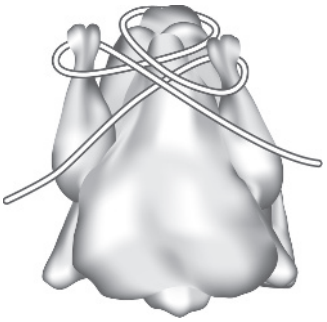


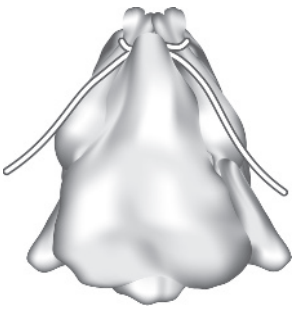
FIGURE 8-6 Trussing poultry.



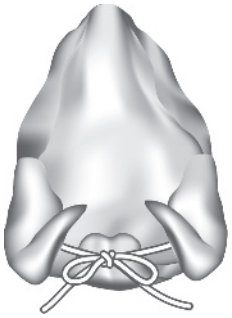
(1) Tuck the wings under the back to avoid overcooking.



(2) Loop a butcher string (three times as long as the poultry) as shown.



(3) Pull the ends of the string together.



(4) Turn poultry over, tuck string under the wings, and tie it over the neck flap.

CHEMIST'S CORNER 8-2

Aroma of Roasting Chicken

The classic aroma of roasting chicken comes from volatile compounds such as carbonyls and hydrogen sulfide (8).

Basting

Basting chickens and turkeys helps prevent drying of the skin and meat. This involves using a wide spoon or brush or a special tool called a baster to periodically cover the bird with liquid from the drippings, melted butter, or barbecue or other sauce. Any sauce containing sugar (brown or white), such as barbecue sauce, will increase browning, possibly to an undesirable degree, and should be

Truss To tie the legs and wings against the body of the bird to prevent them from overcooking before the breast is done and to enhance presentation.

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applied toward the end of the cooking process to avoid burning the sauce. The number and timing of bastings depend on the size of the bird and whether or not it has been covered early in the cooking with an oil-soaked cloth or other covering, but basting once every half hour is usually more than adequate. Basting helps the skin to brown, but to prevent overbrowning, tent the bird with aluminum foil two-thirds of the way through the cooking time.

Duck and goose do not need to be basted; they are so high in fat that they are self-basting. For the same reason, any stuffing for these fowl should be cooked separately because it would become too soaked with fat if prepared in the cavity of the bird.

Stuffing

Stuffing refers to anything that is placed in the cavity of a bird during cooking. This is usually the familiar breadcrumb or cornbread stuffing; however, other foods such as vegetables and meats are sometimes stuffed in the bird's cavity. Dressing is distinguished from stuffing by being heated separately in a casserole or pan and served as a side dish.

The main ingredient of stuffing/dressing is cut cubes of day-old bread, packaged stuffing mixes, or rice. This starch-based foundation absorbs the juices released during cooking, which is why it is important that it be dried; otherwise, the dressing will be mushy. Bread cubes (¼ to ½ inch for turkey, smaller cubes for chicken) can be dried by spreading them out on a cookie sheet and baking them on low (275°F [135°C]) for 15 minutes or leaving them on the counter overnight. If grains such as rice are to be the main stuffing ingredient, they should be cooked and cooled before being combined with the other ingredients. Added to this bread or grain base is a **mirepoix** (meer-PWAH). Apricot or apple pieces, nuts, mushrooms, oysters, raisins, or other items may also be added to the base, according to personal preference.

Mirepoix A collection of lightly sautéed, chopped vegetables (a 2:1:1 ratio by weight of onions, celery, and carrots) flavored with spices and herbs (most commonly, sage, thyme, marjoram, and chopped parsley).

FIGURE 8-7 Carving roast chicken.



(1) Steady the chicken on a sanitary cutting board. To remove the leg, slice through the skin holding the leg to the breast.



(2) Push the leg down to partially dislodge the joint, cut through the meat between the leg and breast, and then cut through the joint.



(3) To separate the breast meat, brace the chicken with a fork, slicing just inside the keel bone. Move the knife downward, pulling/cutting the breast section away from the rib cage.

Digital Works

A liquid such as broth or water is then added to hold the mixture together, and eggs may be included to add cohesiveness. If the stuffing is going into the bird, only enough liquid to make the stuffing barely hold together should be added; if it is too moist, it will not be able to soak up juices.

All the ingredients should be lightly tossed together and then spooned into the poultry cavity. Stuffing should not be packed in but should fill only three-quarters of the cavity because the stuffing will expand as it cooks. It is important to remember that stuffing a bird increases roasting time and plan accordingly. The center of the stuffing needs to reach a final temperature of 165°F (74°C) in order to destroy microorganisms.

A stuffed bird should be allowed to stand for only a short time after being removed from the oven and before it is served. It should be refrigerated as soon as possible after that, and all the stuffing should be taken out of the bird's cavity before refrigerating. It cannot be stressed enough that stuffings, particularly those with eggs as an ingredient, are an ideal medium in which microorganisms can grow and flourish.

If stuffing is not used, then apple, potato, carrot, onion, or celery stalks may be placed in the cavity to absorb off-flavors. The fat and off-flavors absorbed by any such fruits or vegetables during cooking render them unappetizing to eat, and they are usually discarded.

Carving

Chicken is carved into the breast, leg, thigh, and wing pieces using the technique illustrated in Figure 8-7. Turkey should be allowed to stand for about 20 minutes after it is removed from the oven before carving. This allows the flesh to firm up and makes carving easier. Figure 8-8 demonstrates carving a turkey. Carve only what will be used immediately to avoid drying and cooling of the turkey meat pieces.

Broiling or Grilling

Except when cooking a whole bird on a spit over hot coals, only cut-up poultry is used for broiling or grilling. It is frequently marinated or coated with butter and seasonings before being broiled or grilled. In the interest of food safety, marination must take place under refrigeration. A marinade must be fully cooked if it is to be served or used for basting. Failure to heat the marinade to a sufficient temperature to kill the bacteria that remain in it from the raw chicken may cause a foodborne illness. For the same reason, unless it is thoroughly washed in the interim, the plate used to carry the raw poultry to the grill should never be used to carry it back to the table after it has been cooked.

Vegetable sprays applied to the pan or grill help to prevent sticking. When an oven broiler is used, the poultry pieces are put skin side up on a rack in the broiler pan and placed approximately 6 inches below the heat source. The same procedure is used when grilling over coals, except that the skin side goes down. The cooking time varies according to thickness, but, in general, chicken takes 20 minutes per side. Turkey pieces are larger and so require longer cooking. After the skin side is browned, use tongs to turn the poultry pieces over because the piercing tines of a fork will allow juices to be lost. Sauces

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FIGURE 8-8 Carving a turkey.



(1) Slice down between the thigh and the breast. Don't let the fork puncture the outside skin, causing juices to be lost.



(2) Push the thigh down (and bend under if necessary) to disjoint the bone; cut through the rest of the meat and any cartilage to separate it from the breast.



(3) Separate the thigh from the drumstick by cutting through the meat.



(4) Twist the thigh around the drumstick and cut through the joint.



(5) Slice the drumstick (and thigh; not shown).



(6) Remove the wing by first twisting and then cutting from the joint.



(7) Remove the skin back and slice the breast meat.



(8) Lift each slice using the knife and fork.

Amy C. Brown

are best added during the last 15 minutes of preparation because high heat readily burns sugar, which is the main ingredient of many barbecue sauces.

Frying

Poultry pieces can be sautéed, pan-fried, deep-fried, or stir-fried.

Sautéing

Small poultry pieces are placed in a skillet or pan with a small amount of oil for quick preparation. Pieces must be turned to ensure adequate doneness. Sautéing can also be used to brown larger poultry pieces prior to their being baked or braised to completion.

Pan-Frying

Pan-fried chicken pieces are usually breaded or floured before they are fried over high heat in approximately ¼ inch of fat. The breading adds texture and flavor and keeps moisture from being lost from the fried food; it also allows heat to be transmitted to the food while limiting its absorption of fat. Fry with the skin side down first; when that side is brown, turn it over with tongs and brown the other side. Lower the heat and turn the pieces occasionally, for 30 to 45 minutes, or until done. If the poultry is placed in the oven following browning, the method of preparation is referred to as "oven-fried," even though it is actually baked.

Deep-Frying

Deep-frying poultry pieces that have been breaded, floured, or battered involves submerging them completely in oil heated to between 325°F and 350°F (160°C and 180°C).

Stir-Frying

Stir-frying is lightly frying bite-size pieces of boned chicken while stirring them frequently in a tiny amount of oil. Vegetables, also cut into small pieces, are usually added, along with soy sauce and/or other seasonings.

Moist-Heat Preparation

Poultry can also be prepared by moist-heat methods such as braising, stewing, poaching, and microwaving.

Braising

Although braising, also called "fricasseeing," can be applied to any poultry, it is of particular value when it comes to preparing older, tougher birds. The slow, moist heating tenderizes the meat and makes it easier to chew. The chicken or turkey is first cut into pieces and browned in a small amount of oil and/or butter; it may be floured or breaded first. Liquid is added, and the poultry is simmered in a tightly covered pan until tender. The initial browning is important because it helps create a rich flavor and holds in the juices. Desired seasonings are added with the liquid.

Stewing

Any whole or cut-up fresh poultry can be stewed; it is covered in cold salted water and heated to the boiling point, at which point, the heat is immediately lowered to a simmer. An average 3½ pound chicken usually takes about 2 to 2½ hours. The bones and skin may or may not be removed from the pot, and dumplings, which are made from a dough mixture, can be placed gently on top of the simmering chicken 12 to 15 minutes before the end of preparation time.

Poaching

Chicken pieces can be poached fairly quickly in a small amount of water. The chicken pieces, such as breasts, are placed in a frying pan and covered with 1⅓ cups water. The water is brought to a boil and then reduced to a simmer, and the chicken is cooked about 10 to 15 minutes or until tender.

Microwaving

Microwave ovens do not always heat food deeply or evenly enough, and power levels vary from brand to brand, so it is suggested that stuffed poultry, particularly turkeys, be prepared in a conventional oven. The microwave

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CAREER CORNER

Food Safety Inspector and Food and Drug Branch Supervisor

Mr. Lance Wong majored in biology in college. Soon after graduating, he decided to pursue a master of science degree in public health. He is now the Hawaii State Health Department's Food and Drug branch supervisor. Food safety inspectors working for the Sanitation Branch are responsible for inspecting restaurants, caterers, hotels, lunch wagons, and all other commercial food preparers. Inspectors also inspect food manufacturers, bakeries, supermarkets, open markets (such as exist in Chinatown), pharmacies, and delis.



Courtesy of Lance Wong

Mr. Lance Wong

Mr. Wong trains staff on the importance of "talking to people, developing a positive rapport, and focusing on training and education rather than to be a heavy-handed enforcer." The primary goal, he says, is to "convey to the food establishments that food safety is their number one priority and that foodborne illness is bad for business."

manufacturer's instructions should be followed for preparing all other poultry. Once thawed in the microwave oven, the poultry should be cooked immediately.

In general, microwave directions call for smaller pieces of poultry rather than whole fowl. If a recipe calls for chicken pieces, a microwave can be handy. The poultry pieces are arranged skin side up, with the thickest portions toward the outside of the dish and any loose flaps of skin tucked under. The dish is covered with wax paper or plastic wrap and cooked on high for about 8 minutes per pound, or according to the manufacturer's directions. Chicken breasts are heated on high for about 10 minutes or until well done. The pieces should be rotated at the 5-minute mark.

Flavor and appearance are enhanced if the pieces are initially covered with browning sauce, barbecue sauce, or some other topping. Cooking is completed when the flesh is firm and fork tender, and the juices run clear instead of pink. However, using a thermometer to verify internal temperature is advised. The finished pieces should be left to stand about 5 minutes before serving. If they are to be used in a salad or other dish, it is best to chill them in the refrigerator for at least 2 hours. Two boned, skinned chicken breasts will yield 1 cup of cubed chicken meat.

STORAGE OF POULTRY

Precautions should be taken in the handling of poultry because of the possibility of bacterial contamination. Raw poultry is a major source of *Campylobacter* and *Salmonella*, two of the most common causes of foodborne illness (see Chapter 4). In 1993, the irradiation of poultry was approved for commercial use in the control of *Salmonella* following several studies demonstrating that irradiation reduces bacterial concentration (19). Irradiated poultry, however, is not sterile and should be handled using the same precautions used for any raw poultry. In 1992, the use of trisodium phosphate (TSP), a colorless, odorless, flavorless chemical mixture, also received approval for use by the poultry industry on poultry carcasses to further aid in reducing *Salmonella* contamination (see Chemist's Corner 8-3).

Refrigerated

Fresh, ready-to-cook poultry can be kept safely in the refrigerator at 40°F (4°C) or below for up to 3 days (Chemist's Corner 8-4). It should be stored in the vapor-proof wrapping in which it is purchased because repackaging increases the risk of bacterial contamination. It is best kept in the bottom portion of the refrigerator to prevent its drippings from contaminating other foods. Chickens labeled "fresh" should not have been exposed to temperatures below 26°F (−3°C), the temperature at which chicken freezes.

CHEMIST'S CORNER 8-3

How TSP Kills Bacteria

Trisodium phosphate (TSP) is approved for use as an antibacterial agent in preslaughter and postslaughter chicken carcasses. TSP prevents bacterial growth by disrupting the cell membrane of the bacteria. When the cell membrane is broken, the contents of the bacterium leak out, resulting in its death (10).

CHEMIST'S CORNER 8-4

Oxidation of Cooked Poultry

Dark meat is higher in both myoglobin and fat than white meat (refer to Figure 8-1). Consequently, it is more easily oxidized because the iron in the myoglobin acts as a metal catalyst to speed up the oxidation of its polyunsaturated fatty acids. The oxidation of the polyunsaturated fatty acids found naturally in the meat results in disagreeable off-odors (11). As a result, chicken legs, with their dark meat, cannot be stored as long as chicken breasts.

Frozen

Frozen whole poultry can be stored from 6 to 12 months at 0°F (−18°C), whereas leftover cooked poultry can be frozen for up to 4 months. The meat will decline in moistness and eating quality if it is kept frozen for longer periods. Breaded or fried poultry should never be thawed and refrozen.

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PICTORIAL SUMMARY / 8: Poultry

Humans domesticated chickens more than 4,000 years ago. These days, the consumption of poultry, especially chicken and turkey, continues to increase in popularity.

CLASSIFICATION OF POULTRY

Poultry, or domesticated birds raised for their meat, includes the following:



Chicken
- Broilers
- Fryers
- Roasters
- Capons
- Cornish game hens



Turkey
- Young tom
- Young hen



Duck



Goose



Pigeon



Guinea fowl

Domesticated birds are classified according to age and weight, and the classifications vary from species to species. Chickens are sold as broilers and/or fryers, roasters, capons, and Cornish hens. The majority of the turkeys coming to market are young hens, hens, young toms, and toms.

COMPOSITION OF POULTRY

Poultry, like meat, is a high-quality protein food. Contrary to the popular notion that poultry is always lower in fat and cholesterol, poultry is very similar to many other meats in nutritive value. Poultry does provide less fat if the skin is removed. The amount of myoglobin determines whether the flesh is white or dark.

PURCHASING POULTRY

All poultry scheduled to be transported interstate must have the USDA stamp of approval. For birds sold intrastate, USDA inspection is voluntary. However, strict state inspection guidelines are enforced. These may vary slightly from state to state but are close to federal standards. USDA grade stamps indicate A, B, and C quality, with A being the best. Many processors use their own grading system and stamps.

The least expensive way to buy poultry is to purchase it as a ready-to-cook whole bird. The larger the bird, the more edible meat per pound. For chicken and turkey, approximately ½ pound of whole bird is needed for each serving.

Poultry is available for purchase in the following forms:

- Fresh
- Frozen
- Cooked
- Canned
- Dehydrated
- Live
- Dressed
- Ready-to-cook
- As convenience food

PREPARATION OF POULTRY

Poultry can be prepared in any number of ways:

Dry-Heat Methods
- Roasting
- Baking
- Broiling
- Grilling
- Frying

Moist-Heat Methods
- Braising
- Stewing
- Poaching



Regardless of the preparation method selected, poultry should always arrive on the table well done, as determined by the combined use of internal temperature, color changes, touch, and time/weight tables. Poultry is sufficiently cooked when the internal temperature reaches 165°F (74°C) for 15 seconds.

Microwave ovens are not recommended for cooking poultry, except for smaller pieces. Thawing frozen poultry is best done in the refrigerator.

When handling fresh or frozen poultry, cleanliness, avoidance of cross-contamination, and personal hygiene are of utmost importance in preventing foodborne illnesses.

Cutting Up a Chicken





STORAGE OF POULTRY

Fresh poultry will keep in the refrigerator for up to 3 days, while frozen poultry will keep in the freezer for 6 to 12 months. All prepared foods should be refrigerated in covered containers and guarded against *Salmonella*.

- Store in the refrigerator a maximum of 3 days.
- Freeze for a maximum of 6 to 12 months if fresh, or 4 months if cooked.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. What is the name for chickens that are older and larger than broilers/fryers?
   a. Capons
   b. Roasters
   c. Cornish game hens
   d. Roosters

2. Contrary to popular belief, the level of _____ in poultry is similar to that of other meats.
   a. carbohydrate
   b. white meat
   c. cholesterol
   d. fiber

3. How long should it take an 8- to 12-pound turkey to thaw in a 40°F (4.4°C) refrigerator?
   a. 3–5 days
   b. 2–3 days
   c. 2–5 days
   d. 1½–2½ days

4. A mirepoix is defined as a 2:1:1 ratio of _____ flavored with spices and herbs.
   a. carrots, onions, and celery
   b. potatoes, onions, and carrots
   c. onions, potatoes, and carrots
   d. onions, celery, and carrots

5. Poultry is sufficiently cooked when the internal temperature reaches _____
   a. 125°F (52°C).
   b. 145°F (63°C).
   c. 165°F (74°C).
   d. 185°F (85°C).

6. A good rule of thumb is to purchase approximately _____ pound(s) of poultry (with the exceptions of geese, duck, or turkey) per person to be served.
   a. ¼
   b. ½
   c. 1
   d. 1½

7. What term is used to describe poultry that have had their entrails (inner organs) removed from their body cavity?
   a. Trussed
   b. Unstuffed
   c. Eviscerated
   d. Basted

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe how poultry is classified, and then briefly discuss the various classifications of chicken.
2. What are the USDA grades for poultry, and on what criteria are they based?
3. Purchasing poultry is often based on *type* and *style*. Briefly define these two terms.
4. Approximately how many pounds per serving would you purchase of chicken? Duck? Goose? Turkey?
5. Discuss the methods for determining the doneness of baked chicken or turkey.
6. Describe the basic steps involved in roasting or baking poultry.
7. Discuss the purpose and process of trussing, of basting, and of adding a mirepoix to stuffing.
8. How is poultry braised, and what is the value of this preparation process?
9. What are the general recommendations for microwaving poultry?
10. What precautions should be taken when handling and storing poultry?

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9



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Fish and Shellfish

Classification of Fish and Shellfish 177
Composition of Fish 178
Purchasing Fish and Shellfish 180
Preparation of Fish and Shellfish 190
Storage of Fish and Shellfish 193

Humans were eating fish, shellfish, and sea mammals long before they started cultivating plants or domesticating animals for food. Stone Age site excavations have uncovered fishnets, spears, and fishing hooks made from the upper beaks of birds. Seafood is now the only major food source that is still hunted. Most other food sources are raised or grown.

At present, there are more than 20,000 known species of edible fish, shellfish, and sea mammals. Of these, approximately 250 species are harvested commercially in the United States, of which millions of tons are served up annually for the consumption of humans and domesticated animals. This chapter focuses on those species and examines their classification, composition, purchase, preparation, and storage.

CLASSIFICATION OF FISH AND SHELLFISH

The staggering variety of creatures harvested from the water makes it difficult to classify them using only one set of criteria. As a result, they may be categorized in any of several ways: vertebrate or invertebrate, saltwater or freshwater, and lean or fat. Although these classifications are used to distinguish among different fish, a vertebrate could live in saltwater or freshwater and be either lean or fat. The Food and Drug Administration (FDA) has attempted to standardize fish nomenclature by publishing the *Guide to Acceptable Market Names for Seafood Sold in Interstate Commerce* and requiring that fish be named according to this publication (24). Though the FDA guide is the recommended way to classify fish and shellfish, the three methods mentioned above—(1) vertebrate or invertebrate, (2) saltwater or freshwater, and (3) lean or fat—are commonly used and thus are described here.

Vertebrate or Invertebrate

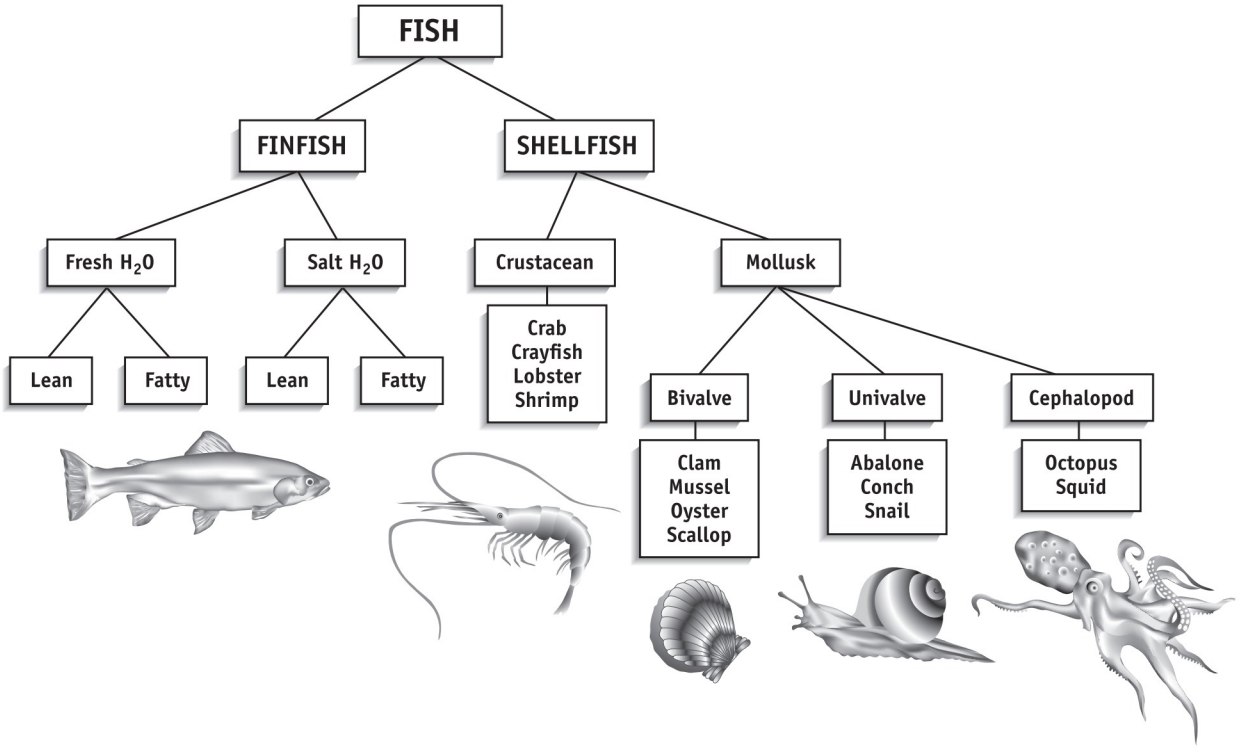
This classification divides water animals according to the presence or absence of a backbone (Figure 9-1).

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FIGURE 9-1 Classification of fish.



Vertebrates

The vertebrate category includes **finfish** which obtain their oxygen from the water through their gills, and sea mammals, which must get their oxygen from the air above the water's surface. Finfish are found in the freshwater of rivers, lakes, and streams, and the saltwater of oceans and seas. The most popular finfish in North America are tuna, cod, Alaska pollock, salmon, catfish, and flounder/sole. Sea mammals include dolphin, whale, and seal.

Invertebrates

The invertebrate category includes shellfish, most of which have external skeletons or shells. The term *shellfish* is a commercial rather than a scientific classification, and includes the invertebrate **crustaceans** and **mollusks**. Examples of crustaceans are shrimp, crab, lobster, and crayfish. Mollusks include bivalves, univalves, and cephalopods. Bivalve creatures, including clams, oysters, mussels, and scallops, are contained within two hard shells that are hinged together. The univalves, such as conch and abalone, have only a single hard shell. Cephalopods, which include octopus and squid, have an almost rubbery soft inner shell, which will be familiar to parakeet owners as a cuttlebone.

Finfish Fish that have fins and internal skeletons.

Crustacean An invertebrate animal with a segmented body covered by an exoskeleton consisting of a hard upper shell and a soft under shell.

Mollusk An invertebrate animal with a soft, unsegmented body usually enclosed in a shell.

Saltwater or Freshwater

The majority of the fish eaten in the United States are taken from salty waters, but many also come from freshwater lakes, ponds, and streams. Saltwater fish often have a more distinct flavor than freshwater fish. However, sole is a very mild-flavored saltwater fish and is one of several exceptions to the taste generalization (Table 9-1). Other saltwater fish include halibut, cod, flounder, haddock, mackerel, red snapper, salmon, shark, striped bass, swordfish, and tuna. Catfish, perch, pike, and trout are the most common freshwater varieties.

Lean or Fat

Fish are sometimes identified by their fat content, but, in this case, *fat* is a relative term. Fish are not very fatty as compared with most of the other meats. A 3-ounce cooked portion of a lean fish (less than 5% fat) such as cod, pike, haddock, flounder, sole, whiting, red snapper, halibut, or bass contains less than 2.5 grams of fat (Table 9-2). The same portion of fatty fish (more than 5% fat) yields 5 to 101 grams of fat. Examples include salmon, mackerel, lake trout, tuna, butterfish, whitefish, and herring.

COMPOSITION OF FISH

Structure of Finfish

Regardless of their classification, fish are usually tender when they come to the table, and three structural factors contribute to this tenderness: collagen, amino acid content, and muscle structure.

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TABLE 9-1 Common Fish and Shellfish Grouped by Flavor and Texture

	Flavor		
Texture	*Mild Flavor*	*Moderate Flavor*	*Full Flavor*
Delicate	Cod	Butterfish	Mussels
	Crab	Lake perch	Oysters
	Flounder	Whitefish	
	Haddock	Whiting	
	Hake		
	Pollock		
	Scallops		
	Sole		
Moderate	Crayfish	Mullet	Bluefish
	Lobster	Ocean perch	Mackerel
	Pike (walleye)	Shad	Salmon (canned)
	Orange roughy	Smelt	Sardines (canned)
	Shrimp	Surimi products	
	Tilapia	Trout	
		Sea trout (weakfish)	
		Tuna (canned)	
Firm	Grouper	Catfish	Clams
	Halibut	Mahi mahi	Marlin
	Monkfish	Octopus	Salmon
	Sea bass	Pompano	Swordfish
	Snapper	Shark	Tuna
	Squid	Sturgeon	
	Tautog (blackfish)		
	Tilefish		
	Wolffish		

TABLE 9-2 Lean versus Fatty Fish: Fat Content of 3-Ounce Cooked Portions of Fish and Shellfish

Lean Fish

Very Low Fat—Less Than 2.5 Grams Total Fat

Clams	Haddock	Pike (northern)	Red snapper
Cod	Halibut	Pike (walleye)	Snow crab
Cusk	Northern lobster	Pollock (Atlantic)	Sole
Blue crab	Mahi mahi	Ocean pout	Squid
Dungeness crab	Monkfish	Orange roughy	Tuna (skipjack)
Flounder	Perch (freshwater)	Scallops	Tuna (yellowfin)
Grouper	Ocean perch	Shrimp	Whiting

Low Fat—More Than 2.5 Grams But Less Than 5 Grams Total Fat

Bass (freshwater)	Croaker	Salmon (pink)	Swordfish
Bluefish	Mullet	Shark	Rainbow trout
Blue mussels	Oysters (eastern)	Smelt	Sea trout
Catfish	Salmon (chum)	Striped bass	Wolffish (ocean catfish)

Fatty Fish

Moderate Fat—More Than 5 Grams But Less Than 10 Grams Total Fat

Butterfish	Salmon (Atlantic)	Lake trout
Herring	Salmon (coho)	Tuna (bluefin)
Mackerel (Spanish)	Salmon (sockeye)	Whitefish

Higher Fat—More Than 10 Grams Total Fat

Mackerel (Atlantic)	Salmon (king)

Source: U.S. Department of Fisheries.

Collagen

When compared with meat or poultry, fish muscle has lower amounts of collagen. The bodies of land animals average 15% connective tissue by weight, whereas fish are only 3% collagen (43).

Amino Acid Content

Another reason fish is tender is that it contains less of the amino acid hydroxyproline in its connective tissue. When fish is cooked, the collagen breaks down more easily at a lower temperature and converts to gelatin.

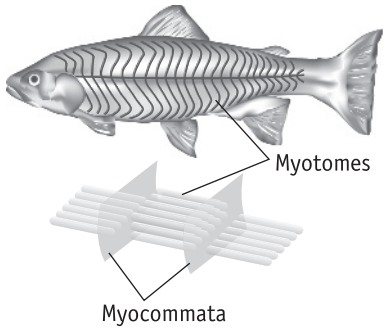
Muscle Structure

Unlike mammals and birds, whose muscles are arranged in very long bundles of fibers, fish muscles are shorter (less than an inch in length) and are arranged into **myotomes** which are separated by connective tissue called **myocommata** (Figure 9-2). This combination of structure and chemistry contributes to the characteristic flaking of prepared fish as the heat softens the collagen in the myocommata. The gel-forming ability of the muscle proteins in fish can also contribute to a soft, tender, gel-like texture (39).

Pigments

When fish flesh is exposed to air during preparation, it will vary in color as a result of the presence of white, pink,

FIGURE 9-2 Fish muscle, unlike other meats, is arranged in layers of short fibers (myotomes) separated by very thin sheets (myocommata).



Myotomes Layers of short fibers in fish muscle.

Myocommata Large sheets of very thin connective tissue separating the myotomes in fish muscle.

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or red pigments. The color of a fish's flesh depends on whether that fish relied predominantly on quick or slow movements to stay alive. Red or darker colored flesh, as seen in salmon, has a higher concentration of the "slow-twitch fibers" needed for long-distance swimming and endurance. White meat, like that of the sole, has more "fast-twitch fibers," which are designed for quick bursts of speed of brief duration between long periods on "cruise control." Some fish, such as tuna, are composed of both fast-twitch and slow-twitch fibers, giving them dark, light, and white meat. A higher fat content will also darken the color of the flesh, as seen in fatty fish such as mackerel and tuna.

The concentration of myoglobin contributes to the overall color of fish flesh. The more oxygen required by the muscle, the more myoglobin proteins are necessary because they carry the oxygen. Unfortunately, a higher myoglobin concentration results in quicker rancidity because the iron in myoglobin accelerates the oxidation of fat found in the muscle (2).

How & Why?

Why do salmon have that characteristic pink/orange hue?

Sometimes a specific pigment adds a special hue. In this case, a carotenoid pigment, astaxanthin, imparts a characteristic orange-pink color to certain salmon and trout that feed on insects and crustaceans containing this pigment.

PURCHASING FISH AND SHELLFISH

Commonly purchased fish and shellfish and their uses are listed in Table 9-3. Retailers providing consumers with nutrition information must abide by the FDA's nutrition labeling regulations for fish and shellfish (23). Fish processors may submit to inspection and grading on a voluntary basis.

TABLE 9-3 Types of Fish and Shellfish and Their Uses

Common Name(s)	Uses
American pollock (Boston bluefish)	Baked, broiled, pan-fried, steamed, or poached
American shad (buck roe; white shad)	Baked, broiled, planked, stuffed, or sautéed
Atlantic croaker (croaker; hardhead)	Baked, broiled, poached, pan-fried, or oven-fried
Blue crab	Steamed (boiled), cakes, patties, deviled, stuffed, casseroles, salads, or appetizers
Carp	Not a favorite of Americans; eaten by Europeans
Catfish	Baked, broiled, grilled, barbecued, smoked, sautéed, or stuffed
Cod (codfish; scrod)	Baked, broiled, poached, fried, or steamed; oven finish or deep-fry breaded portions and sticks
Crayfish (crawfish)	Like lobster; thick soup, crayfish bisque
Dungeness crab	Steamed, baked, broiled, simmered, casseroles, salads, appetizers, cocktails, and sauces
Flounder (blackback, fluke; summer flounder, winter flounder)	Baked, broiled, poached, fried, steamed; oven finish or deep-fry breaded fillets, sticks, or portions
Geoduck clam	Steaks, fried, minced as dip or chowder; party snacks
Haddock (scrod)	Same as flounder
Halibut (North Pacific halibut)	Baked, broiled, poached, fried, or steamed
Herring (Pacific Sea herring)	Bait, oil, fertilizer; cooked or eaten as kippered herring
Jonah crab	Steamed, simmered, or broiled; casseroles, salads, appetizers, cocktails, and sauces
King crab	Used interchangeably with other crabmeat recipes; casseroles, salads, appetizers, cocktails, and sauces
Lake trout	Baked, broiled, poached, fried, steamed, or sautéed
Lingcod	Broiled, sautéed, baked, poached, or deep fried
Lobster (spiny lobster)	Baked, broiled, or simmered; variety of recipes for use
Mackerel	Baked, broiled, fried, poached, or steamed
Menhaden (pogy; fatback)	Seldom for human consumption
Mullet (black or striped mullet)	Deep-fried, oven-fried, baked, or broiled
Ocean perch (redfish; rockfish; rosefish)	Baked, broiled, poached, or steamed fillets; oven fried or deep-fried, breaded, raw, or cooked portions
Ocean quahog clam (mahogany quahog; black quahog)	Deep-fried; pan-fried patties; deviled clams; Manhattan clam chowder; clam cakes and rolls
Oysters (Eastern or Atlantic oyster; Pacific oyster; Western oyster)	Steamed, baked, sautéed, or used in variety of dishes
Pacific cod	Baked, broiled, poached, fried, or steamed; oven-finish breaded, cooked portions or sticks, deep-fried frozen breaded cuts
Pompano (cobblerfish; butterfish; Pacific oyster; Western oyster)	Baked, broiled, pan-fried, or deep-fried
Porgy (scup)	Baked, pan-fried, or sautéed
Rainbow trout	Baked, broiled, pan-fried, poached, or steamed
Red crab	Broiled, baked, steamed, sautéed, or served cold; suitable in any recipe for crab

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TABLE 9-3 *(continued)*

Common Name(s)	Uses
Red snapper	Broiled, baked, steamed, or boiled
Rockfish	Baked, broiled, fried, and in chowders
Sablefish (black cod)	Ready-to-eat; steamed; used in casseroles or salads
Salmon	Baked, broiled, barbecued, fried, steamed, or poached; variety of recipes and dishes
Sardines (Atlantic herring)	Ready-to-eat snack; convenience food
Scallop	Boiled or sautéed, cocktails
Sea bass (striped bass)	Baked, broiled, pan-fried, oven-fried, or poached
Shrimp (Northern shrimp; North Pacific shrimp; Southern shrimp)	Simmered, baked, broiled, fried, or oven-finish; cocktail; hundreds of uses such as casseroles, salads, and sauces
Smelt (eulachon)	Broiled, fried, baked, or prepared in casserole
Snow crab (tanner; queen)	Used interchangeably with other crabmeat recipes
Sole (gray sole; witch flounder)	Baked, broiled, fried, steamed, or deep-fried
Spanish mackerel	Baked, broiled, or smoked
Squid (inkfish; bone squid; taw taw; calamari; sea arrow)	Fried or baked with a stuffing; salads; sauces; combination dishes
Sturgeon	Smoked, poached, or pan fried
Sunray Venus clam	Chowder, fritters, patties, dips, and clam loaf
Surf clam	Steamed, fried, or broiled; in chowders, fritters, sauces, dips, or salads
Swordfish	Baked, broiled, fried, poached, or steamed
Tuna	As it comes from the can; variety of recipes
Weakfish (gray sea trout; squeteagues)	Baked, broiled, sautéed, or pan-fried
Whiting (frost fish; hake; silver hake)	Baked, broiled, pan-fried, poached, or steamed; portions and sticks oven-finished
Yellow perch	Baked, broiled, or pan- or deep-fried

Inspection/Grading

Unlike inspection of meat and poultry, inspection of finfish is voluntary. Inspection, when it occurs, is based on the wholesomeness of the fish and the sanitary conditions of the processing plant. The National Marine Fisheries Service of the U.S. Department of Commerce is responsible for fish inspections, which are paid for by the processor.

Only inspected finfish can be graded. Grading, too, is voluntary and paid for by the processor. Fish products are graded U.S. Grade A, U.S. Grade B, and substandard. Quality grades are based on appearance, texture, uniformity, good flavor, fresh odor, and an absence of defects. Breaded fish products are further evaluated in terms of their breading and bone-to-fish ratio. Labels should be read whenever possible to find out whether or not the fish product has been inspected and graded.

Shellfish Certification

The U.S. Department of Commerce also oversees the monthly online publication of the Interstate Certified Shellfish Shippers List (ICSSL), which is a PDF list of department-certified shippers of oysters, clams, mussels, and scallops (available at www.fda.gov/food/guidanceregulation/federalstatefoodprograms/ucm2006753.htm). Only shellfish from these certified waters, which have been tested and found to be free of excessive levels of various microorganisms, can be sold for consumption. Wholesale containers of shellfish must then be labeled to include the harvester's name, address, and certification number; the date and location of harvest; and the type and quantity of shellfish. Shellfish that have been *shucked*, or removed from their shells, must also be tagged with a "sell by date" (for containers under 64 fluid ounces) or "date shucked" (over 64 fluid ounces). Food-service operations are required to keep these tags for at least 90 days upon receipt. If shellfish are not properly tagged or are obtained from uncertified waters, the Department of Commerce may report the violation to the FDA, which is the regulatory agency with final jurisdiction over commerce in shellfish.

Selection of Finfish

The criteria for selection of vertebrate and invertebrate seafood are very different and so will be described separately. Finfish can be purchased fresh or frozen, canned, cured, fabricated, or as fish roe.

Fresh and Frozen Fish

Fish can be purchased fresh or frozen in several forms: whole, drawn, dressed, steaks, fillets, and sticks (Figure 9-3).

- ***Whole fish.*** The body is entirely intact.
- ***Drawn fish.*** Whole fish that have had their entrails (inner organs) removed.
- ***Dressed fish.*** The head, tail, fins, and scales have been removed in addition to the entrails.
- ***Steaks.*** Cut from dressed fish by slicing from the top fin to the bottom fin at a 90-degree angle at varying thicknesses. Steaks contain a portion of the backbone and other bones. Some steaks from large fish such as tuna are commonly called fillets, even though they are actually steaks (20).
- ***Fillets.*** Made by slicing the fish lengthwise from front to back to avoid the bones. A fillet is one whole, boneless side of the fish (20).
- ***Fish sticks.*** Uniform portions cut from fillets or steaks. They can also be made from minced fish that is then shaped, breaded, and frozen.

Variety of Finfish

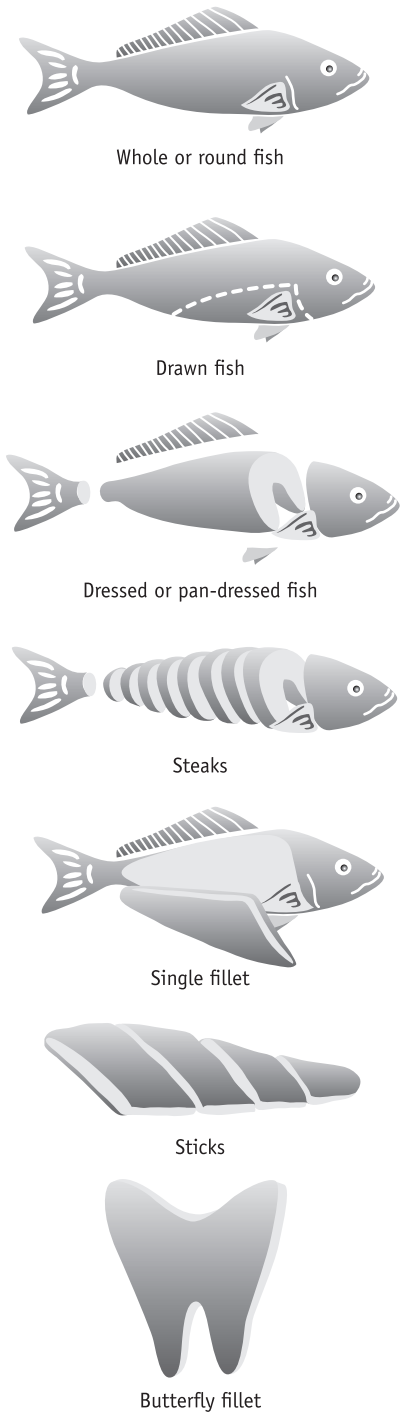
There are subtle differences in flavor even among different varieties of the same type of fish. For example, there are two types of salmon—Atlantic and Pacific. Among Pacific salmon, there are five types—chinook (king), coho (silver), chum (keta), pink, and sockeye.

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FIGURE 9-3 Forms of finfish available for purchase.



Source: Department of Fisheries.

Gaping The separation of fish flesh into flakes that occurs as the steak or fillet ages.

How & Why?

What is DNA bar coding?

Fish geneticists have found that about 33% of seafood products are fraudulently identified—for example, rockfish may be labeled as red snapper, or perch as shark. DNA bar coding properly identifies fish flesh based on its gene sequences (15).

Determining Freshness of Fish

Sniffing for aroma may be the safest and easiest method of determining whether fish is fresh, but other criteria can be applied in addition to the "sniff test." When selecting whole fish, look for skin that is bright and shiny and eyes that bulge, are jet black, and have translucent corneas (the part surrounding the pupil). The fish should have a "fresh fish" aroma, tight scales, firm flesh, a stiff body, red gills, and a belly free of swelling or gas. The same criteria hold true for drawn fish with the exception of the potential gas-filled belly, which, of course, has been removed. At the market, look for fish that is stored on, but not directly in contact with, ice. The flesh should look shiny, moist, and plump (3). Avoid fish that looks spongy or gapes apart.

Rigor Mortis

A stiff body is preferred when selecting a finfish because it is an indication that it is still in rigor mortis, which occurs after slaughter. Flesh that is allowed to go through rigor mortis (stiff to relaxed muscles) has a better texture and flavor. The water-holding capacity of the proteins is increased, which makes the flesh juicier than that of fish that have not undergone rigor mortis. For these reasons, it is better that handling, packing, processing, and freezing be avoided while fish are in the rigor state (6). It is also recommended that fish not be subjected to excessive stress prior to slaughter, if possible, because this results in stronger rigor mortis that is detrimental to texture (21).

Rigor mortis in fish can last anywhere from several hours to days, depending on the species, temperature, and condition of the fish when caught. Stiffness is delayed if caught fish are immediately placed on ice and kept chilled. Freshness is extended under these conditions because bacterial spoilage does not occur until after rigor mortis has passed. Freezing fish immediately after capture, rather than chilling them on ice and allowing rigor mortis to proceed until the muscles relax again, results in a tough-textured flesh. Cooking fish prior to rigor mortis also results in a tough texture.

Phosphate Treatment of Fresh Finfish

The meat of the fish should not be slimy, but this can be tricky to judge because of the practice of soaking fish in a special phosphate-containing solution to prevent moisture loss (which can produce slime). This solution increases the pH of the tissue, which denatures the proteins and makes them more capable of binding water. Thus, it restores the water-binding capacity of the muscle proteins and prevents the flesh from becoming dry and stringy. Fishermen frequently treat fish with this solution to cut down on the water loss, which might endanger their weight-based profits. Without this solution, fish that is refrigerated may lose up to 80% of its water-binding capacity within 5 days after harvest. Treatment with phosphates also partially inhibits the oxidation of the natural fats in fish, which can result in "fishy" smells when the phosphates bind with the metal ions that promote oxidation.

Signs of Decay in Fresh Finfish

Other changes occur in a fish after death: the eyes flatten and become concave (although this may also be a result of the fish having been picked up by the eye sockets), the pupil turns gray or creamy brown, and the cornea becomes opaque and discolored. In addition, the bright red gills turn a paler brown and, as a result, are sometimes removed.

When the gills turn brown and the eyes lose their bright look, the fish may be cut up as steaks, fillets, or fish sticks. Steaks and fillets should have a shiny, smooth surface that has no signs of curling at the edges. The pieces should be cut cleanly with no signs of blood, skin fragments, or loose bone, and they should be firm and free of **gaping** (Figure 9-4). Although gaping is a sign of aging, it may also be a result of rough handling, processing before rigor

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FIGURE 9-4 A badly gaping fish fillet.



Warren Price Photography/Shutterstock.com

mortis is complete, the fish having been caught after spawning, or even genetics. Certain fish, such as bluefish and hake, are known to gape more easily (18). Gaping is caused by the separation of the myotomes (13).

Mercury Contamination

Mercury occurs naturally in the environment, but it can also be released into the air through industrial pollution (7, 22). Concerns about mercury contamination in fish date back to 1953 in Minamata, Japan, where certain manufacturing plants polluted the water with mercury (mercury can fall from the air into the water, where it becomes methylmercury). The fish there became contaminated and in turn caused health problems for about 120 people in the region who ate the fish. Infants who became sick had not eaten the fish, but their mothers had consumed the contaminated fish during pregnancy.

How & Why?

Why are some fish higher in mercury than others?

Mercury makes its way into water from either natural or industrial sources and is taken up into the gills of fish as they swim. It stays in the body for long periods of time, and small fish store this mercury in their flesh. Larger fish feed off of small fish. This means that larger fish are exposed to even higher levels of mercury because every time they eat a small fish, they add mercury to their flesh. This is why larger, predatory fish and fish with long lives, such as swordfish, have the highest levels of mercury (22).

NUTRIENT CONTENT

Protein. Fish is a high-protein food. In fact, fish is so **high in protein—about 18 to 20%**—that the food industry has devised the means to make protein concentrates by grinding whole fish, including the calcium-rich bones (if consumed), dehydrating it, and removing the fat to take away the fishy flavor. The resulting concentrate of between 70 and 80% pure protein is used as an additive in foods such as noodles to increase both their protein quality and their calcium content (37).

Fat and Carbohydrates. As a general rule, finfish are a **low-fat food**. Most fish, **unless they have been fried**, are lower in fat than equivalent amounts of beef, pork, lamb, and even poultry. With the exceptions of mackerel, shark, herring, and eel, fish generally contain fewer than **160 kcalories per 3-ounce cooked** portion. Most of the kcalories in fish are derived from protein and fat, with few, if any, from carbohydrates. Shellfish contain carbohydrates in the form of glycogen, ranging in concentration from 1 to 3% by weight. Although fish and shellfish are relatively low in fat, **some crustaceans such as shrimp contain approximately 125 milligrams of cholesterol per 100 grams** (42).

Functional Foods. Even though fat does contribute to kcalories, the fat from fish is a good source of **omega-3 fatty acids** (Table 9-4), which are linked to several health benefits (32, 45). The consumption of omega-3 fatty acids has been reported to be related to a decrease in the risk of heart disease (12, 29). It has also been suggested that they play a beneficial role in the alleviation of psoriasis and some inflammatory diseases, such as rheumatoid arthritis (48), lupus erythematosus (26), and inflammatory bowel disease (5). High levels of omega-3 fatty acids are thought to be necessary for early brain development (45).

Vitamins and Minerals. Fish is also a **good source of the B vitamins**—thiamine (B_1), riboflavin (B_2), niacin, B_6 (pyridoxine), and B_{12}—although small amounts of these water-soluble vitamins may be lost through decomposition, heating (cooking or canning), and/or extraction in water or salt solutions. The higher the fat content is, the higher the levels of the fat-soluble vitamins A and D in the fish. Long before vitamin supplements became available, children were given (notoriously awful-tasting) **cod liver oil as a dietary supplement of vitamin D** to help protect them against rickets. Fish flesh is also a significant source of **some minerals**. Iodine is found primarily in saltwater fish. Sardines and salmon canned with the bones are good sources of calcium, and fish does contain some iron (35). For those watching their intake of **sodium, dried or smoked fish** have higher concentrations than the fresh forms.

TABLE 9-4 Fish High in Omega-3 Fatty Acids (3-ounce cooked portion)

More Than 1.0 Gram	Between 0.5 and 1.0 Gram
Herring	Bass (freshwater)
Mackerel (Pacific, jack, Spanish)	Bluefish
Salmon (Atlantic, king, pink)	Mackerel (Atlantic)
Tuna (bluefin)	Salmon (chum, coho, sockeye)
Whitefish	Smelt
	Striped bass
	Swordfish
	Rainbow trout

The mercury found in fish is different from the type of mercury used in thermometers or dental amalgam (22). Nearly all fish contain minute amounts of methylmercury that are not harmful to humans. However, mercury can accumulate to levels that are toxic to the

Omega-3 fatty acids
Polyunsaturated fatty acids in which the first double bond is three carbons from the methyl ($-CH_3$) end; examples are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

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developing central nervous system (brain and spinal cord), so its potential health risk is especially high to those who are in the early stages of brain development.

Because excess mercury may cause damage to the developing brain and nervous system (22), women who might become pregnant, women who are pregnant and/or nursing, and young children are particularly vulnerable to its effects. However, these groups also need to have sufficient weekly fish intake because fish contains protein, other nutrients, and possibly healthy types of fat (omega-3 fatty acids) that reduce the risk of heart disease and other health problems, as well as contribute to growth and development before birth, in early infancy, and in childhood (22). This is why the FDA issued the following new recommendations for these groups (2017; initially in 2001) (Figure 9-5).

How Much Fish to Buy

Part of selecting finfish is knowing how much to buy. A few general guidelines exist. About ½ pound of steaks makes an appropriate portion per person. Fillets or sticks require about ¼ to ⅓ pound per person. Purchases of ½ to ¾ pound for each person will be required when buying dressed fish, and ¾ to 1 pound per serving for whole or drawn fish.

Processed Fish Products

Fish mince, also called ground fish or fish hamburgers, can be prepared with mechanical deboners (see Chemist's Corner 9-1) (40). This often results in a poor texture due to enzymes in the fish meat. Attempts to improve the texture of fish mince include the addition of cornstarch.

Canned Fish

About half of all fish consumed in the United States is canned. Tuna accounts for approximately three-fourths of canned fish consumption. Other commonly canned fish and shellfish include salmon, sardines, shrimp, clams, and crab (41). Canning alleviates the problem of the rapid perishability of fish.

Tuna

Six species of tuna are canned and sold in the United States: yellowfish, skipjack, bluefin, Oriental tuna, little tuna, and albacore. Canned tuna labeled "white"

FIGURE 9-5 Advice about eating fish. What pregnant women and parents should know.

Fish and other prortein-rich foods have nutrients that can help your child's growth and development. For women of childbearing age (about 16–49 years old), especially pregnant and breastfeeding women, and for parents and caregivers of young children.

- *Eat 2 to 3 servings of fish a week from the "Best Choices" list OR 1 serving from the "Good Choices" list.*
- *Eat a variety of fish.*
- *Serve 1 to 2 servings of fish a week to children, starting at age 2. Serving size equals 4 ounces for an adult and 2 ounces for children 4–7 years of age.*
- *If you eat fish caught by family or friends, check for fish advisories.*
- *If there is no advisory, eat only one serving and no other fish that week.**

Best Choices EAT 2 TO 3 SERVINGS A WEEK

Anchovy	Herring	Scallop
Atlantic croaker	Lobster,	Shad
Atlantic mackerel	American and spiny	Shrimp
Black sea bass	Mullet	Skate
Butterfish	Oyster	Smelt
Catfish	Pacific chub	Sole
Clam	mackerel	Squid
Cod	Perch, freshwater	Tilapia
Crab	and ocean	Trout, freshwater
Crawfish	Pickerel	Tuna, canned light
Flounder	Plaice	(includes skipjack)
Haddock	Pollock	Whitefish
Hake	Salmon	Whiting
	Sardine	

OR

Good Choices EAT 1 SERVING A WEEK

Bluefish	Monkfish	Tilefish (Atlantic
Buffalofish	Rockfish	Ocean)
Carp	Sablefish	Tuna, albacore/
Chilean sea bass/	Sheepshead	white tuna, canned
Patagonian toothfish	Snapper	and fresh/frozen
Grouper	Spanish mackerel	Tuna, yellowfin
Halibut	Striped bass	Weakfish/seatrout
Mahi mahi/	(ocean)	White croaker/
dolphinfish		Pacific croaker

Choices to Avoid HIGHEST MERCURY LEVELS

King mackerel	Shark	Tilefish
Marlin	Swordfish	(Gulf of Mexico)
Orange roughy		Tuna, bigeye

*Some fish caught by family and friends, such as larger carp, catfish, trout and perch, are more likely to have fish advisories due to mercury or other contaminants. State advisories will tell you how often you can safely eat those fish.

www.FDA.gov/fishadvice
www.EPA.gov/fishadvice

EPA United States Environmental Protection Agency

FDA U.S. Food & Drug ADMINISTRATION

US Food and Drug Administration FDA

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CHEMIST'S CORNER 9-1

Why Fish Mince Develops a Bad Texture

Some fish species, including haddock, cod, and pollock, become tough when they are processed into fish mince. This is partly due to a chemical called trimethylamine oxide (TMAO) in the fish meat (47). TMAO is thought to help fish regulate water and salt when they live in the ocean. After mincing and refrigeration, TMAO is broken down to trimethylamine (TMA) by bacteria, resulting in the "spoiled fish" odor. When fish are frozen rather than refrigerated, TMAO instead breaks down to dimethylamine (DMA) and formaldehyde. DMA does not cause a bad odor, but formaldehyde causes a biochemical reaction that creates links between protein molecules. These links cause the fish to bind water poorly, and the fish meat becomes dry and "cottony."

comes from albacore and is the most expensive. All other tuna is labeled "light meat tuna," although some of it can be quite dark. Canned tuna comes in three different styles: fancy or solid pack (a fillet or whole piece), chunk (large pieces), and flake (fine pieces or grated). Solid pack has the best appearance and is also the most expensive. Tuna may be canned in either water or oil, so buyers should examine labels for nutrition information. The total kcalories can vary drastically depending on the canning medium. Each tablespoon of vegetable oil added to a can of tuna contains about 100 kcalories and 15 grams of fat.

Salmon

Chinook (king) salmon is the most expensive of the canned salmons. In the less expensive ranges are sockeye (red salmon), coho (medium red), pink, and chum. Salmon is often packed with the bones, which increases the calcium content (if the bones are consumed).

Sardines

Sardines are always packed with their bones unless otherwise noted on the label. They typically come packed in tomato sauce, mustard sauce, or oil, but they are also available packed in jalapeño sauce or plain water.

Cured Fish

Fish may be cured by drying, salting, or smoking. Curing is one of the oldest ways of preserving fish. Although distinctive tastes and prolonged keeping times are achieved using any of the curing techniques, curing can also harden the outer surfaces. Smoked salmon, smoked haddock (finnan haddie), pickled herring, and smoked herring, also known as kippered herring, are some of the more familiar forms of cured fish. Caviar, discussed later, also belongs in the cured category because it is preserved by salting (Table 9-5).

Anchovies

Anchovies are tiny, bony fish that have been cured with salt. They come to the market either salt-packed or oil-packed and in cans as whole fish, fillets, or anchovy paste. Because of their strong flavor, anchovies are usually used as a garnish or in salad dressings and sauces rather than as a food in themselves. The salt-packed anchovies must first be rinsed, but their flavor tends to be superior to the oil-packed variety.

Fabricated Fish

In an attempt to counter the twin problems of the expense and perishability of fish, several fish products, including fish sticks, fish cakes, nuggets, and simulated fillets, have been developed using fabricated fish. Fabricated fish products make use of the less popular species. The fish are mechanically deboned into a minced fish product, recovering 60 to 90% of the edible meat, and the flesh is then ground, seasoned, shaped, and breaded (1). These products are commonly frozen for sale to the consumer.

TABLE 9-5 Preserved Fish/Roe

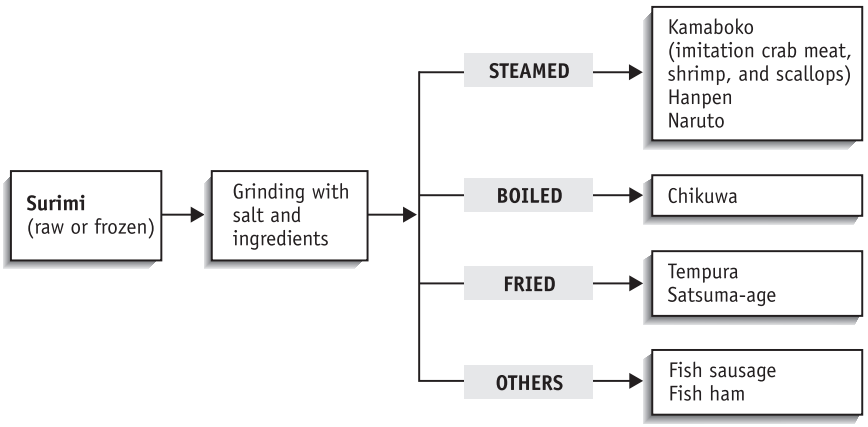
Type	Description
Anchovy	Tiny, very fatty fish with a powerful flavor, which are cured by having most of their fat content removed by pressure and fermentation.
Arbroath smokies	Haddocks or whiting that are brined.
Bismarck herring	German herrings from the Baltic filleted and marinated in vinegar with onion rings for 2 to 3 days.
Bloaters	First developed at Yarmouth, England, in 1835, bloaters owe their special flavor to the activity of gut enzymes. They are dry-salted and smoked.
Block fillets	Haddock or whiting are brined, dyed to make them a bright yellow, and then smoked.
Bombay duck	A well-known Indian condiment made from dried bummalo. It is used as a condiment with curries.
Glasgow pales	So-called because after brining they are lightly smoked.
Katsuoboshi	A Japanese fried fish that can also be smoked.
Lutefisk	The reconstituted unsalted cod from Norway known as stockfish or stockfisk.
Kippers	Good-quality fresh herring, soaked in brine and then smoked.
Matjes herrings	Young Netherlands herring caught in the spring, before they become too fatty.
Migaki-nishin	Japanese dried fish fillets and abalone.
Roes and caviars	Roe is fish eggs. In the United States and many other countries, caviar is defined as the salted roe of any fish species. In Europe, caviar is defined as only the roe from sturgeons (beluga, ossetra, and sevruga) originating in the Caspian Sea.
Rollmops	Herring fillets packed in spiced brine.
Sardine	Fish, cooked either by frying in peanut oil or steam cooking.
Smoked eels	Brined, dry-salted, and smoked.
Smoked salmon	Dry-salted with fine salt and smoked. Some curers add brown sugar, saltpeter, and rum.
Smoked sprats	The most famous are the *Kieler Sprotten*—brined sprats from Germany.
Smoked trout	Rainbow and brown trout are brined, speared on rods, smoked, and then hot-smoked.

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FIGURE 9-6 Surimi products.



Surimi

The very high cost of genuine crabmeat has led to the introduction in this country of **Surimi**, which has been used for centuries in Japan. More than 900 years ago, a Japanese fisherman discovered that fish would last much longer if it was minced, washed, mixed with salt and spices, ground into a paste, and then cooked (43). Today the deboned and minced fish is treated to produce a pure-white product with a somewhat elastic, chewy texture that "sets" when the mixture forms a translucent, elastic, moist gel (39) (Chemist's Corner 9-2). Adding starch or egg whites enhances binding, texture, and flavoring. Flavors such as salt and sugar are added directly. Red coloring is often added to impart the appearance of cooked crab legs.

Surimi at this stage cannot be consumed until it is cooked, and it is the method of cooking that determines the type of food produced (Figure 9-6). North Americans are most familiar with kamaboko, which is surimi that has been steamed and shaped into pieces resembling crab, shrimp, or scallops (27). Although the taste may be very similar to crab, the nutritional values are not. The resultant product usually has 75% less cholesterol than the original shellfish but very little, if any, of the omega-3 fatty acids. It usually has more sodium because of the added salt.

Surimi Japanese for "minced meat"; a fabricated fish product usually made from Alaska pollock, a deep-sea whitefish, which is skinned, deboned, minced, washed, strained, and shaped into pieces to resemble crab, shrimp, or scallops.

Food Additives in Fish

Preservatives are often added to fabricated fish products to maintain their shelf life. One such preservative is phosphate, which is often added because it increases water-binding capacity and contributes to a greater freezing stability (11).

Caviar

Caviar, despite the mystique surrounding it as a food of the very rich, is really just fish eggs, also known as roe. The eggs of vertebrate fish, which are held together by a thin membranous sac, are available from female fish only during the spawning season and are highly perishable. The official definition of caviar varies according to the country in which it is sold. In the United States and many other countries, caviar is the clean, salted fish eggs of any fish species. The label is required to list the particular type of fish serving as the caviar source. In Europe, caviar is more narrowly defined by law as the eggs of the Caspian Sea sturgeon.

The most expensive, largest-grained caviar comes from the beluga sturgeon. These fish can live for more than 70 years and may grow to a length of 25 feet (19). Like chicken eggs, roe is very high in cholesterol—about 94 mg per tablespoon. It is also high in salt, but the best caviar is *malassol*, which in Russian means "little salt." To protect the taste of caviar, it is served with a bone or shell spoon because metal imparts an off-flavor. It is sometimes served on a neutral-tasting bread that has been toasted on one side, with the caviar gently placed on the untoasted side.

CHEMIST'S CORNER 9-2

Surimi

Surimi's "springy" texture is derived in part from gums that are added to help form gels. Another influence is washing, which leaves behind the water-insoluble (myofibrillar) protein that gives surimi its elasticity and gel-forming capacity. Sugars such as sucrose and sorbitol are added as cryoprotectants to protect the myofibrillar proteins from denaturation during freezing (43). Starch granules make the surimi more compact by swelling with water around the protein matrix and filling in the interstitial spaces (39). Improved gel strength is obtained by adding egg whites, which inhibit endogenous protease activity in fish flesh. Salt is then added to the surimi to solubilize its protein and produce a firm, elastic gel, and again later during freezing for stabilization (30).

Freshwater roe is often breaded and fried, but the surrounding sac must be pierced first or it may explode during frying, causing severe burns. A major drawback to fresh fish roe is that it stays fresh for only a day or two at the most; it is usually preserved in a brine solution, which imparts a salty flavor, firms the roe, and extends its usable time. The roe sold in the unrefrigerated section of the supermarket has been pasteurized to extend its shelf life. Fish such as shad and herring from North Atlantic waters are popular roe sources, as are Pacific salmon and whitefish from the Great Lakes. Other roe sources include cod, carp, pike-perch, and gray mullet (Table 9-6) (19).

Selection of Shellfish

The purchaser of shellfish is faced with several different forms from which to choose. The first decision is whether to buy them alive or processed.

Purchasing Live Shellfish

Lobsters, crabs, oysters, and clams all may be purchased alive and in their shells. Shellfish are highly perishable; to maintain their quality, they must be

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TABLE 9-6 Sources of Caviar and Roe

Sturgeon	
Beluga	The beluga, the largest of the Caspian Sea sturgeon, produces the rarest and most expensive caviar. Beluga eggs are large and gray.
Osetra	Osetra caviar are more available than beluga. The medium-size eggs are gray-brown and have a nutty, meaty taste.
Sevruga	The smallest of the Caspian Sea sturgeon, the sevruga produces small, gray eggs with a stronger, fishier taste than the other Caspian Sea caviars. Sevruga caviar is particularly popular in Russia and Europe.
Other Roe-Producing Fish	
Lumpfish	The lumpfish, caught off Iceland, produces small, colorful (black, red, or yellow) eggs that are popular as a garnish.
Salmon	The large, pinkish eggs of the salmon, from the Pacific Northwest, are also frequently used as a garnish.
Whitefish	The North American Whitefish produces small, golden eggs with a distinct crunch and mild flavor.
American paddlefish	This denizen of the Mississippi River and its tributaries produces roe that looks like sevruga caviar. The small, gray eggs have a tangy flavor.

kept alive until they are cooked or, in the case of oysters, consumed raw.

Selecting Live Mollusks

It is easy to tell whether or not crustaceans are alive, as they are normally active creatures; in contrast, determining the state of mollusks in their closed shells poses more of a puzzle. Tapping on the shell should cause it to close more tightly; the rule in most cases is that if the shell remains open, the mollusk is dead and should be discarded. The exceptions to this rule are mussels, which ordinarily gape, and longneck (steamer or soft-shell) clams, which normally have a gap in the shells where the "neck" protrudes. Any shells that are broken, have a decaying odor, or float should be discarded.

The "R-Month Rule"

An old rule of thumb held that shellfish should be eaten only during the months with the letter *r* in their names because bacterial illnesses are more common in the warmer months of May through August. This is still a valid guideline, although modern methods of harvesting and storage provide a safer supply of shellfish year round.

Purchasing Processed Shellfish

Shellfish can be sold raw within their shells, after removal of the shell, or after cooking. The shelf life of shellfish is longest when they are sold with their shells on, with minimal processing (14). They can be further processed by opening the shell via steam, pressure, or flames. The meat can then be removed from the shell by cutting it from the shell and/or placing the shellfish in brine, where the shells sink, and the meat floats.

Shellfish can also be bought cooked in the shell and chilled or frozen. Alternatively, the meat can be removed from the shell and sold fresh, chilled, frozen, canned, salted, smoked, or dried. Shellfish can be sold headless and in their shell, as in the case of shrimp or lobster tail, or they may be shucked, or removed from the shell, with a special knife. Shucked shrimp, scallops, oysters, and clams are often breaded and frozen. Shrimp may also be sold with the intestinal tract removed, a form known as "peeled and deveined."

Shucking Shellfish

Shucking bivalves such as clams and oysters is a somewhat dangerous process (Figure 9-7). The hand holding the bivalve should be protected with a towel or a metal-mesh glove. The hinge is severed as the shells are pried apart, and the empty half of the shell is discarded; the muscle attachment to the other shell is spliced so the meat can be removed. An average worker can shuck almost 7 pounds in an hour, but automated shucking speeds up the process.

Oysters

Oysters can be bought live in the shell, or shucked and then chilled, frozen, or canned. Live oysters should have tightly closed shells. Any gap between the shells means the oyster is dead and should be discarded. Select shucked oysters that are plump and full-bodied; about 1 cup is equal to 1 serving. If the oysters are in their shell, buy half a dozen per person. Three varieties of oyster are commonly available in the United States: eastern oysters from the Atlantic coast, and Olympia (small) and Japanese (large) oysters from the Pacific coast. Well-refrigerated oysters in the shell have a longer shelf life than other mollusks because their shells remain very tightly closed, whereas other shellfish have a tendency to gape, making them more susceptible to drying out and dying.

FIGURE 9-7 Steps to shucking oysters.



1. Hold oyster, flatter shell up, with a folded towel, and place the tip of the knife near the hinge at the pointed end.



2. Move the tip of the knife around to the front side. Pry and push the tip to bore into the shell until it pops open.



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Clams

Clams can be bought in the same forms as oysters, and, as with oysters, their shells should be closed tightly, and there should be no decaying odor. About six to eight shelled clams are required per serving. A variety of clams can be purchased. Clams may be soft-shell or hard-shell. Soft-shell clams are not, in fact, soft, but their shells are thin and brittle. Their neck (often called a "foot") sometimes sticks out like a long, soft hose to siphon and release ocean water. Soft-shell clams are also known as longnecks or pissers because of this long tube. Soft-shell clams do not completely close, so they are very susceptible to drying out and dying. A limp neck hanging out of the shell signals that the clam is dead and should be discarded (18). Soft-shell clams should be consumed within a day of purchase. They should never be eaten raw, which is why they are sometimes called steamers or fryers. Even if cooked, they are often more sandy or gritty than hard-shell clams because of their partially opened shell. As a result, they are often soaked in cold salted water in an attempt to eliminate the sand, and then served with the broth they were cooked in to rinse off any remaining grit.

The meat of hard-shell clams is less tender than that of soft-shell clams. East Coast hard-shell clams include cherrystones, which are the most common variety; littlenecks, which are the smallest and most tender; and chowders or quahogs (pronounced KO-hog by Cape Cod natives), which are the largest. The larger the clam muscle is, the tougher the meat will be, so they are often chopped up and used in clam chowder or stews. West Coast varieties include razor and pismo clams.

Scallops

In North America, the only part of the scallop that is eaten is the creamy white or tan-colored abductor muscle responsible for opening and closing the shell to move it through the water. Scallops cannot close their shell tightly when taken from the water, so they are usually shucked and then sold fresh, frozen, or canned. This sweet-tasting mollusk varies in diameter from ½ inch to 2 inches, and about ¼ to ⅓ pound is an adequate portion for one person. The three main varieties of scallops available are bay scallops, which are small, sweet, and delicate; sea scallops, which are larger and not as delicate; and calico scallops, the least expensive, tiniest, and blandest in flavor. Calico scallops are often sold cooked or frozen.

FIGURE 9-8 Mussels are often steamed open and served in the shell.



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Mussels

The black or dark-blue colored shells of common mussels should be scrubbed free of barnacles, but the "beards" or black threads used to attach the shells to solid foundations in the ocean should not be pulled out until the mussels are ready to be cooked because removing them kills the mussel (18). Mussels are heated in their shells after being purchased live (Figure 9-8), or they are shucked and packed in brine. Extremely hollow or heavy-feeling mussels should be discarded because they are either dead or filled with sand. Also available are the larger, green-lipped New Zealand mussels, whose size makes them ideal for stuffing and baking.

Abalone

Abalone is expensive because the supply is limited (18). These large mollusks are found mostly in the waters off California and northern Mexico. Unlike the other mollusks discussed, abalone have only one shell. Most of the animal consists of a massive, muscular foot. Only abalone with meat weighing at least ¼ pound may be legally harvested; some extremely large abalone yield as much as 3 pounds. The strict regulations governing the harvesting of wild abalone have led to abalone farming, primarily in California and Hawaii (36).

Lobsters

Lobsters are the largest of the crustaceans. They are mainly purchased as Northern (or Maine) lobster, or spiny or rock lobster varieties (Figure 9-9). Gourmet cooks prefer the female lobster for its finer flavor and because it contains "coral," or lobster roe, which is considered a delicacy. When cooked, the roe turns from dark green to red and is often used to color a sauce or is served alone as a garnish. Another delicacy, found in both male and female lobsters, is the pale green liver, known as tomalley.

The majority of the meat from a lobster is in the tail, but there is also some in the claws of the Maine lobster. Lobsters are right-handed or left-handed, as indicated by which claw is the larger, and although the larger claw has more meat, that from the smaller claw is sweeter and more tender. Northern lobsters with one or both claws missing are sometimes sold as "culls." They are less expensive and are attractive to the buyer interested only in the tail meat. Unless they are canned or frozen, lobsters must remain alive until cooked, at which point their natural dark blue-gray or greenish color turns deep orange or red.

FIGURE 9-9 Northern lobster (*left*); spiny or rock lobster (*right*).



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FIGURE 9-10 Peeling and deveining shrimp.



Amy C. Brown

(1) Peel the shrimp's shell off after pulling away the legs.



(2) Make a slight incision down the back to expose the black intestine.



(3) Using the knife's point, lift and remove the intestine.

Shrimp

The tail harbors most of the meat in shrimp. They are sold, headless, in either the raw shell-on (green shrimp), cooked shell-on, or cooked and peeled form. All three forms come both fresh and frozen, but the majority of shrimp are frozen.

Peeling and Cleaning Shrimp

When shrimp are bought in their shells, they must first be peeled. Medium or large shrimp are then deveined, which involves removing the dark-colored "sand vein" that runs along the shrimp's back (Figure 9-10). The "sand vein" is usually left in small shrimp, where it is undetectable.

How & Why?

Why must the sand vein in large shrimp be removed?

The sand vein is actually the shrimp's intestines. In larger shrimp, it contributes a gritty, muddy taste if it is not removed.

After cleaning, the shrimp are dried by pressing them between paper towels to absorb as much moisture as possible. Before they are cooked, shrimp are somewhat grayish green, but they turn dark pink to borderline red when heated.

How Much Shrimp to Buy

In general, the serving size averages ⅓ to ½ pound for headless, unpeeled shrimp, or ¼ to ⅓ pound for peeled and deveined shrimp. Shrimp are available in small, medium, large medium, large, and jumbo sizes, but these descriptions are not official, nor are they used consistently by shrimp sellers (18). As a result, shrimp is purchased by "count per pound." The smaller the shrimp are, the higher the count per pound (Figure 9-11). For example, the number 51/60 on a shrimp package means that there are 51 to 60 individual shrimp in 1 pound. Seeing 21/25 on the label indicates that the shrimp in that designation are larger because there are 21 to 25 shrimp for the same weight of 1 pound. A U/15 or U/10A means "under 15" or "under 10" shrimp per pound. These would be the largest shrimp available. It is an incorrect but common practice to identify the largest jumbo-size shrimp as **prawns** True prawns have lobster-like pincer claws and are different from shrimp in other ways. Another shrimp-related North American misnomer is the use of the word "**scampi**" for describing large broiled shrimp seasoned with butter and garlic.

Canned Shrimp

Glass-like beads are sometimes found in canned shrimp, but they are completely harmless. They are formed during canning, specifically under the high heats of sterilization. Called struvite crystals, they consist of magnesium-ammonium phosphate compounds that form when the magnesium from seawater combines with the ammonia that is produced during heating of the shellfish's natural protein. Phosphate treatment prevents struvite crystal formation because the phosphates bind with the magnesium. Struvite crystals can be crushed to a powder by a fingernail or dissolved by boiling for a few minutes in the weak acid of lemon juice or vinegar.

Crab

Crabs can be sold live, raw, or cooked. Most of their meat is found in their claws and legs. The four top commercially harvested crabs are the blue crab from the Atlantic and Gulf coasts, stone crabs from Florida, Dungeness crabs from the Pacific coast, and, most expensive, king crabs from the northern Pacific waters. Soft-shelled blue crabs are considered a delicacy, particularly on the East Coast. These crabs are caught while molting, a process during which they shed their shells and are left with a temporarily soft exterior. Until this new surface is completely hardened, which may take several days, the crab is more vulnerable to predators, especially two-legged ones such as birds and humans.

Prawn A large crustacean that resembles shrimp but is biologically different. Large shrimp are often called by this name.

Scampi A crustacean found in Italy and not generally available in North America. The term is often used incorrectly to describe a popular shrimp dish.

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FIGURE 9-11 Shrimp size described by "count per pound."



Amy C. Brown

Canned Crab

Canned crab may have a blue tint. This is caused by copper in the crab's blood combining with the ammonia in its flesh. Although the color may appear unappetizing, it is completely harmless.

Crayfish

Referred to as either crayfish, crawdads, or crawfish, these small crustaceans average 4 ounces in weight. Crayfish are similar in appearance to lobsters but smaller, and their first pair of walking legs do not develop into huge, flesh-rich claws. Only their tails serve as a source of meat. They are found mainly in freshwater streams and ponds of the southeastern United States, especially Louisiana. Crayfish are sold both head-on and tails only, fresh and frozen.

PREPARATION OF FISH AND SHELLFISH

Great care must be taken not to overcook seafood; cooking too long or at too high a temperature is the most common mistake when preparing fish or shellfish. It results in excessive flakiness, dryness, and flavor loss in fish and toughness in shellfish. For shellfish, however, the "well-done rule" should always be observed, especially when microwaving, because of the increased chance of their carrying foodborne illness. Shellfish are often simmered or steamed; the results with dry heat are harder to guarantee because the meat may dry out and toughen. Nevertheless, with precautions such as breading taken against drying, shrimp, lobster tails, and half-shelled oysters and clams are fairly commonly baked, broiled, or fried (see Figure 7 in the color insert). Both temperature and time need to be carefully controlled in either dry- or moist-heat preparation of seafood. The following discussion refers to the preparation of finfish unless shellfish is specifically mentioned.

Dry-Heat Preparation

Methods to prepare fish with the use of dry heat include baking, broiling, grilling, and frying.

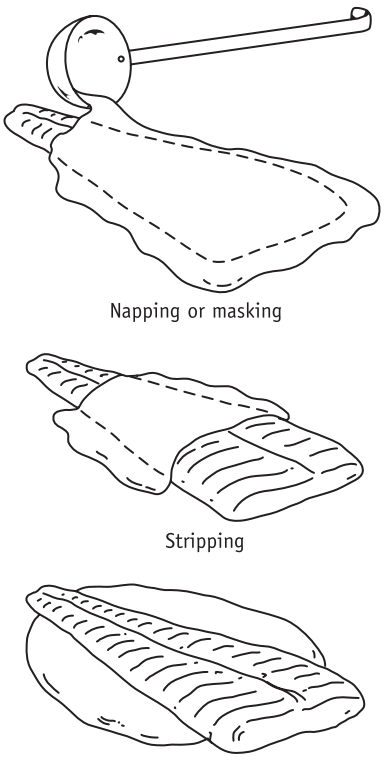
Baking

Fish to be baked should be rinsed, patted dry with paper towels, and placed in a shallow pan. Season as desired, and place in a moderate oven (350 to 400°F [180 to 200°C]). Baking time will vary depending on the shape and thickness of the fish, but a general rule of thumb is to bake up to 10 minutes per inch of thickness measured at the thickest diameter of the fish. Basting with butter or covering the fish with vegetables cuts down on moisture loss. Some prefer to prepare whole or drawn fish with the head and tail left on to help keep juices inside. Additional flavor can be added by filling the cavity with herbs and spices. Leaving the skin on whole or drawn fish seals in the moisture and flavor. Moisture loss may also be prevented by wrapping the fish in foil, parchment paper, grape leaves, or leafy greens. These techniques of enclosing the fish technically result in a moist-heat cooking method because the fish steams in its own juices. The flavor, moisture, color, and texture of baked fish are often enhanced by the addition of sauces (Figure 9-12).

Determining Doneness of Fresh Fish

Fish is done when it flakes easily with the gentle pressure of a fork without falling apart. The opaque look of fish that has been properly prepared is caused by denatured proteins that unwind and hook together with other proteins so that water can attach, resulting in a whitish hue. The presence of this "white" mesh results in a moist and tender flesh. Heating much beyond this stage tightens the protein bonds, shrinks the protein mesh, and squeezes out the water, resulting in tough, dry, unappetizing fish flesh (16). Other signs of doneness include any bone being no longer pink and/or the flesh becoming firm, turning from translucent to opaque, and/or separating from the bone.

FIGURE 9-12 Saucing a fish.



Source: Mizer et al., *Food Preparation for the Professional* (John Wiley & Sons, 1998).

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Baking Shellfish

Shellfish are often prepared by baking; examples include lobster thermidor, baked soft-shell clams, and oysters Rockefeller. In lobster thermidor, the lobster is split in half and baked. The meat is then extracted and mixed with a seasoned béchamel sauce before being put back in the lobster shell and baked again until golden brown and heated through. If soft-shell clams are to be baked in the oven, they are placed in a pan layered with rock salt and baked at 425°F (218°C) for about 15 minutes or until the shells open. Oysters Rockefeller is made by pouring a spinach mixture over half-shell oysters in a pan layered with rock salt. They are baked at 475°F (246°C) for about 10 minutes and then browned briefly under a broiler.

Broiling

Dressed or filleted finfish or fish steaks are best broiled at 5 inches or less below the heat source. Lean fish should be coated with melted butter, margarine, or oil, but this step can be omitted with most fatty fish. Season the fish as desired, place it skin-side down on a pan that has been greased to avoid sticking, and broil it on one side until tender. Lobsters and large shrimp can also be broiled. Whole lobsters need to be killed and split before broiling, whereas lobster tails can be broiled whole.

Grilling

Fish can be grilled on an outside grill or in the oven. Grilling is not recommended for delicate fish such as sole because it may stick to the grill and fall apart easily. Fatty, firm-fleshed fish such as salmon, bluefish, and mackerel that have been drawn or cut into steaks are well suited for grilling. In addition, larger shrimp may be put on skewers such as kabobs and grilled. A fat coating such as oil or even mayonnaise can be applied to the fish to prevent it from sticking to the grill. The grill itself should be scraped of any residue and lightly oiled to prevent sticking. Steaks are seasoned as desired and cooked on both sides if thick, but thin steaks or fillets are cooked on only one side. The fish should be about 4 inches from the heat source. When the fish flakes easily, serve it immediately. Drawn fish can be checked for doneness by slipping the tip of a paring knife into the back of the fish and pulling away. It is done if it clings briefly before giving way, but it is overdone and dry if cooked to the "flakes easily" stage.

Frying

Lean fish less than ½ inch thick, shrimp, and scallops will sauté nicely in a small amount of butter and/or oil. The fish is seasoned as desired and sautéed over medium heat until it is cooked about three-quarters of the way through, at which time it is turned gently with a spatula and heated until the flesh flakes easily. Shellfish are best sautéed on high heat for a short time. Shrimp and scallops are ideal for this type of preparation. When done, scallops will be firm and look opaque, and shrimp will be opaque and pink.

Sautéed Fish Variations

Sautéed fish may be prepared **à la meunière** (a-lah-muhn-YAIR). The dish can be served amandine (with almonds), Florentine (with spinach), or à la belle (with mushrooms). A variation of this method that uses more fat is used to prepare trout and other small fish. They are seasoned, breaded or dipped in cornmeal or flour, and pan-fried until golden brown on both sides. Breading mild fish such as tilapia adds more body and flavor (34).

Deep-Fried Fish

Deep-frying is a popular method for preparing battered or breaded lean fish and shellfish (shrimp, scallops, clams, and oysters). Whole small fish, shellfish (which must first be shelled), fish fillets, or steaks are dipped in batter or seasoned breading mix before being deep-fried in oil until golden brown. The oil is heated to 350°F (180°C) for large fish and about 180°F (82°C) for small seafood such as fish strips, oysters, or clams (36). Fish is always fried alone because it imparts a fishy taste to the oil, which would be picked up by other foods fried in the same oil. Lean fish are preferred because unpleasant oily tastes often occur in fatty fish that are deep-fried.

Moist-Heat Preparation

The moisture of fish is sometimes better retained through moist-heat preparation methods such as poaching, simmering, steaming, and microwaving.

Poaching

Fish is a delicate food suitable for poaching. The lower water temperature of 160 to 180°F (71 to 82°C), which keeps bubbles small and clinging to the sides of the pan, protects the delicate flesh of fish. If a whole, drawn, or dressed fish is being poached, it can be wrapped in cheesecloth to hold it together. The liquid may be a **court bouillon** or a **fumet** Although fatty fish such as salmon can be poached, white, lean fish such as cod, pike, haddock, flounder, sole, whiting, red snapper, halibut, and bass are best suited for this method. Sole fillets are thin enough to make paupiettes, or rolled fillets (Figure 9-13).

When poaching fish, the water should never be allowed to boil. Boiling causes flavor loss and toughens the fish, whereas low temperatures retain maximum flavor and moisture. A well-seasoned poaching liquid is also important. Seasonings and/or chopped vegetables



CALORIE CONTROL
Fish and Shellfish

Fish and shellfish are lower in kcalories and fat as compared with an equal amount of meat (beef, pork, or lamb) or poultry. In fact, fish average 100 to 200 kcalories per 3 ounces. Following are a few helpful hints:

- Water over oil. Choose fish canned in water instead of oil.
- Baked or broiled over breaded and fried. The healthier option is to choose fish that has been baked, broiled, steamed, grilled, or cooked by any method other than breaded and fried.

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À la meunière Fish seasoned, lightly floured, and sautéed in clarified butter or oil and served with a sauce made with butter and parsley.

Court bouillon Seasoned stock containing white wine and/or vinegar.

Fumet A flavorful fish stock made with white wine.

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FIGURE 9-13 Rolled fish fillet (paupiette): Thin fillets (usually sole) are rolled with the skin side inside so the flesh cooks on the outside.



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such as tomatoes or shallots add flavor, texture, and color. The poaching liquid is often reduced and sometimes thickened for use as a sauce. The fish is placed in the middle of a baking or frying pan, and cooking liquid is added until it covers up to an eighth to a quarter of the fish's thickness. Some recipes call for covering the entire fish in liquid, but too much liquid may dilute delicate flavors. On the other hand, too little liquid will evaporate and cause the fish to dry out during cooking.

Fish fillets can be poached in an oven set at 350°F (180°C) or in a pan on top of a range set at poaching temperatures. The pan can be covered to trap more heat and moisture and to prevent volatile flavor compounds from escaping. This technique, when using only a small amount of liquid, is more akin to steaming, another moist-heat method.

Simmering

Simmering uses slightly higher temperatures than poaching does—180°F (82°C) to just under boiling, where gentle bubbles rise but barely break the surface. This method is most often used to cook shrimp, even though the expression "boiled shrimp" is commonly used for the outcome of this process. Shrimp are often simmered and then chilled, shelled, and deveined for shrimp cocktail.

Lobster, crab, and crayfish may also be simmered. The live lobster, crab, or crayfish is killed by inserting it headfirst into boiling water that has been salted with 2 teaspoons per quart. Prior to placing crayfish in the water, the middle tail fin must be grabbed, twisted, and pulled to remove the stomach and intestinal vein. Lobsters will curl their tails when first dropped into the water, which may cause toughening. This is prevented by killing the lobster with the point of a sharp knife inserted directly between the head and the shell. A more expensive technique involves submerging the crustacean in a container of beer or wine, which inebriates it and causes it to relax. After the shellfish is submerged, the water is brought back to a boil and then immediately reduced to a simmer. Heating time averages 5 minutes per pound for a lobster; a whole crayfish takes less than 7 minutes. When done, the crustacean is immediately removed from the water to prevent further cooking, drained well, and served at once with clarified butter and lemon (Chemist's Corner 9-3). Lobsters are often split in half at restaurants for the diners' convenience.

Steaming

Fish can be steamed in the oven if it is tightly covered in a baking dish, aluminum foil, or parchment paper, or in a pan on top of the range. When fish is wrapped with parchment paper, along with seasonings and aromatic vegetables if desired, and cooked in the oven, this is known as cooking *en papillote*. When the fish is done, the parchment envelope puffs up, turns brown, and provides a dramatic presentation. Each person may then be served a portion still wrapped in its own paper package, making for a novel dining experience. Fish may also be cooked in foil envelopes, although these are generally removed before the fish is served at the table. Regardless of the way it is accomplished, steaming heats the fish in its own juices, which locks in the flavor and aroma.

CHEMIST'S CORNER 9-3

Lemon Juice and Fish Odor

The characteristic smell of fish comes primarily from trimethylamine, a component of certain phospholipids located in the fat of the fish. Freshly caught fish do not smell until they degenerate. In fact, one way to determine the degree of bacterial deterioration of fish is to measure the amount of trimethylamine (38). Bacteria and enzymes that contribute to decay split the trimethylamine from the phospholipid and release it into a form that has a "fishy" odor. Adding an acid, such as lemon juice, to cooked fish reduces this odor by converting the unpleasant-smelling liquid trimethylamine into an odorless solid.

Steaming Shellfish

Lobster tails, clams, and mussels can also be prepared by steaming. Frozen lobster tails are thawed and "saddle-backed," which involves splitting the tail by cutting through the hard top shell and pulling the meat out so it lies on top (Figure 9-14). The tail is then seasoned and steamed shell-down in a covered pan for a few minutes. Clams and mussels are steamed by placing them in a covered pot with a small amount of liquid on the bottom. Steaming clams or mussels just until the shells open does not kill microorganisms, so it is important to steam them for about 5 minutes or to a temperature of 145°F (63°C). Pressure steaming is not recommended because it tends to toughen both fish and shellfish.

Clambakes Are Underground Steamings

At a clambake, clams are, in fact, steamed rather than baked. A hole 1 foot deep and 3 feet wide is dug into the sand and lined with smooth, round rocks. This serves as the base of a fire that will be kept going for 2 or 3 hours until the rocks and/or embers have been sufficiently heated. The embers are raked over the rocks and removed, and soaked seaweed is placed over the rocks to a depth of about 6 inches. Chicken-wire mesh is laid over that to serve as a platform for a layer of hard-shell clams, which are then covered with sweet potatoes, followed by broiler chickens cut into quarters, partially husked corn, and then a layer of soft-shell clams. The whole pile is splashed with a bucket of seawater, covered with a wet tarp, and allowed to "bake," or rather steam, for about an hour. Doneness of the clams is tested by checking to see whether their shells have opened. The chickens take longer and thus need to be tested for doneness separately.

Microwaving

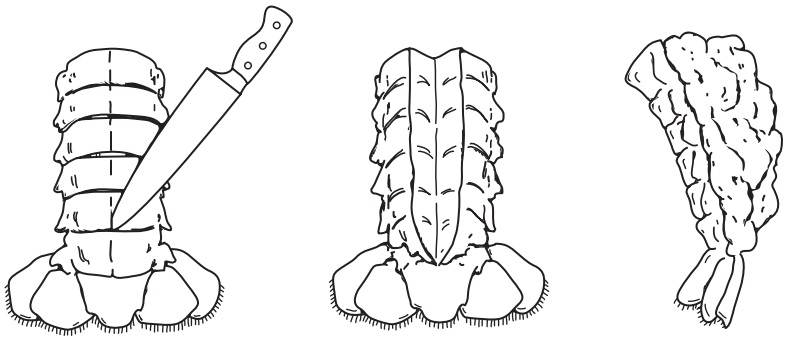
Almost any form of fish can be microwaved. If it is commercially frozen, the

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FIGURE 9-14 How to saddleback a lobster tail.



defrosting instructions on the package should be followed. In general, instructions call for arranging fish fillets or steaks or small fish in a single layer, with thicker portions toward the outside of a microwave-safe dish. Desired seasonings and dots of butter are added before covering with plastic wrap to trap the moisture. Fish can also be poached in the microwave oven.

Raw Fish Preparation

Sashimi

Sashimi (sah-shee-mee) is a Japanese fish dish that is simply raw fish consumed by itself, often sliced very thinly.

Sushi

Sushi (soo-shee) refers to rice products, and is derived from the word "sour" because it refers to how rice is mixed with vinegar and molded into various shapes (rolls, rectangles, etc.) (Figure 9-15). The pressed rice is often served with other ingredients—raw fish (sashimi), cooked fish or shellfish, eel, fish eggs, vegetables, and/or spices (9).

Ceviche

Ceviche is raw fish that is prepared with an acidic marinade, lemon- or lime-juice based, that denatures the proteins and turns the flesh white. This type of preparation does not involve heating, and thus the fish should still be considered "raw" and treated accordingly.

Food Safety Concerns

The Centers for Disease Control and Prevention (CDC) warns that eating raw fish or shellfish can be hazardous because they may contain bacteria, viruses, or parasites. Foodborne illnesses may result and in some cases lead to intestinal infections that are difficult to treat and cause further complications. Pregnant or nursing women are particularly vulnerable, as are the very young, the elderly, and anyone with a serious illness or compromised immune system. Raw fish have been known to harbor worms (anisakiasis parasites), and only heating to 145°F (63°C) for at least 1 minute or freezing the fish in a commercial freezer to 210°F (14°C) for 7 days ensures their destruction (see Chapter 4). Shellfish, especially mollusks, are particularly prone to carrying contaminants because they are filter feeders whose usual habitat is in shallow waters, which are more likely to be subject to bacterial, viral, and chemical pollution. Consuming, or even shucking, raw oysters is a potential concern because they may carry *Vibrio vulnificus*, *V. cholera*, *V. parahaemolyticus*, Norovirus, or hepatitis A (28).

STORAGE OF FISH AND SHELLFISH

Fish can be purchased fresh, frozen, canned, or cured. Each style has its own storage requirements (see the back inside cover of this book), but it is important to stress once again that all fresh fish and shellfish are highly perishable and require that precautions be taken to ensure freshness. Although proper preparation helps to destroy microorganisms that occur naturally or are introduced

FIGURE 9-15 Different types of selected sushi.

Gunkan	Loose ingredients (roe, oysters, sea urchin, fruit, etc.) over a rice base held together by a seafood wrap.	
Maki	Rice rolled with an outside covering of nori (seaweed), and cut into circles. The centers can include a myriad of ingredients including seafood (fish, roe, etc.) and vegetables (avocado, cucumber, carrots, etc.).	
Nigiri	Rice pressed into a rectangle, topped with raw (or cooked) seafood (e.g., tuna, salmon, eel, urchin) or other ingredients such as an egg omelet (*tamago*), and then possibly wrapped with a band of seaweed.	
Temaki	Sushi rolled into a cone shape.	
Uramaki (or roll)	Similar to maki, but without the seaweed wrap which is on the inside of the rice covering. The outside is usually coated (e.g., sesame seeds or tobiko (roe).	

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during handling, fish, and especially shellfish, must be stored properly to reduce the risk of foodborne illness.

Fresh Finfish

Fresh fish are best consumed within a day or two of purchase. Fish do not store well for longer periods because the flesh is much more perishable than animal tissue for several reasons. One of these is that all raw seafood carries some bacteria, which multiply rapidly above 40°F (4°C).

Refrigerated

Fish should be stored in the coldest portion of the refrigerator. It should also be tightly wrapped to prevent odors from coming in contact with other foods. Fish bought wrapped in butcher paper should be rewrapped in plastic wrap and then in aluminum foil, but prepackaged fish and shellfish can be left in the original package in which they were purchased. Any exposure to oxygen increases perishability because the high levels of polyunsaturated fatty acids in fish can be oxidized into compounds that affect odor and taste (33). Storing wrapped fish in a colander with ice will help keep it cool (3). Another storage method is to wash and pat dry the fish, wrap it in wax paper, then place it in an airtight container (4).

Spoilage Factors

Other factors that can contribute to spoilage are proteolytic enzymes, natural toxins, and contaminants. Proteolytic enzymes break down muscle proteins and provide amino acids for bacterial growth (46). Bacterial enzymes can also break down proteins to amino acids and elevate the levels of histamine, a toxin (44). Excessive consumption of histamine leads to a foodborne illness known as scombroid fish poisoning or scombrotoxism (discussed more fully in Chapter 4). Excessive histamine may accumulate in tuna, tuna-like fish, mahi mahi, bluefish, and other species that usually have not been chilled immediately after being caught.

Storing Caviar

Caviar is particularly sensitive to oxygen and cannot be left out in the air for more than 1 hour. Unopened caviar can be stored in the refrigerator for up to 3 months, but once opened, it should be consumed within 3 days.

Fresh Shellfish

It is a good practice to eat fresh shellfish the day they are bought. If they must be kept, the storage requirements are varied and depend on the type of shellfish. Most fresh shellfish may be kept alive in cool, salty, wet environments, preferably in the refrigerator. Storing fresh shellfish on ice may kill them if they become submerged in freshwater from the melting ice. Live oysters, clams, and mussels should be well aerated in the refrigerator and not stored in plastic bags or in freshwater, where they will die. Any dead animals, indicated by an open shell or lack of response when tapped, should be discarded. Crabs, usually sold precooked, should be stored in the coldest part of the refrigerator and used within a day or two. Once cooked, all crustaceans must be refrigerated at temperatures below 40°F (4°C) and consumed within 2 days.

Frozen

Freezing greatly extends the keeping time of fish that, depending on the type, can be stored in the freezer up to 9 months. It is absolutely necessary, in order to arrest microbial growth, to freeze fish if they are not cleaned (eviscerated) within 24 hours of being caught (8). Once cleaned, the general rule is that lean fish keep longer than fatty fish. Freezing lean fish often results in firmer fillets because of their low water-holding capacity; freezing fatty fish is limited by the deterioration of their fat content (lipid oxidation). Fish should be stored at 0°F (−18°C) or below and never refrozen once thawed. Prepackaged and frozen fish can stay in their original wrappers but should be kept airtight in order to prevent them from drying out.

Not all shellfish freeze as well as fresh fish. For example, freezing lobster (whole, cooked) results in tougher meat, off-flavors, and difficulty in removing the meat from the shell (10). On the other hand, cooked shrimp freezes fairly well.

Thawing

Fish is best thawed by transferring it from the freezer to the refrigerator 1 day before preparation; once thawed, it should be cooked immediately. The exceptions are breaded frozen fish, and fish fillets or steaks weighing less than ½ pound; these should not be thawed before cooking because they will become mushy. Frozen, raw shellfish can also be prepared from the frozen state, whereas frozen precooked shellfish can be used as is after thawing.

Even though it is the most healthful and popular method of preserving fish, freezing tends to cause a reduction in quality, making fish dryer, tougher, and less springy, and possibly affecting the flavor (17) (Chemist's Corner 9-4).

Canned and Cured

Canned fish can stay on the shelf for up to 12 months, but any dented, damaged, or bulging cans should be discarded. Unused fish from an opened can should be moved to a covered glass or plastic container and can be stored for up to a week in the refrigerator. Cured fish can be refrigerated, frozen, or canned. Chapter 28 discusses canning and curing in more detail.

CHEMIST'S CORNER 9-4

Effect of Freezing on Fish

Freezing fish decreases its quality because the myofibrillar proteins are disrupted (denatured and/or aggregated) (31). The result is a subsequent loss in the muscle proteins' functional properties such as protein solubility, gel-forming ability, and water retention. These properties are important to quality. The tougher texture of frozen fish is thought to be due in part to the enzyme trimethylamine oxide (TMAO) demethylase, which breaks down TMAO to dimethylamine and formaldehyde. Formaldehyde is believed to be a cross-linking agent that is responsible for a tougher texture (31). Additives can counteract the negative effect of freezing on the quality of fish. Polymerized phosphates improve the texture of frozen fish by increasing water retention, reducing thaw drip, and decreasing cooking losses. Polyphosphates achieve this effect by increasing the binding of phosphates to meat proteins, breaking down actomyosin to actin and myosin, elevating pH, and improving ionic strength (11).

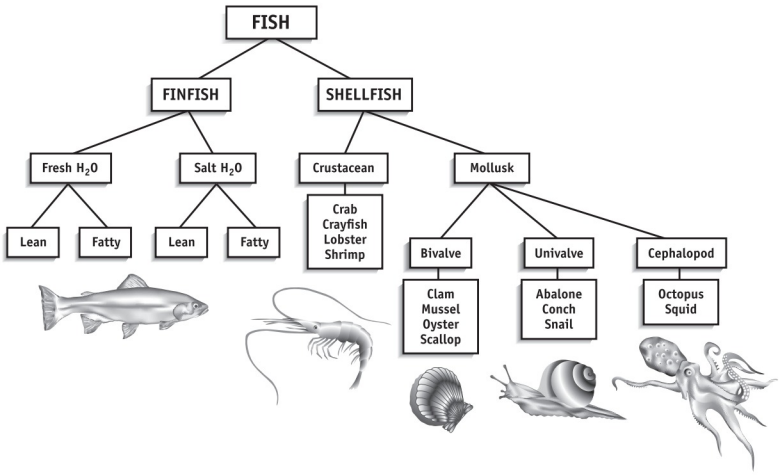
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PICTORIAL SUMMARY / 9: Fish And Shellfish

There are more than 20,000 known species of edible fish, shellfish, and sea mammals. Of these, approximately 250 species are harvested commercially in the United States, with millions of tons consumed by humans and domesticated animals annually.



CLASSIFICATION OF FISH AND SHELLFISH

Fish can be classified three different ways:

- Vertebrate or invertebrate: Vertebrate fish or finfish have fins and internal skeletons; invertebrate fish, or shellfish (mollusks and crustaceans), have external skeletons.
- Saltwater or freshwater.
- Lean or fatty.

COMPOSITION OF FISH

Fish and shellfish are more tender than other flesh foods, and, nutritionally, 3 ounces of fish contain fewer kcalories than the same amount of beef, pork, lamb, or poultry. Fish is high in protein and relatively low in fat. Small amounts of carbohydrate may be present in fish in the form of glycogen. The fat in fish is polyunsaturated, and, depending on the fish, may be high in omega-3 fatty acids. Fish is also a good source of many B vitamins.



PURCHASING FISH AND SHELLFISH

Inspection of fish is voluntary and is based on the wholesomeness of the fish and the processing plant. Only inspected fish products can be graded U.S. Grade A, U.S. Grade B, or substandard. Grades for shellfish such as shrimp and oysters are based on size. Fish can be purchased fresh or frozen in a variety of market forms, as well as canned, cured, and fabricated (surimi). Fish roe is also sold. Shellfish can be purchased alive, cooked in their shell, or shucked, to be refrigerated, frozen, or canned.



Whole or round fish



Drawn fish



Dressed or pan-dressed fish



Steaks



Single fillet



Sticks



Butterfly fillet

PREPARATION OF FISH AND SHELLFISH

Overcooking is the most common mistake in the preparation of fish, resulting in excessive flakiness, dryness, and flavor loss. Dry heat is the most popular method of preparation, and includes baking, broiling, grilling, and frying. Moist-heat methods include poaching, simmering, steaming, and microwaving. Fish cook quickly and are done when the bone is no longer pink and the flesh turns from a translucent to an opaque color, is firm to the touch, separates from the bone (if present), and is moist and flakes easily at the segments without falling apart.



STORAGE OF FISH AND SHELLFISH



Fresh fish are best consumed within a day or two. If fish is purchased in butcher paper, it should be rewrapped with plastic wrap and aluminum foil. Prepackaged fish and shellfish can stay in the original package. Fish should be frozen at 0°F (–18°C) or below and never refrozen after it is thawed. Breaded fish or fish fillets or steaks weighing less than ½ pound need not be thawed before heating. Most fresh shellfish must be kept alive prior to preparation. Canned fish can stay on the shelf for up to 12 months, but leftovers should be refrigerated in a glass or plastic container and used within 3 days.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. A dressed fish is described as a:
   a. whole fish with entrails removed.
   b. fish that has been sliced from top fin to bottom fin.
   c. fish body that is entirely intact.
   d. fish from which the head, tail, fins, scales, and entrails have been removed.

2. Which of the following fish are good sources of omega-3 fatty acids?
   a. Flounder and grouper
   b. Halibut and haddock
   c. Salmon and mackerel
   d. Puffer and cod

3. What term is used to describe the separation of fish flesh into flakes that occurs as the steak or fillet ages?
   a. Roping
   b. Gaping
   c. Stripping
   d. Slicing

4. What is the name of the process used to remove the "sand vein" or intestine from fresh shrimp?
   a. Deveining
   b. Sand veining
   c. Incising
   d. Shelling

5. Which of the following is a crustacean?
   a. Scallop
   b. Clam
   c. Oyster
   d. Crab

6. A food product consisting of compacted rice served with raw fish, cooked fish or shellfish, vegetables, and/or spices is called _____
   a. sashimi.
   b. sushi.
   c. ceviche.
   d. surimi.

7. Canned fish can be stored on the shelf for _____ months.
   a. 3
   b. 6
   c. 12
   d. 24

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe the various ways in which fish and shellfish are categorized.
2. Describe the structural factors that make fish flesh so much more tender than beef or poultry.
3. Discuss the factors that affect the pigmentation of fish flesh.
4. Describe the nutrient content of fish, and explain why fish are said to have a greater nutritional value than other sources of protein.
5. Describe the qualities used as criteria in the inspection and grading of finfish.
6. Describe each of the different ways that vertebrate fish can be purchased: whole, drawn, dressed, steaks, fillets, and sticks.
7. What qualities should be considered when selecting vertebrate fish?
8. Define *caviar,* and explain how this definition may vary in different countries.
9. What is surimi, how is it prepared, and how is it used?
10. Define the following: *tomalley, prawns, scampi, struvite crystals*, and *fumet*.
11. Describe the basic methods of preparing vertebrate fish through baking, poaching, and steaming.

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10



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Milk

Functions of Milk in Foods 198
Composition of Milk . . . 198
Purchasing Milk 202
Types of Milk 204
Milk Products in Food Preparation 212
Storage of Milk Products 215

People have been using milk as a food source for thousands of years. Records from ancient Babylon, Egypt, and India show evidence of cattle being raised for their milk (Figure 10-1). Milk is a unique beverage that provides complete protein, many of the B vitamins, vitamins A and D, and calcium. In fact, approximately 80% of the calcium ingested by Americans is derived from dairy products. Because a lack of dietary calcium causes poor bone development in children and is a risk factor for osteoporosis (porous bones) in later life, milk is a vital source of nutrition for millions of people. Although milk is rich in many nutrients, it is low in vitamins C and E and iron, and it contains no complex carbohydrates or fiber.

FIGURE 10-1 Dairy scene from ancient Egypt. Found in the tomb of Princess Kewitt.



DEA / G. DAGLI ORTI/Getty Images

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TABLE 10-1 How Milk Ingredients Are Used by the Food Industry

Ingredient/Description	Function/Food Examples
Caseins The major proteins found in milk. Extracted from skim milk via acidification or enzyme precipitation.	Improve nutritive value of bakery items, **medical foods**; binder in processed meats.
Caseinates Made from casein by adding sodium, calcium, potassium, or combinations of these salts (to make it water-soluble).	Nutrition bars, medical foods, soups, sauces, whipped toppings, and bakery products.
Hydrolysates Manufactured by the enzymatic hydrolysis of milk proteins.	Improves the proteins' stability, solubility, viscosity, emulsification, and whipping ability.
Lactose A disaccharide (galactose and glucose) extracted from the whey found in milk. Makes up around 2–8% of milk (by weight).	Improves the water-holding capacity of processed meats (ham), texture of frozen desserts such as ice cream, and color of baked goods (browning ability).
Milk protein concentrates (MPC) or milk protein isolates (MPI) Casein and whey proteins isolated from fresh nonfat milk (42–85% protein) that are high in bound calcium.	Their natural milk flavor is ideal for infant formula, weight-loss products, sports nutrition items, cheese products, and liquid beverages.
Whey powder Crystallizing whey creates a sweet or acidic powder high in lactose and minerals. Demineralized and delactosed whey powders are available.	Used for infant formulas, baked items, confectionaries, dry mixes, processed cheese, sausages, and weight-loss product formulations.
Whey protein concentrates (WPC) or whey protein isolates (WPI) Concentrated wheys are high in protein (35%, 50–80%, 80+% protein), but low in lactose and minerals.	Used for dry beverage mixes, nutrition bars, protein-fortified food, and sports nutrition products.

This chapter focuses on fluid cow's milk—its composition and variations, the purchasing of milk products, its use in food preparation, and its safe storage. Cheese, butter, and frozen dairy products are covered in Chapters 11, 22, and 26, respectively. Although milk from other animals, such as goats, sheep, and camels, is a common part of the diet in some parts of the world, in this book, unless otherwise indicated, the word *milk* refers only to cow's milk.

FUNCTIONS OF MILK IN FOODS

Numerous food products contain milk or some component of milk. The presence of milk in the diet is pervasive. Milk is itself a beverage, but there are also all sorts of drinks that use milk as a base—smoothies, milk shakes, yogurt drinks, eggnog, kefir, and many more. Food products made primarily from milk include cheese, yogurt, sour cream, and whipped cream, to name just a few. Many foods rely on milk or ingredients derived from milk, including pizza, cheese soufflés, sandwiches, casseroles, quiches, sauces, processed meats, soups, dressings, infant formulas, coffee creams, nutrition bars, sports nutrition products, breads, cereals, cakes, pies, puddings, cookies, ice cream, milk chocolate, caramels, frozen yogurt, and many other desserts.

Butter is made from milk, so all the foods incorporating this fat are dairy-based to some degree. The various functions of and foods made with milk fat are discussed in Chapter 22 (see Table 22-1).

The food industry uses specific components of milk, separated out, as ingredients in processed foods (Table 10-1) (10). The proteins are commonly added to many processed foods to improve their nutritive value. Certain proteins (caseinates) contribute to emulsifying and stabilizing, whereas others (whey proteins) assist with gelling. The milk sugar, lactose, aids with browning of baked goods and is also important in the manufacture of confectionary and frozen desserts. Overall, milk contributes to processed foods by improving protein content (sports bars, chips, etc.), moisture, mixing ability (emulsification), foaming, texture, and flavor.

Medical food A food to be taken under the supervision of a physician and intended for the dietary management of a disease/condition for which distinctive nutritional requirements are established by scientific evaluation.

COMPOSITION OF MILK

Nutrients

The basic composition of milk remains the same regardless of its source. Milk is primarily water—87.4%. Figure 10-2 shows that the remaining 13% by weight consists of carbohydrate, fat, protein, and minerals (50). The high concentration of water gives milk a near-neutral pH of 6.6. Among domesticated cattle, the breed, stage of lactation, type of feed ingested, and season of the year all tend to slightly influence milk's content.

Carbohydrate

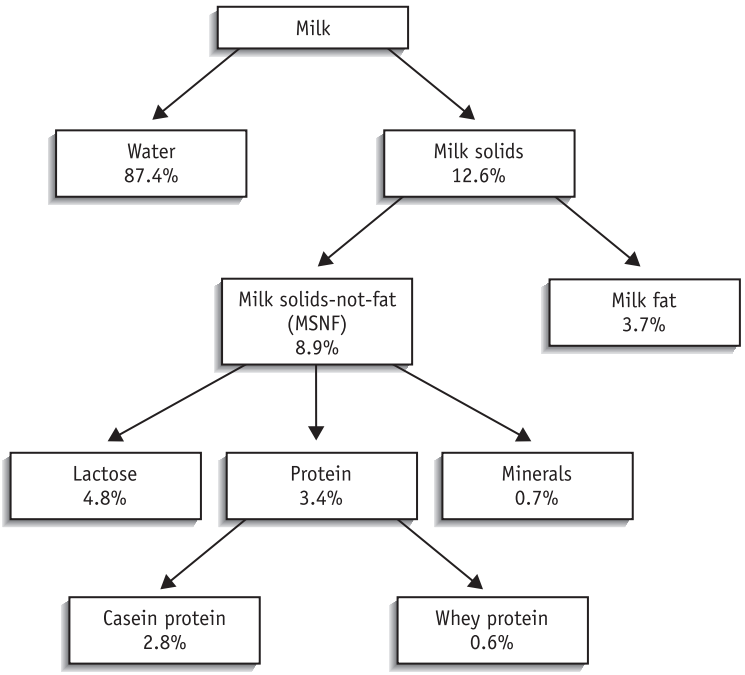
Lactose, or milk sugar, is the primary carbohydrate found in milk—12 grams per 8-ounce cup. When bacteria in milk metabolize lactose, lactic acid is produced. The flavor of cheeses and fermented milk products such as yogurt

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FIGURE 10-2 Composition of milk.



and sour cream is, in part, derived from lactic acid. Lactose is less soluble than sucrose, which may cause it to crystallize into lumps in nonfat dry milk (NFDM) and to produce a sandy texture in ice cream.

How & Why?

Why does drinking milk cause problems for some people?

Lactose intolerance is a condition in which a person is unable to digest lactose, the form of sugar found in milk, because of insufficient quantities of lactase, the enzyme required to break the lactose disaccharide into its two monosaccharide units (15). It is a common food intolerance, affecting 30 to 50 million Americans, especially certain ethnic groups: 90% of Asian Americans, 80% of Native Americans, 65% of African Americans, and 50% of Hispanics (48). For people with lactose intolerance, fermented milk products containing less lactose are usually more easily digested than those that are not fermented.

How & Why?

How is a milk allergy different from an intolerance?

Whereas a food intolerance is an inability to digest or absorb certain foods, a food allergy is an immune response to a molecule (usually a protein) found in food (48). Thus, milk allergy is a reaction of a person's immune system to the protein (casein or whey) in milk. Milk allergies affect about 3% of infants and children, but about 20% outgrow them by age 4, and 80% by age 16 (56).

Protein

The protein in milk is a complete protein; that is, it contains all the essential amino acids in adequate quantities to support growth and the maintenance of life. A cup of milk contains approximately 8 grams of protein. Two cup equivalents of milk or milk products a day provide almost half the protein recommended for a healthy adult woman and one-third that for a man.

The two predominant types of protein found in milk are **casein** and **whey** (Chemist's Corner 10-1) (9). Casein accounts for about 80% of the protein in milk, whereas whey protein constitutes about 18%.

Whey proteins consist primarily of lactalbumin and lactoglobulin (36). Whey is the liquid portion of milk that separates from the curd during cheese production (36). The nutritious whey protein can be isolated by subjecting the whey to an ultrafiltration process, resulting in protein concentrates that are used extensively by the food industry as emulsifiers and as foaming and gelling agents (43). Adding milk proteins to other foods generally improves their texture, mouthfeel, moisture retention, and flavor (47). Whey proteins are often added to foods—especially those based on grains and beans that are low in lysine—to improve their protein profile (41).

Fat

The fat in milk, called "milk fat" or "butterfat," plays a major role in the flavor, mouthfeel, and stability of milk products (22). The creaminess of milk chocolate, for example, is due to its milk fat, which softens the characteristic brittleness of cocoa butter (6). Milk fat consists of triglycerides surrounded by phospholipid-protein membranes (lipoproteins), which allow them to be dispersed in the fluid portion of milk (primarily water). Milk fat contains short-chain fatty acids (butyric acid [4:0]) and medium-chain fatty acids (caproic [6:0], caprylic [8:0], and capric [10:0]) acids. The fatty acids in milk fat are approximately 66% saturated, 30% monounsaturated, and 4% polyunsaturated.

Casein The primary protein (80%) found in milk; it can be precipitated (solidified out of solution) with acid or certain enzymes.

Whey The watery component of milk removed from the curd in cheese manufacture. Consists primarily of water (93%), lactose, and whey proteins (primarily lactalbumin and lactoglobulin).

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CHEMIST'S CORNER 10-1

Casein and Whey Proteins

Casein is a name for a family of related phosphoproteins—α- (including α_{s1}- and α_{s2}-), β-, and κ-caseins (Table 10-2). Structurally, the caseins are large, amphoteric (capable of reacting as either an acid or a base, depending on the pH), random coils. They are often referred to as phosphoproteins because they contain phosphorus (and calcium) when at a pH above 4.6. Below a pH of 4.6, the casein is completely free of salts (13).

The casein proteins are not very soluble in water. Specifically, α_{s1}-, α_{s2}-, and β-casein are hydrophobic (water-fearing) proteins, whereas κ-casein is more hydrophilic (water-loving) because of its hydrophilic glycopeptide at one end of the molecule. Within the watery medium of milk, the majority of protein (casein) is dispersed in a suspension of particles (micelles) called "casein micelles." These are small, spherical structures (50 to 300 nm in diameter) formed when caseins and calcium phosphate gather in clusters of several thousand individual protein molecules (12). The more hydrophobic sections of the proteins tend to be located in the interior of the micelles, whereas the more hydrophilic κ-casein tends to be located on the surface. This allows the hydrophobic casein molecules to be suspended in water and also forms what has been termed a "hairy layer" that prevents aggregation of the micelles under normal conditions.

In contrast, the whey proteins are much smaller, compact, globular, helical proteins (19). The whey proteins are easily separated from the larger caseins by the addition of acid, which precipitates the caseins but leaves the whey proteins in solution. Decreasing the acidity from pH 6.6 to 4.6 or lower releases the calcium phosphate, magnesium, and citrate ions from the interior of the micelles (12). This important food principle underlies the acid method of forming curd during yogurt or cheese production. The other method utilizes proteolytic enzymes (see Chapter 11).

TABLE 10-2 Milk Proteins: Approximate Percentage of the Major Proteins Found in Milk

Protein	% Total Protein
Caseins	***80***
α_s-Casein (includes α_{s1}- and α_{s2}-casein)	48
β-Casein	20
κ-Casein	12
Whey Proteins	***18***
β-Lactoglobulin	9
α-Lactalbumin	5
Immunoglobulins	2
Serum albumin	2

Fat and Kilocalorie Content of Milks

An 8-ounce cup of fluid milk provides 86 to 150 kcalories and 0 to 8 grams of fat. (See the fat and caloric content of various milk products in the Calorie Control feature.) Buttermilk, despite its name, contains only about 2 grams of fat per cup and fewer than half the kcalories of whole milk. Although this milk is made differently now, it was originally the fluid remaining when the fat from whole milk was removed to make butter—hence the name *buttermilk*. Other types of milk products vary greatly in their fat content per cup, from condensed milk, with about 27 grams, to fat-free (nonfat) milk, with less than half a gram.

Cholesterol

Like other animal products, milk contains cholesterol—an average of 33 mg in a cup of whole milk, 18 mg in reduced-fat (2%) milk, and 4 mg in fat-free (nonfat) milk. The fat and cholesterol content of milk and other dairy foods, such as cheese, butter, and ice cream, drives some consumers to seek lower-fat alternatives to dairy products (see the Calorie Control box).

Vitamins

Milk contains vitamins A and D, riboflavin (B_2), and tryptophan, an amino acid important in the formation of the B vitamin niacin. It is low in vitamins C and E. Milk exposed to ultraviolet light loses riboflavin, so it is packaged in cardboard or opaque plastic containers to prevent the degradation of this vitamin by light (45).

Vitamins A and D Fortification

Many milks are fortified with vitamins A and D. Vitamin D is found naturally in very few foods and was initially added to milk, a staple food, to reduce the incidence of rickets, a bone-softening condition in children that was at one time endemic in North America. Before the fortification of milk was widely practiced, many children grew up with severely bowed legs and other effects of vitamin D deficiency.

Because vitamins A and D are fat soluble, they are found in the milk fat of whole milk. For this reason, whole milk is not required to be fortified with either vitamin, although many milk manufacturers add both. However, vitamin A is diminished in reduced-fat (2% fat) and fat-free (nonfat) milks, dried whole milk, and evaporated skim milk, so vitamin A fortification is required. Fortification with vitamin D in reduced-fat and fat-free milks is optional, but 98% of milk processors add it anyway. Vitamin D fortification is required for evaporated whole and fat-free milks.

Minerals

The major mineral in milk is calcium, with 1 cup of milk containing, on average, 300 mg. Three cups of milk a day provide a substantial portion of the 1,000 mg Dietary Reference Intake (DRI) for adults 19 to 50 years of age. Milk can also provide calcium in other forms, such as yogurt, pudding, ice cream, custards, hot chocolate, and cheese.

Other primary minerals found in milk and milk products include phosphorus, potassium, magnesium, sodium, chloride, and sulfur. Although milk is rich in many minerals, it is low in iron.

Color Compounds

Factors that contribute to the color of milk are fat, colloidally dispersed casein and calcium complexes, and water-soluble riboflavin (B_2). These compounds, by interfering with light transmission,

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contribute to milk's opaque, ivory color. The amount of carotene (a pigment found in some plants such as grass and flowers) in the cow's feed influences the color of its milk. Both riboflavin (B_2) and carotenoid pigments dissolved in the milk fat contribute to the yellowish tinge of butter and cream (see Chapter 22).

How & Why?

Why does nonfat milk have a bluish hue?

Removing any of the fat eliminates a proportional amount of carotenoid pigments and solids, resulting in the color changing from a yellowish white to the bluish hue seen in fat-free (nonfat) milk.

Food Additives

The practice of adding vitamin D to milk began in the 1930s to reduce a public health problem: rickets, a bone disease in children (8). This practice, recommended by the American Medical Association's Council on Foods and Nutrition, nearly eliminated this disease in the United States. Vitamin A fortification was initiated in the 1940s because of the increasing popularity of reduced-fat and fat-free milk. Vitamin A is a fat-soluble vitamin, so it dissolves in the fatty portion of the milk. Fortifying these milks with vitamin A replaces that which is lost when the fat is removed.

Although not defined as a food additive, the recombinant bovine growth hormone (rBGH) is given to approximately 5 to 30% of dairy cattle to make them produce about 10% more milk. It is considered unlikely that rBGH poses any health risk to humans, as this protein hormone is digested in the stomach. Steroid hormone use is not permitted in dairy cattle, as it is in cattle raised for their meat. Consumers have the option of purchasing rBGH-free or certified organic milk and milk products (48).

CALORIE CONTROL
Milk and Milk Products

- **Avoid excess consumption.** The daily recommendation for milk is two 1-cup servings, according to the Exchange Lists, or 3 cups, according to ChooseMyPlate.gov. Every cup of milk averages 100 kcalories (ranges from 86 to 150 kcalories), 3 to 8 grams of fat, 12 grams of carbohydrate, and 8 grams of protein.
- **Portion control.** Remember that one large glass of milk may contain about two 8-ounce cups that doubles the kcalories.
- **Choose lower-fat options.** The recommended milk portions are for the low-fat (1% = 102 kcalories for each cup) or fat-free (nonfat or skim = 86 kcalories) milk options. Table 10-3 lists the kcalorie and fat contents of various dairy products, whereas Table 10-4 provides a "choose more" and "choose less" list.
- **Choose less often:** whole milk, chocolate milk, eggnog, evaporated milk, condensed milk, whole-milk yogurt, creams, and sour cream; foods made with these ingredients such as cream soups and ice cream.

TABLE 10-3 Kilocalorie and Fat Content of Selected Milk Products*

		Nutrients/Cup	
Milk Product		Kilocalories	Fat (g)
Fluid milk	Fat-free (nonfat; skim)	86	0
	Low-fat (1%)	102	3
	Reduced-fat (2%)	121	5
	Whole	150	8
Flavored fluid milk	Chocolate		
	Low-fat (1%)	158	3
	Reduced-fat (2%)	179	5
	Whole	209	9
	Eggnog		
	Reduced-fat (2%)	189	8
	Whole	342	19
Canned milk	Whole evaporated	338	19
	Fat-free (nonfat) evaporated	199	1
	Sweetened condensed	982	27
	Sweetened condensed (fat-free)	632	0
Cultured milk	Buttermilk	99	2
	Yogurt (plain)		
	Fat-free (nonfat)	137	0
	Reduced-fat (2%)	155	4
	Whole	150	8
	Yogurt (fruit-flavored)		
	Fat-free (nonfat)	100	0
	Reduced-fat (2%)	231	3
	Whole	250	6
	Sour cream (1 Tbsp)	31	3
Cream	Half-and-half	315	28
	1 Tbsp	20	2
	Light whipping	698	74
	1 Tbsp	44	5
	Heavy whipping	821	88
	1 Tbsp	51	6
	Cream substitute (1 Tbsp)	20	2

*Milk averages 12 grams of carbohydrate and 8 grams of protein per cup.

(*Continued*)

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TABLE 10-4 Dairy Products to "Choose More" or "Choose Less" to Reduce Dietary Fat

Product	Choose More	Choose Less
Milk	Fat-free (nonfat; skim) Low-fat (1%) Reduced-fat (2%) Fat-free dried Buttermilk Fat-free evaporated Fat-free or low-fat chocolate	Whole Evaporated Condensed
Yogurt	Fat-free Low-fat Reduced-fat (2%)	Whole-milk Custard-style
Cream	Light cream cheese Light sour cream Mocha Nondairy creamers	Whipping cream Half-and-half Sour cream Sweet cream Cream cheese spreads Cream soups Creamy dressings
Cheese	Lower-fat cheese (see Chapter 11)	Cheese with > 6 g of fat/ounce
Frozen Desserts	Sherbet Ice milk Frozen reduced-fat (2%) yogurt	Ice cream Frozen whole-milk yogurt

Source: Adapted from the National Dairy Council.

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PURCHASING MILK

Grades

Milk is graded according to its bacterial count. The highest grade, Grade A, has the lowest count. The law requires that all Grade A milk and milk products crossing state lines be pasteurized. It is illegal to sell raw (unpasteurized) milk across state lines for consumer use. Although Grade A is the most common grade of milk sold, Grade B is also available. In addition, different grades exist for fat-free (nonfat) dry milk: U.S. Extra and U.S. Standard. Grading is voluntary and is paid for by the dairy industry. The USDA is responsible for grading; the U.S. Public Health Service recommends and enforces specific procedures for pasteurization (Grade A Milk Ordinance), laboratory tests, and sanitation at dairy farms and processing plants.

Pasteurization A food preservation process in which liquids (milk, beer, soups, or juices) are heated to a specified temperature for a certain period of time to destroy most microorganisms (bacteria, yeasts, and molds) that could cause disease, spoilage, or undesired fermentation.

Ultrapasteurization A process in which a milk product is heated above 145°F (63°C) but below 280°F (138°C) for 0.01 to 15 seconds.

Pasteurization

Milk is an excellent growth medium for microorganisms such as bacteria, yeast, and molds. In the early 1900s, it was frequently the vehicle for carrying such serious foodborne illnesses as typhoid, diphtheria, scarlet fever, and tuberculosis.

Pasteurization, named after Louis Pasteur (1822–1895), its originator, is a heating process that was originally used on wine and beer to minimize microbial growth. It was soon discovered that pasteurizing milk—that is, heating it below its boiling point for a short time—helped reduce many associated foodborne illnesses. Pasteurization destroys almost 100% of pathogenic bacteria, yeasts, and molds and 95 to 99% of other nonpathogenic bacteria. The process of pasteurization also inactivates many of the enzymes that cause the off-flavors of rancidity. Almost all milk sold commercially in North America is first pasteurized. In some states, where allowed by law, there is a small niche market for unpasteurized, or raw, milk.

To ensure that sufficient pasteurization has occurred, milk processors measure the activity of a specific enzyme found in milk, alkaline phosphatase. If this enzyme is no longer active, then the milk is safe for consumption. The several different types of pasteurization are classified by the temperatures and times utilized, but milk processors most commonly use the first two listed in Table 10-5: 145°F (63°C) and 161°F (72°C) (31). Even though pasteurized milk is no longer pathogenic, it will still spoil because the 1 to 5% nonpathogenic bacteria remaining convert lactose to lactic acid.

Ultrapasteurization

A process called **ultrapasteurization** uses higher temperatures than 145°F (63°C) and shorter times (0.01 to 15 seconds) than regular pasteurization to extend the shelf life of milk products, but they still have to be refrigerated (17).

Ultrahigh-Temperature Processing

The combination of higher-temperature pasteurization (280°F [138°C] for at least 2 seconds) with sterile packaging techniques is called **ultrahigh-temperature (UHT)** processing (sterilization). UHT processing destroys even more bacteria than standard pasteurization and increases the milk's shelf life. This milk is then packaged aseptically (in an environment free from pathogens) in sterile containers and sealed so that it can be stored

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TABLE 10-5 Pasteurization Temperatures for Grade A Milk

Type of Processing	Temperature* °F	Temperature* °C	Time	Refrigeration Required?
Pasteurization				
Low-temperature longer-time (LTLT)*	145	63	30 minutes	Yes
High-temperature short-time (HTST)*	161	72	15 seconds	Yes
Higher-heat shorter-time (HHST)	212	100	0.01 second	Yes
Ultrapasteurization (UP)	280	138	2 seconds	Yes, but product has longer shelf life
Ultrahigh-temperature (UHT) pasteurization (sterilization)†	280–302	138–150	2 seconds	Not until opened

*Increase temperature by 5°F (3°C) if the milk contains added sweeteners, 18% or greater total solids, or 10% or more fat content.

†Also known as "aseptic processing" where the UP or UHT diary product is aseptically packaged in sterile containers in an aseptic environment.

Sources: www.fda.gov/downloads/food/guidanceregulation/guidancedocumentsregulatoryinformation/milk/ucm513508.pdf; and International Dairy Foods Association.

FIGURE 10-3 Equipment used to homogenize milk. In this process, milk fat globules are physically broken down into many more smaller globules to prevent the fat from grouping together.



Nigel Cattlin/Minden Pictures

How & Why?

How is milk homogenized?

The mechanical process of homogenization pumps the milk under a high pressure of 2,000 to 2,500 pounds per square inch through a machine that contains fine holes, which breaks up the fat globules. This decreases the fat globule size to less than 2 microns. The now very small droplets of milk fat are surrounded by the original lipoprotein membrane and also by casein micelles, which have adsorbed to the surface. This interfacial film prevents them from joining together and separating out. The liquid and fat components of the milk are now, in effect, homogenized.

unrefrigerated for up to 3 months (2). After the aseptic seal is broken, the milk must be refrigerated. Originally, this preparation method was used on less-frequently purchased milk products such as whipping cream, half-and-half, and eggnog, but it is now used on a wider variety of products.

Homogenization

Fat is less dense than water, causing it to float to the top of milk. This results in the thick layer of yellowish cream that rises to the top of unprocessed milk. **Homogenization** prevents this separation of water and fat, which is known as creaming (Figure 10-3).

Most milk in the United States is homogenized. This purely mechanical process has no effect on nutrient content; however, sensory changes do occur, resulting in a creamier texture, whiter color, and blander flavor. Homogenized milk also **coagulates** more easily, making puddings, white sauces, and cocoa more viscous. Its increased surface tension gives it a greater foaming capacity. Homogenized milk is also more prone to the rancidity caused by the addition of oxygen to the double bonds of the unsaturated fatty acids. Pasteurizing milk before homogenization inhibits rancidity because the lipase enzymes responsible for breaking down fat are inactivated.

Ultrahigh-temperature (UHT) Milk Milk that has been pasteurized using very high temperatures (280°F [138°C]), is aseptically sealed, and is capable of being stored unrefrigerated for up to 3 months.

Homogenization A mechanical process that breaks up the fat globules in milk into much smaller globules that do not clump together and are permanently dispersed in a very fine emulsion.

Coagulate To clot or become semisolid. In milk, denatured proteins often separate from the liquid by coagulation.

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TYPES OF MILK

About half the milk produced in the United States is sold as fluid milk and cream. Much of the rest comes to market as butter, cheese, and ice cream. The available market forms of milk include fluid milk—whole, reduced-fat (2%), low-fat (1%), fat-free (nonfat), UHT, chocolate, canned, and many others—dry milk, cream, and cultured milk products such as yogurt and buttermilk.

Fresh Fluid Cow Milks

The four major types of milk considered "fresh fluid" cow milks are whole, reduced-fat, low-fat, and fat-free or nonfat.

Whole Milk

To be classified as whole, milk must contain 3.25% milk fat and at least 8.25% **milk solids-not-fat (MSNF)** (Table 10-6). The milk is usually fortified with vitamins A and D, but this is optional (23).

Reduced-Fat and Low-Fat Milks

These milks have had some of their fat removed so that milk-fat levels are decreased to 2.0 and 1.0%, respectively, as noted on the carton. A minimum of 8.25% MSNF is necessary, but if it exceeds 10%, then the milk must be labeled "protein-fortified" or "fortified with protein." The addition of milk solids improves the consistency, taste, and nutritive content of reduced- and low-fat milks. Vitamin A fortification is required, although the addition of vitamin D is optional.

Fat-Free or Nonfat Milk

Nonfat is synonymous with *fat-free*, a term that has replaced the older milk designation of *skim*. Removing as much fat as technologically possible results in fat-free milk that should contain no more than 0.5% milk fat and a minimum of 8.25% MSNF. Vitamin A fortification is required, although the addition of vitamin D is optional. Figure 10-4 shows that fat-free milk is a nutritious beverage that delivers more nutrients for fewer kcalories than the same amount (one cup) of a soft drink. Nonetheless, less fat-free milk than reduced-fat milk is consumed in the United States, and overall, children are drinking less milk because they are drinking more of other beverages, such as soft drinks and fruit juices (16).

TABLE 10-6 Standards of Identity for Milk Products

		Pasteurization[a] Ultrapasteurization[b] UHT Processing[c]	Homogenization	Fat % (min./range)	MSNF % min.	Vitamin D	Vitamin A
FLUID	Milk	M [a, b, c]	Opt.	3.25	8.25	Opt.	Opt.
	Reduced-fat milk	M [a, b, c]	Opt.	0.5-2.0	8.25	Opt.	M
	Fat-free milk	M [a, b, c]	Opt.	<0.5	8.25	Opt.	M
CREAM	Half-and-half	M [a, b, c]	Opt.	10.5-18.0			
	Light cream [coffee cream or table cream]	M [a, b, c]	Opt.	18-30			
	Light whipping cream	M [a, b, c]	Opt.	30-36			
	Heavy whipping cream	M [a, b, c]	Opt.	36			
CAN	Evaporated milk		M	6.5	25.0	M	Opt.
	Condensed milk	M [a]	Opt.	7.5	25.5	Opt.	
	Sweetened condensed milk	M	Opt.	8.0	28		
DRY	Fat-free dry milk	M	Opt.	Max 1.5			
	Fat-free dry milk fortified with vitamins A and D	M	Opt.	Max 1.5		M	M
CULTURED	Sour cream	M	Opt.	18			
	Acidified sour cream	M	Opt.	18			
	Sour half-and-half	M	Opt.	10.5-18.0			
	Acidified sour half-and-half	M	Opt.	10.5-18.0			
	Yogurt	M [a, c]	Opt.	3.25	8.25	Opt.	Opt.
	Reduced-fat yogurt	M [a, c]	Opt.	0.5-2.0	8.25	Opt.	Opt.
	Fat-free yogurt	M [a, c]	Opt.	<0.5	8.25	Opt.	Opt.

60% H_2O removed
No vitamins added
15% sugar added

M = Mandatory
Opt. = Optional
a Pasteurization is mandatory but declaration of term *pasteurized* is optional. Raw or unpasteurized milk may be sold within some states, but it is a violation of federal law to sell it across state lines.
b Ultrapasteurization is an optional process—declaration of term *ultrapasteurized* is mandatory on principal display panel, if applicable.
c UHT declaration is on label although not included in standards at this time.

Source: National Dairy Council.

Fresh Fluid Milks from Other Animals

Not all milk comes from cows. The history of the use of milk from various animals dates so far back that no one knows when the practice actually started. Cows provide almost all of the milk consumed in North America, but goats rank a close second in supplying milk to other regions such as Norway, Switzerland, the Mediterranean area, Latin America, and parts of Asia and Africa. Goat's milk is low in folate and vitamins D, C, and B_{12}. Some people in Spain, the Netherlands, Italy, and the Balkans also get milk from sheep. Reindeer are used for milk in the arctic region, while the llama in South America sometimes serves as a source of milk, as does the water buffalo in parts of the Philippines, Asia, and India.

Flavored Fluid Milks

Flavored milk is created by adding a flavoring agent plus sugar to milk, thereby making the product more

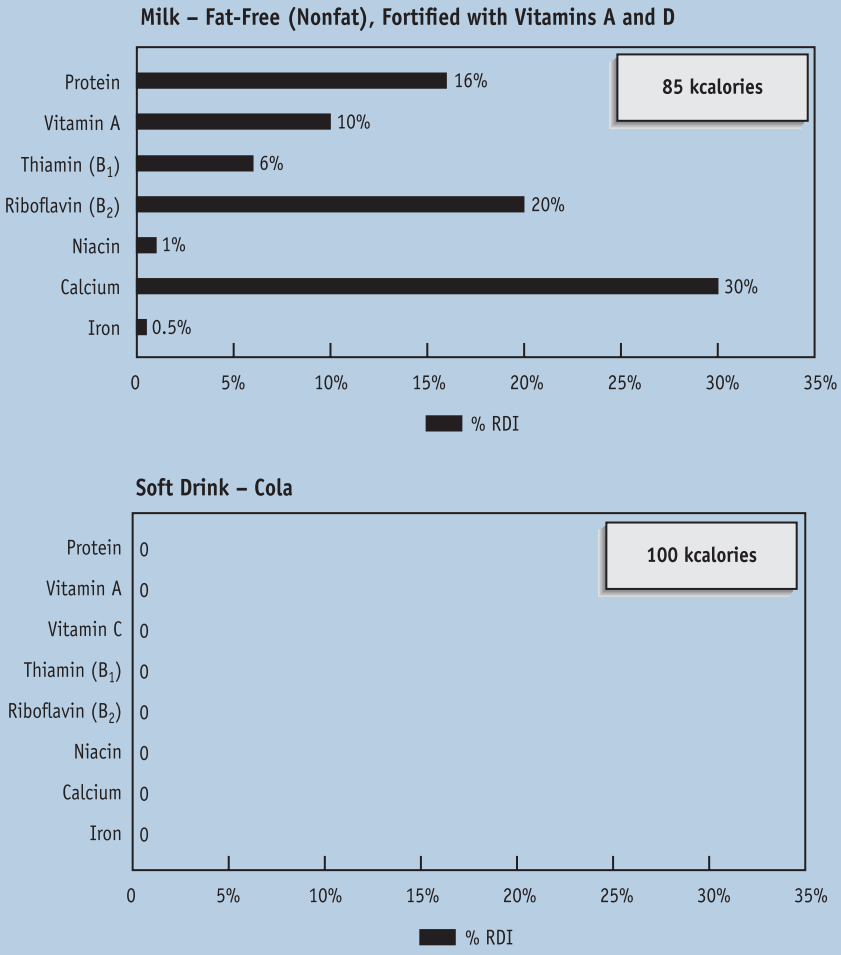
Milk solids-not-fat (MSNF)
Federal standard identifying the total solids, primarily proteins and lactose, found in milk, minus the fat.

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FIGURE 10-4 Selected nutrient content of milk (fat-free) vs. soft drink (1 cup, 8 fl oz, 245 g).



appetizing to customers. The first flavored milk was sold at the Wisconsin State Fair in 1921. Since then, many flavors have become available, including fruit, chocolate, vanilla, coffee, caramel, cappuccino, peanut butter, root beer, and vegetable (3). Because milk contains 88% water, most flavoring agents are water-based so they will dissolve and stay in solution within milk.

Chocolate Milk

Chocolate flavoring comes from cocoa, natural or Dutch chocolate, chocolate liquor, or chocolate syrup. This flavoring agent requires a stabilizer to prevent the cocoa from settling out of the milk (3). A common stabilizer is kappa II carrageenan (0.02 to 0.03%), which reacts with milk proteins to produce a gel, giving chocolate milk a thicker mouthfeel than regular milk. Other stabilizers include cellulose, guar gum, and xanthan gum, which can also add foaming characteristics to milkshake products. Guar or locust gum is used when a thickening quality is desired, such as in milkshakes.

Pasteurized milk containing 1.5% liquid chocolate, or 1% cocoa and 5% sugar can be called chocolate milk. Chocolate milk is, in fact, a suspension in which the continuous phase consists of milk fat and cocoa butter, while the dispersed phase includes the cocoa particles, fat-free milk solids, and sugar (24). Fortification with vitamins A and D is optional for chocolate whole milk, but fat-free chocolate milk must be fortified. Whole chocolate milk is high in kcalories because the additional sugar and cocoa contribute approximately 58 kcalories per cup to its already higher kcalorie count, for a total of 209 kcalories per cup. Chocolate milk made with reduced-fat milk provides 179 kcalories and 5 grams of fat per cup, whereas chocolate low-fat milk provides only 158 kcalories and 2.5 grams of fat per cup.

Eggnog

Packaged, commercially produced eggnog is manufactured to replicate a traditional rich holiday beverage made with eggs, cream or milk, nutmeg, and often spirits. It is sold predominantly during the Thanksgiving and Christmas holidays and is defined as a pasteurized and homogenized mixture of milk, cream, milk solids, eggs, stabilizers, and spice. It contains 6 to 8% milk fat, about double that of whole milk, 9% MSNF, and 1% egg yolk solids. Other ingredients such as sugar, color and flavor additives, rum extract, nutmeg, and vanilla may be added. Although eggnog products vary widely and are available in low-fat versions, an average cup provides 342 kcalories and 19 grams of fat, more than double that found in whole milk.

Ultrahigh-Temperature Milk (UHT)

UHT milk is available in laminated aseptic cartons (42) that, when unopened, can be stored on shelves without refrigeration for up to 3 months (Figure 10-5). UHT milk has a "cooked" flavor at first, which tends to disappear with storage time. After 1 year, UHT milk develops off-flavors described as "sweet," "flat," "musty," "rancid," and "chalky" (32). Chilling UHT milk before serving improves its taste. Once opened, UHT milk must be refrigerated and handled with the same care used for fresh milk. Although it is slightly more expensive than fresh milk and not widely distributed in the United States, UHT milk is ideal for boating, camping, hiking, and other situations in which refrigeration is not always available.

Nutritionally Altered Fluid Milks

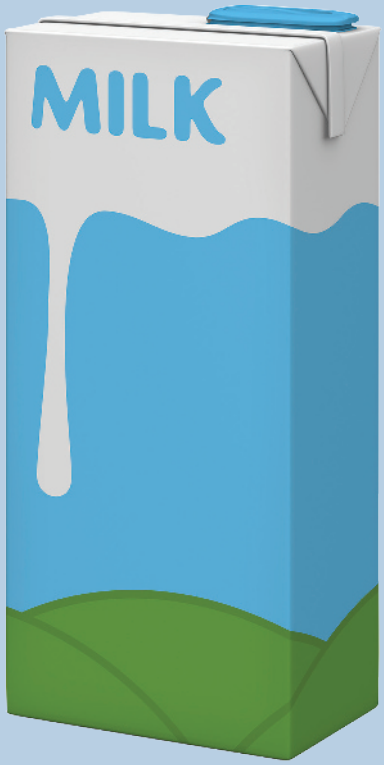
Examples of milks with altered nutrient compositions include imitation, filled, low-sodium, and reduced-lactose milks.

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FIGURE 10-5 UHT milk carton.



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Imitation Milk

Imitation milk looks like milk but usually has little or no dairy content. Ingredients include water, corn syrup solids or sugar to replace the lactose, vegetable oils to replace the milk fat, protein from the sodium caseinate in soybeans, whey or MSNF to substitute for the protein, and some stabilizers, emulsifiers, and flavoring agents.

Nutritionally, imitation milks are lactose-free and so are useful for people with lactase deficiency, but sometimes sodium caseinate and whey are added, which makes these products inappropriate for people with milk-protein allergies. The vegetable fat, like milk fat, may be high in saturated fatty acids from coconut or palm oils used in the manufacture of these products. The calcium and protein contents are about half those found in regular milk. Although the nutrient content of milk is superior to that of imitation milk, the latter is less expensive. To emphasize their products' superiority over imitation milk, some dairy processors place a REAL seal shaped as a drop of milk on their products (Figure 10-6).

Imitation milk A product defined by the FDA as having the appearance, taste, and function of milk (its original counterpart) but as being nutritionally inferior.

FIGURE 10-6 The Real symbol identifies an item as being a real dairy product.



© National Milk Producers Federation

Filled Milk

Filled milk is made by replacing all or part of the milk fat with a vegetable fat. Cholesterol levels drop to zero in filled milk, but if the fat substitute is a saturated vegetable oil such as coconut or palm oil, then there is a higher ratio of saturated to polyunsaturated fats. Both imitation and filled milks are regulated at the state level rather than at the federal level.

Low-Sodium Milk

A cup of milk contains 120 mg of sodium, so people on sodium-restricted diets must watch their milk intake. Low-sodium milks containing only 6 mg per cup are available. These are produced by an ion exchange method that removes all but 5% of the original sodium.

Reduced-Lactose Milk

Any pasteurized milk treated with the enzyme lactase will have most of its lactose converted to its two monosaccharides, glucose and galactose. This doubling of the sugar molecules results in a slightly sweeter flavor. The resulting milk is more easily digested by people who have some degree of lactose intolerance.

Plant-Based "Milks"

Soy Milk

Soy milk is a milk-like product that is not from any mammal, but rather is made from soybeans that have been soaked, ground, and strained. Soy milk has been consumed for centuries in China and Japan and is believed to have been developed in China around 150 BC (39). Now this milk-like liquid is used not only as a drink but also to make tofu (the cheese of soy milk) and some infant formulas. Some vegetarians use it as a substitute for cow's milk. As useful as it is, soy milk is lacking in certain nutrients. Only soy milks fortified with methionine (an essential amino acid), calcium, and vitamin B_{12} should be substituted for cow's milk for growing children. On the other hand, the absence of the carbohydrate lactose makes soy milk ideal for people with lactose intolerance.

Rice Milk

Another milk suitable for people with lactose intolerance is rice milk. It contains no lactose because it is made primarily from brown rice, filtered water, and a small amount of brown rice sweetener. Even though rice milk is made from rice, not all rice milks are gluten-free, so some are inappropriate for people with gluten sensitivity or celiac disease (an immune system condition that makes them allergic to gluten). Although rice contains no gluten, some rice milks are made using barley enzymes to convert the carbohydrates in brown rice to naturally occurring sugars. This is why rice milk is somewhat sweeter than soy milk. In addition, the flavor of either rice or soy milk can be enhanced by adding vanilla flavoring, making these milks even more acceptable to consumers than their plain counterparts.

Almond Milk

Similar to soy and rice milk is almond milk, a milky drink made from ground almonds. The short shelf life of milk before the age of refrigeration meant that milk did not stay fresh very long. During medieval times, cooks turned to a milky liquid produced by grinding almonds or walnuts. Homemade versions can be made by

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combining ground almonds and water in a blender. Commercial almond milk products are available in plain, vanilla, or chocolate flavors.

Nut Milks

Nut milks other than almond milk can be prepared by grinding nuts such as hazelnuts and mixing them with water.

Hemp Milk

This newer plant-based milk alternative is a nondairy milk with a slightly nutty flavor and a "putty" color is made by mixing water with the crushed seeds of the hemp plant.

Grain Milk

Grain milks may be made from oats, barley, wheat, rye, or flour mixed with water. It has a lower protein content and higher carbohydrate content than dairy milk.

Coconut Milk

Coconut milk is not milk, but the grated meat of the mature coconut mixed with a little hot water and strained. It should not be confused with coconut water which is the clear liquid inside young, green coconuts. The rich, thick, and creamy nature of coconut milk allows it to add texture to soups and desserts, and serve as a cream substitute in some recipes (35). It is most commonly used in Southeast Asian cuisine, particularly Thai. Coconut cream is the thickest portion, which separates to the surface in canned coconut milk. Canned coconut milk contains almost 500 kcalories per cup and 50 grams of fat. "Lite" coconut milk is canned coconut milk with water added. Regardless of the fat content (which can be high), canned coconut milk (usually 5- to 16-ounce cans) needs to be shaken well to mix the "cream" with the water. After opening, coconut milk can be stored in a sealed container in the refrigerator for approximately 2 to 5 days.

Canned Fluid Milks

Milk products are also available to consumers in canned form as whole, evaporated, and sweetened condensed milk.

How & Why?

Why are fluid milks inappropriate for infants?

Only breastfeeding or infant formulas approved by the American Academy of Pediatrics are recommended during the infant's first year (34). Cow's milk is inappropriate because it is low in iron and vitamin C and lacks critical immunity components for human infants. In addition, waiting until 1 year of age to introduce cow's milk reduces the risk of allergies. Likewise, soy milk, rice milk, and almond milk are nutritionally inferior to breast milk or formula and should never be given to infants (birth to 1 year of age) or young children as a *sole* source of nutrition. These so-called milks are not true milks and will not nutritionally support the growth of an infant or very young child. Unsupplemented plant products do not contain the necessary nutrients required by a human infant.

Whole Milk

Some UHT milk is canned for export. Requirements regarding its content are similar to those for whole fluid milk sold in a carton.

Evaporated Milk

Evaporated milk is produced by evaporating at least 60% of the water found in whole milk. By definition, evaporated milk contains at least 7.5% milk fat, contains 25.5% MSNF by weight, derives 34% of its protein from the MSNF, and is fortified with vitamin D. Evaporated milk provides 338 kcalories and 19 grams of fat per cup. Stabilizers are often added to prevent separation of the fat during storage. Fat separation may also be prevented by turning the cans over every few weeks.

The evaporation process begins with exposure of the milk to a temperature of 203°F (95°C) for 10 to 20 minutes. This stabilizes the casein so that it will not coagulate during sterilization. In the next step of evaporation, the milk is heated to 121 to 131°F (50 to 55°C) at reduced atmospheric pressure, which allows the milk to boil



Pat LaCroix/Getty Images

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without reaching the normal boiling temperature of 212.3°F (100°C). It is then homogenized, canned, and sterilized. The high temperatures of canning and the metal of the can may impart cooked and off-flavors to evaporated milk products.

Newer evaporation techniques produce evaporated milk by exposing it to UHT for longer periods of time, placing it in sterilized cans, and aseptically sealing the cans. Compared to evaporated milk produced by the old method, UHT-evaporated milk is less viscous, less white, and has a different flavor.

Fat-free evaporated milk is produced from fat-free milk. By definition, it must contain less than 0.5% fat, at least 20% total solids, and vitamins A and D. The lower fat content (0.5 gram/cup) drops the kcalories to 199 per cup. To reconstitute either regular or fat-free evaporated milk, combine equal volumes of the canned milk and water.

Sweetened Condensed Milk

Sweetened condensed milk contains a large quantity of added sugar, which makes it ideal for preparation of desserts, especially pies and cheesecake. After whole milk has been evaporated 50% by weight, 15% sugar (usually in the form of sucrose) is added. Sweetened condensed milk is defined as containing at least 28% total milk solids and about 8% milk fat. The extra sugar and highly concentrated nature of the nutrients in sweetened condensed milk make it very high in kcalories (982 kcalories per cup) and fat (27 grams per cup). Unlike evaporated milk, sweetened condensed milk does not have to be sterilized because its 40 to 45% by weight sugar concentration prevents microbial spoilage. The sugar content, either added or in the form of lactose, also contributes to the Maillard reaction. During heating, the sugar combines with the protein in the milk to give it a light-brown color. This attribute makes sweetened condensed milk ideal for creating caramel-flavored or caramel-colored desserts such as pumpkin pie.

Agglomerate To gather into a mass or ball. In the case of milk, the smaller protein particles regroup into larger, more porous particles.

Dry Milk

Fluid or canned milks are sometimes heavier to transport than milk purchased in dried form. The two main types of dry milk are nonfat dry milk and instant milk.

Nonfat Dry Milk

Removing all the moisture from milk results in nonfat dry milk (NFDM). NFDM can be made from whole, reduced-fat, low-fat, or fat-free milks, as well as buttermilk, but nonfat is usually selected because it contains the least amount of fat.

After fat-free milk is dried, vitamins A and D may be added, although they are not required. Dried milks that originally contained some fat are required to be fortified with vitamin A and identified as "fortified with vitamins A and D." Powdered milks are reconstituted with water and used like fresh milk. Overall, NFDM is nutritionally similar to fat-free milk, except that the levels of vitamins may be reduced by 20%. The absence of fat also gives it a long shelf life; NFDM can keep for about a year in a cool, dry storage area. Milk powder may be added directly to foods such as puddings, shakes, soups, casseroles, and fluid milk to boost their calcium and protein contents. Although it is inferior in taste to fluid milks, reconstituted NFDM is ideal for making batters and doughs for baked goods.

Instant Milk

Instant milk is different from regular NFDM. It is manufactured by exposing NFDM to steam, after which it is re-dried. The double drying helps instant milk to achieve the ability to **agglomerate** and instantly dissolve in cold water. Generally, about ⅓ cup of instant NFDM will reconstitute into 1 cup of fluid milk, but manufacturers' instructions will vary. Allowing the reconstituted milk to refrigerate for several hours and adding a teaspoon of vanilla per chilled half gallon make it taste more like regular milk. In addition, more milk solids can be added by food manufacturers to make it more flavorful and nutritious.

How & Why?

How is milk dried?

Milk is dried by either a spray, foam-spray, or roller drying process. In spray drying, concentrated milk is sprayed into hot air, whereas foam-spray drying sends a jet of hot air into the concentrated milk. Roller drying consists of moving pasteurized fluid or condensed milk through two steam-heated rollers.

Cultured Milk Products

Cultured or fermented milk products have been used for centuries and have long been believed to have the potential to benefit human health (Figure 10-7) (38). Some cultured milk products commonly consumed in North America and discussed here are as follows:

- **Buttermilk**
- **Yogurt**
- **Acidophilus milk**
- **Kefir**
- **Sour cream**

Cultures Added to Milk

Microbial food cultures are composed of bacteria, fungi, and/or yeast (44). These microorganisms may be naturally present within the food or added intentionally. When microbial food cultures are naturally present in a food, they are not considered an ingredient and thus are not required to be listed on the label (44). When cultures are added during the production process, the term *cultured* followed by the name of the substrate (e.g., *milk*) must be listed as an ingredient. Starter cultures (microorganisms grown in a medium such as liquids, grains, or seeds), which are sometimes referred as a mother culture, are used to ferment foods such as yogurt, breads, poi, sauerkraut, and others.

Curd Formation

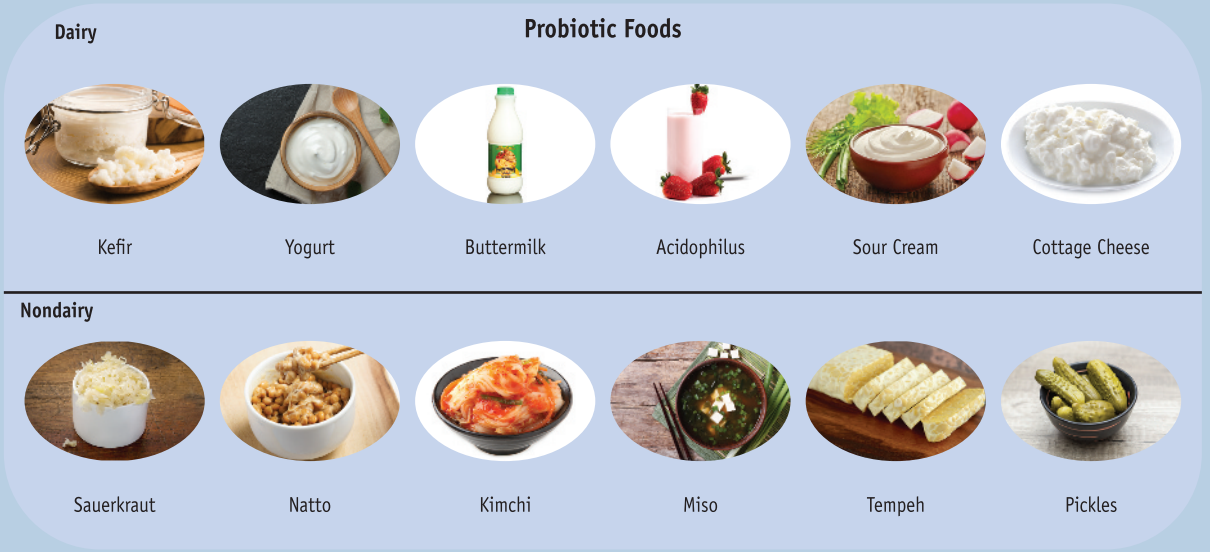
The one common factor among diverse cultured milk products is the addition of bacterial cultures to ferment their

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FIGURE 10-7 Probiotic food examples.



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lactose into lactic acid. The increased acid concentration causes the casein to precipitate out, which gives the milk a more **curd**-like consistency. The type of bacterial culture inoculated into the milk largely determines the flavor of the resultant product. Bacteria influence the quality of fermented dairy products through the amount and type of acids they produce. Some protein is also broken down to provide nitrogen for bacterial growth, and this makes the curd softer and more digestible.

Lactic Acid Bacteria

The bacteria used to ferment dairy products in the United States are often "lactic acid–producing bacterial cultures" or "propionic acid–producing bacteria" (47). The function of these bacteria may be described as "culturing" or "action." In the United States, only yogurt is mandated to be made with specific bacterial strains—specifically, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (47). Thus, it is not possible to accurately document the composition of bacteria used in other dairy products. However, the U.S. government granted "prior sanction" for the use of harmless lactic acid–producing bacteria in foods, and the regulation of bacterial starter cultures in meats and breads is similar to that for cultures used in dairy products.

Microorganisms for Foods Lists

- "Microorganisms & Microbial-Derived Ingredients Used in Food" is published online by the U.S. Food and Drug Administration at (www.fda.gov/food/ingredientspackaginglabeling/gras/microorganismsmicrobialderivedingredients/default.htm).
- The European Food Safety Authority (EFSA) published a list of organisms designated as Qualified Presumption of Safety (QPS) based on historical use and scientific research (18).
- The International Dairy Federation (IDF) and the European Food and Food Cultures Association (EFFCA) have jointly published a list of microorganisms that are documented to have a history of safe use in the food supply (18, 31).

Buttermilk

Buttermilk contains little or no butterfat. This cultured milk is used in many baked products to add moisture and tanginess and to provide an acid source for leavening (1). Low-fat or full-fat buttermilk can be used, with the higher-fat products providing more richness.

Traditionally, sweet natural buttermilk was the liquid left over after fresh cream had been chilled and churned to produce butter (54). Natural buttermilk is often dried and used in baked products and ice cream because the phospholipids obtained from the fat-droplet membranes, which are broken down during churning, make it an excellent emulsifier. However, most buttermilk sold to consumers is cultured by adding *Streptococcus lactis* or *Lactobacillus bulgaricus* bacteria to pasteurized nonfat, reduced-fat, or low-fat milk. The bacterial cultures in buttermilk convert the sugar (lactose) into lactic acid, which is the reason that buttermilk tastes more sour than regular milk. As the milk becomes more acidic and its pH falls, some of the proteins precipitate out. This is *clabbering*, an older term used to describe the thickening of milk (54). The end result is that buttermilk is more sour, more bubbly, and thicker than regular milk. If a recipe calls for buttermilk, a substitute can be made by adding 1 tablespoon of white vinegar or lemon juice to 1 cup of milk and letting the mixture stand for 10 minutes.

Curd The coagulated or thickened part of milk.

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Flavor may be enhanced by adding other bacteria, butterfat granules or flakes, natural sweeteners, citric acid (up to 0.15%), salt, and artificial flavors or colors. Fortification with vitamins A and D is optional. Cultured buttermilk must contain less than 0.5% milk fat and at least 8.25% MSNF and have an acidic pH of about 4.6. It is not mandatory that this pH be created by lactic acid–generating bacteria, but when these bacteria are not used, the milk should be labeled "acidified buttermilk." A fat content between 0.5 and 2.0% changes the name to "cultured low-fat milk" or "acidified low-fat milk." A milk fat content over 3.25% is denoted by "cultured milk" or "acidified milk." Buttermilk has a longer shelf life than milk because its higher acid content inhibits the growth of spoilage-causing bacteria, and its lower fat content makes it less likely to go rancid. Salt may be added to further inhibit bacterial growth.

Yogurt

The term *yogurt* comes from the Turkish name "Yoghurmak," meaning, "to thicken" (20). This name reflects the thickening process that turns milk into yogurt. Yogurt is a fermented product created when bacteria are added to milk to ferment the milk's lactose to lactic acid—a process that has been in use since prehistory (47). These bacteria influence the acidity, texture, and shelf life of the dairy products to which they are added (Chemist's Corner 10-2). Traditionally, bacteria were naturally present and thus considered natural components. Now, these same bacteria may be added during the manufacturing process, but the end result is the same.

People in the Middle East have been eating yogurt for thousands of years. This smooth, semisolid, fermented dairy product can be made from whole, reduced-fat, or fat-free milks.

Consistency of Yogurts

Firm yogurt is known as the *set* style, whereas a more runny, semiliquid consistency is characteristic of *stirred* yogurt. The even thicker consistency of Greek yogurt is obtained by straining it through a filter to separate out even more whey. French yogurt tastes different from American yogurt because of their higher fat content derived from using whole milk, added cream, and or evaporated milk. Yogurt drinks are extremely runny but are also gaining in popularity.

Yogurt Definition

To be called yogurt, a milk product must contain at least 8.25% MSNF and 0.5% acid. Fat content requirements for whole, reduced-fat, and fat-free yogurt are 3.25%, 0.5 to 3.0%, and less than 0.5%, respectively (51). There are no federal standards for frozen yogurt, a popular dessert choice for those watching their dietary fat intakes.

How & Why?

How is yogurt made?

Yogurt is produced by mixing two types of bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, and adding them to pasteurized, homogenized milk to which some MSNF are also usually added. The whole mixture, including the bacteria, is held at a warm temperature (108 to 115°F [42 to 46°C]) to allow fermentation to develop the desired consistency, flavor, and acidity. Although the milk used to make yogurt is usually slightly higher in lactose because of the addition of MSNF, fermentation decreases the amount of lactose to 4% (44). During fermentation, the bacteria convert lactose to lactic acid, increasing the acidity. In addition, folate (a B vitamin) levels increase as a natural by-product of bacterial growth.

Active Culture Yogurts

After the yogurt has reached the desired consistency, the fermentation and accompanying changes caused by the bacteria are discontinued. To accomplish this, bacterial growth can be inhibited by either chilling or heating the yogurt. If the yogurt is chilled, the culture remains alive, whereas the heated yogurt's cultures are destroyed. Yogurts containing live bacteria are labeled "with active yogurt cultures," "living yogurt cultures," or "contains active cultures." Only yogurt containing viable cultures is recommended for people with lactase deficiency or those taking antibiotics (40, 49). Consuming fermented milk products containing live cultures reportedly helps restore the normal intestinal bacteria eliminated by antibiotics, and it has been associated with the treatment of diarrhea (14). Intestinal bacteria are beneficial because they help to produce some B vitamins and vitamin K.

CHEMIST'S CORNER 10-2

Flavor Compounds in Yogurt

The tartness of yogurt is partially derived from the bacterial conversion of lactose to lactic acid and acetaldehyde (10). A buttery flavor is also generated as bacteria break down the natural citric acid in milk to produce diacetyl.

Other Ingredients Added to Yogurt

After fermentation, several ingredients, including gelatin and NFDM, may be added to yogurt to create a firmer texture, reduce the perception of acidity, or add color. The addition of sweeteners such as sugar, honey, fruit, fruit extracts, flavorings, and alternative sweeteners has increased the popularity of yogurt—over 85% of yogurt currently consumed in the United States is flavored. Yogurt with fruits blended throughout is called Swiss- or French-style yogurt, whereas yogurt with fruit on the bottom is known as sundae style. The sweeteners and other flavorings added to yogurt increase its kcalorie content. Whole yogurt, at 150 kcalories per cup when plain, jumps to 250 kcalories per cup when it is sweetened.

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Functional Foods—Probiotics

Yogurt is the most common vehicle for **probiotics** (e.g., *Lactobacillus* and *Bifidobacterium*) and **prebiotics** (21). Manufacturers often add prebiotics such as inulin, galacto-oligosaccharides, and fructooligosaccharides (FOS) to probiotics because they act as food for microorganisms (37). The suggestion that probiotics have a positive impact on health by improving the intestine's microbial balance is attributed to the Nobel Prize–winning Russian scientist Élie Metchnikoff (1845–1916), who suggested that the long, healthy lives of Bulgarian peasants were due to their consumption of fermented milk products (49).

Probiotic Foods

Fermented dairy products are the most common type of probiotic, but really any food with beneficial microorganisms can serve as a probiotic (Table 10-6).

Benefits of Probiotics

Scientific research into the health benefits of probiotics has grown rapidly. The most well-recognized benefit of probiotics is the promotion of general digestive health and wellness (9, 37). Clinical trials have also studied the effects of probiotics on inflammatory bowel conditions, infant diarrhea, antibiotic-associated diarrheas (*Clostridium difficile* colitis), infant colic, bacterial vaginosis, irritable bowel syndrome, oral health, lactose intolerance, immune support, and gut transit time.

Mechanisms of Health Benefits

Probiotics are theorized to exert their beneficial effects in several ways. They are known to create a healthy microbial balance in the intestines, aid digestion by producing helpful enzymes, prevent the attachment of harmful bacteria either directly as a barrier or indirectly through mucin (a muco-protein) production, and stimulate immune function (37). A large portion of the immune system is encompassed by the intestinal tract, and it is believed that probiotics may stimulate activity of immune cells (phagocytic cells, cytokines, and immunoglobulins) and reduce gut inflammation (via cytokines) (49).

Probiotic Foods and Supplements

People in Europe and Japan have long recognized the possible benefits of probiotics and include them in a wide range of food products—yogurts, dairy-based beverages, breakfast drinks, bread and baked goods, soy products, sausages, puddings, and even fruit juices. The Japanese probiotic drink YakultTM is consumed by 28 million people worldwide (55). Dairy-based health "shots," small servings of probiotic-enhanced dairy products, are being marketed as a way to reduce cholesterol or improve digestion (46). Probiotics are also sold in pill form.

Future Research

Because of their newness on the market and the lack of scientific studies supporting their effectiveness, the use of probiotics to treat or prevent illness is controversial. Questions exist about the ability of the microorganisms to stay alive, first during food processing and then during digestion. Another issue is dosage. What is the correct amount to consume and what is too much? It has been suggested that probiotic products should have a minimum number of viable cells, estimated to be between 10^6 to 10^8 colony-forming units per gram (CFU/g) consumed to ensure delivery to the gastrointestinal tract.

The most important question has been lost in the excitement surrounding the new probiotic products entering the market: What is the effect of these extremely high microbial dosages on the natural intestinal tract environment? The possibility that the artificial inflation of "good" bacterial populations or unusual combinations of bacteria not seen before might actually be harmful is an important area of exploration for future research.

Acidophilus Milk

Acidophilus milk is a cultured milk created with the assistance of *Lactobacillus acidophilus*. These bacteria break down lactose to glucose and galactose, resulting in twice as many sugar molecules. The resulting somewhat sweeter milk, usually packaged in cartons, is made by inoculating pasteurized milk with *L. acidophilus* culture and letting it incubate at 99°F (37°C) until a slight curd forms. A slightly acidic, sour taste also results, but this can be eliminated by mixing the bacteria directly into cold milk.

Kefir

Kefir is a fermented milk drink and probiotic originating in the Caucasus Mountains, and widely consumed in Russia and central Asia (7). It is sometimes referred to as "the champagne of milk" because of its bubbly, fizzy nature. Kefir is made by adding bacteria from kefir grains (the grains or mother culture from the grains), *Lactobacillus caucasicus*, and yeast, *Saccharomyces kefir* and *Torula kefir,* to milk (27). The milk is initially heated to 185°F (85°C) for half an hour and then cooled to 73°F (23°C), which allows the milk to ferment to a soft, foamy curd. The strong, tangy, sour taste comes from the formation of lactic acid. Kefir contains about 1% alcohol and a little carbon dioxide as a result of fermentation, and it provides 250 kcalories and 4.5 grams of fat per cup.

Sour Cream

Cream can be soured by *Streptococcus lactis* bacteria or some other acidifying agent. Light cream or half-and-half is fermented at 72°F (22°C) until the acidity from lactic acid reaches 0.5%. A thicker sour cream is produced if MSNF, vegetable gums (carrageenan), or certain enzymes are added. To be labeled "sour cream," a minimum of 18% milk fat is required, although when sweeteners are added, the minimum milk fat content can be lowered to 14.4%. Lower-fat sour creams with

Probiotics Live microbial food ingredients (i.e., bacteria) that have a beneficial effect on human health.

Prebiotics Nondigestible food ingredients (generally fibers such as fructooligosaccharides [FOS] and inulin) that support the growth of probiotics.

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half the fat content of standard sour cream, as well as sour cream substitutes, are also available.

Creams and Substitutes

Creams come with a variety of different fat percentages, and these can also be replaced by various cream substitutes.

Cream

Cream is a collection of fat droplets that floats to the top of nonhomogenized whole milk. The heavier and thicker the cream is, the higher the fat content will be. Cooling the cream firms its fat globules and makes it even thicker. Creams vary in their milk fat content, ranging from a low of 18% to a high of 36%.

Cream manufacturers are not required to list the percentage of fat in the cream on the carton. The fat content of light or coffee cream is 18 to 30%, of light whipping cream, 30 to 36%, and of heavy cream or heavy whipping cream, not less than 36%. Combining cream with pasteurized or ultrapasteurized milk yields half-and-half, which is not true cream and contains only 10.5 to 18% fat.

Some whipping creams contain added sugars and stabilizers to improve their taste and texture. Whipping cream is also sold in pressurized canisters, which provide the taste and texture of whipped cream in a convenient-to-use form. Another option is to purchase a whipped cream dispenser that comes with a nitrous oxide canister (Figure 10-8). The heavy cream is whipped by the nitrous oxide charger and then can be held in the refrigerator for 2 weeks. Flavorings such as sugar (only confectioner's sugar or syrup because regular sugar will clog the dispenser), coffee, cocoa, or liqueurs can be added.

Cream Substitutes

Some of the whipped toppings in pressurized cans and tubs, as well as coffee creamers, dry mixes, imitation sour cream, and snack dips, are made from nondairy ingredients. These products came into being as low-cost substitutes that would last longer on the shelf. Nondairy coffee creamers can last more than a year at room temperature. They often contain saturated fats, but many lighter substitutes have half the kcalories one-third the fat of cream, and no cholesterol. The nondairy whipped toppings in pressurized cans are made from water, vegetable oil, corn syrup solids, sodium caseinate or soy protein, emulsifiers, vegetable gums, coffee whiteners, and artificial flavors and colors. Frozen whipped cream products contain many of the same ingredients.

FIGURE 10-8 Whipped cream dispenser.



MILK PRODUCTS IN FOOD PREPARATION

Flavor Changes

The bland, slightly sweet flavor of milk comes from its lactose, salts, sulfur compounds, and short-chain fatty acids. The percentage of fat determines the mouthfeel and body of a particular milk. Exposure to heat or sunlight, oxidation, the use of copper equipment or utensils, and the feed ingested by the source animal are just a few of the other factors that can influence the flavor of milk (11). For example, an off-flavor develops when the amino acid methionine reacts with the sunlight-sensitive riboflavin (vitamin B_2). The "cooked" flavor of heated milk develops in part because heating denatures whey proteins to release volatile sulfur compounds, which contribute to off-flavors (13). Dairy cattle that are allowed to eat wild onions, ragweed, French weed, beets, potatoes, cabbage, or turnips produce off-flavored milk (52).

Coagulation and Precipitation

Some milk proteins coagulate or precipitate to form a solid clot, or curd, under certain conditions. This food principle makes it possible to produce milk products such as yogurt and cheeses. The conditions that promote clot formation include the application of heat and the addition of acid, enzymes, polyphenolic compounds, and salts.

Heat

When milk is heated to near the boiling point, the whey proteins lactalbumin and lactoglobulin become insoluble, mesh with the milk's calcium phosphate, and precipitate, forming a film on the bottom and sides of the pan. This film can scorch easily. Scorching can be prevented by constant stirring, slow elevation of temperature, or use of a double boiler.

Casein will not coagulate with heat unless it is boiled for long periods of time. Canned evaporated milk, however, which contains higher concentrations of casein, may coagulate during the high heats of sterilization. This is prevented by warming the milk prior to sterilization.

Acid

Adding acid to milk causes the casein (but not the whey proteins) in the milk to coagulate (Chemist's Corner 10-3). Casein precipitates when the normal 6.6 pH of fresh milk drops below 4.6. Sources of acids include acidic foods such as lemon and lime juices, tomato products, certain fruits, and acid-producing bacteria in cultured milk products. Some foods must be carefully

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How & Why?

Why does a skin form on the surface of heated milk?

This is caused by the evaporation of water, which is accompanied by an increased concentration of casein, fat, and mineral salts. This thin skin scorches easily and can trap steam that is trying to escape, causing the milk to boil over. Several steps can be taken to avoid this problem, including using a lid, stirring continually during heating, floating a small pat of butter on top of the milk, or, in the case of hot chocolate, adding whipped cream or marshmallows.

CHEMIST'S CORNER 10-3

Milk Coagulates as pH Drops

The calcium in milk exists in one of two forms: either combined with the casein protein, or as free calcium ions (Ca^{2+}). At milk's near-neutral pH of 6.6, the calcium ions are combined with phosphate and with casein in the casein micelles, creating calcium phosphocaseinate. The casein micelles are colloidally dispersed in the liquid portion of the milk (Figure 10-9) (4).

Normally, the casein proteins are negatively charged, causing them to repel each other in the fluid milk. Coagulation of these casein proteins occurs when the negative charges are neutralized by the hydrogen ions (H^+) from an acid. When the pH drops to 4.6 at temperatures higher than 46°F (8°C), casein becomes very insoluble and precipitates readily into a curd (see Chapter 11 on cheese).

This is casein's isoelectric point—the pH at which it carries no charge; the negative and positive charges on the casein molecules balance each other, and the overall charge is neutral. Milk products coagulated with acid are lower in calcium than those coagulated with an enzyme because the acid releases calcium from the casein molecules, causing it to be lost in the whey:

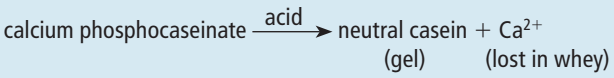
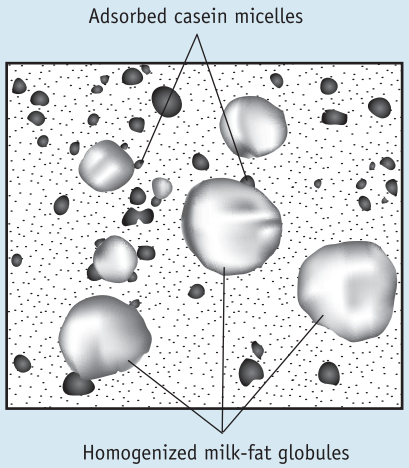


FIGURE 10-9 The role of milk proteins and calcium in coagulation.



prepared because of the coagulating effect of acids on milk products. For example, extra caution is required when combining milk or cream with lemon-flavored tea, tomato soup, or coffee (which is acidic). The key to preventing the milk from coagulating is to add the acid to the milk base instead of the other way around. Avoiding high temperatures after milk has been mixed with acid also helps prevent coagulation.

Polyphenolic Compounds

Some fruits, vegetables, teas, and coffees contain slightly acidic polyphenolic compounds, which, when combined with milk, result in the precipitation of proteins. They also contribute to the curdling of cream or milk that sometimes occurs during preparation of scalloped potatoes or tomato or asparagus soup.

Enzymes

Milk also coagulates and forms curds when it is combined with certain enzymes originating from animal (calf stomachs), plant (fruits), microbial (fungi or bacteria), or, more commonly, genetically modified microbial sources. The enzyme most commonly used to coagulate milk is **chymosin** (or **rennin**), which is used in the production of cheese and ice cream.

One of the major differences between coagulation caused by enzymes and that initiated with acid is that enzyme-coagulated clots are rich in calcium and have a tough, rubbery texture, unlike those created by acid, which are less elastic and more fragile in consistency. Cottage cheese, which is normally coagulated by acid, contains less calcium per ounce (19 mg) than cheddar cheese (204 mg), which is coagulated by enzymes.

Salts

The salts in cured ham, some canned vegetables, and some seasonings can cause milk to curdle. Here again, to prevent curdling, salt or salted foods should be added to the milk base instead of the other way around, and high temperatures must be avoided after these ingredients are combined.

Whipped Milk Products

Liquid milk products such as cream, evaporated milk, and reconstituted NFDM can be made into a foam by whipping air into the liquid. During whipping, the protein in these milk products is mechanically stretched into thin layers that trap air bubbles, fat particles, and liquid (Figure 10-9).

Whipped Cream

Cream expands two to three times in volume when whipped. The stability of milk foams, especially whipped cream, is dependent on several factors: fat content, temperature of the cream, age of the cream, sugar content, equipment used to whip the cream, and length of whipping time.

Fat Content

The higher the fat content of the cream, the more stable the whipped cream will be. Solid fat particles create a more rigid foam. Heavy whipping cream beats more easily than lower-fat whipping creams but becomes lumpy and

Chymosin (rennin) An enzyme sold commercially as rennet that causes milk to clot, forming a curd.

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buttery when overbeaten. An advantage to using heavy whipping cream (36 to 40% butterfat) is that its lower moisture content will prevent pastry crust from becoming soggy when it is filled with cream fillings. Whipping creams with a 30 to 36% fat content result in a softer, less stable foam (25).

Most whipping creams are sold unhomogenized to allow for easier aggregation of the fat globules. When the cream is homogenized, much of its protein surrounds the now smaller and more numerous fat globules instead of being available to envelop the air bubbles that are essential for foam formation. Vegetable gums and gelatin are sometimes added to improve the foaming ability of commercial creams.

Temperature

Cooling cream increases its viscosity or firmness and its tendency to clump. For best results, refrigerate the cream, bowl, and beaters at 45°F (7°C) or less for at least 2 hours before whipping. Cream allowed to warm to room temperature or even to above 50°F (10°C) has more widely dispersed fat globules, which reduces the cream's ability to be whipped and creates a softer texture. The optimal temperatures for whipping various milk products are shown in Figure 10-10.

Most cream is pasteurized, but the heating process denatures an enzyme that helps fat globules cluster, so nonpasteurized creams whip more readily and have a smoother texture (5). Although ultrapasteurized whipping cream takes even longer to beat to a peak-holding consistency, other ingredients can be added to improve its whipping ability and dramatically extend its shelf life.

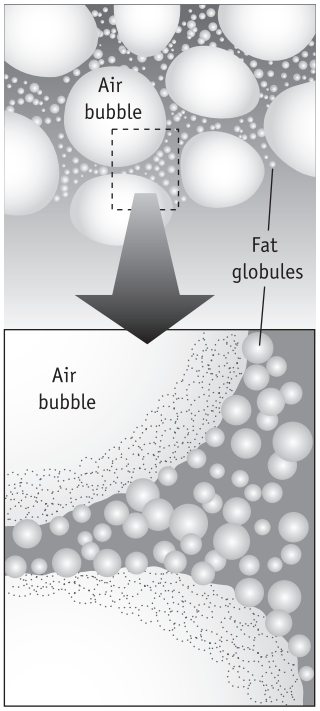
Age

The older the cream is, the greater will be its viscosity and ability to foam. Whipping cream must be at least 1 day old in order to allow it to incorporate the air necessary for the optimal increase in volume.

Sugar

Sugar increases the stability of whipped cream, but it should be added gradually, toward the end of the whipping period. If added earlier, it will increase the whipping time and reduce overall volume and rigidity by delaying the clumping of fat. However, sugar has the benefit of lessening the likelihood of overbeating the cream. For the best stability, powdered sugar should be used instead of granulated sugar because it dissolves more readily in the cold cream, and the cornstarch in the powdered sugar acts as a stabilizer.

FIGURE 10-10 Whipped foam structure. The numerous fat globules in whipped cream surround the air bubbles, giving solid reinforcement to the foam.



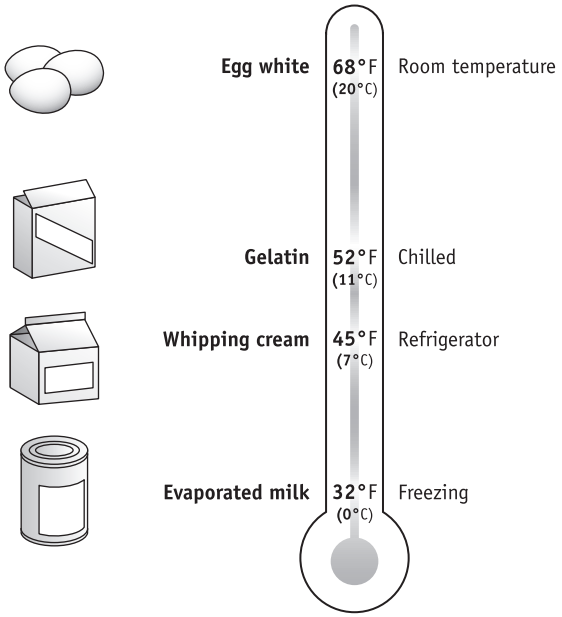
Whipping Time

Physical agitation of the cream is necessary because it disrupts the phospholipid membranes surrounding the fat globules, preventing them from aggregating (28). Overbeating, however, is a common mistake. Overbeating for even a few seconds over the peak point turns whipped cream into butter and whey. The cream turns from glossy to curdled looking. One way to salvage it is to add some more whipping cream and whisk it by hand gently into the overbeaten cream. To whip cream with an electric beater, it is best to beat it on medium high and then slow to a lower speed as soon as the cream starts to thicken. To check for sufficient whipping, the beating is stopped and the beaters are lifted to see if the cream is falling into glossy, large globs with soft peaks. The formation of stiff, yet moist, peaks signals the completion of the whipping process. The cream should be underbeaten slightly if ingredients such as sugar are to be whipped into the cream.

Whipped Evaporated Milk

The high concentration of milk solids in evaporated milk makes it possible to whip it to three times its volume (Figure 10-11), but the flavor, texture, and stability are less acceptable than they are in whipped cream. The flavor

FIGURE 10-11 Optimal temperatures for whipping.



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of evaporated milk has a tendency to overpower other flavors; thus, it is best used with highly flavored foods. Evaporated milk foams are less stable than whipped cream foams, partly because of the former's lower viscosity and lower fat content. This can be compensated for to some degree by chilling the can of evaporated milk in the refrigerator for 12 hours or in the freezer until ice crystals form. Adding 1½ tablespoons of sugar per chilled cup of evaporated milk can further stabilize the protein and resulting foam. Lemon juice can also be used to stabilize the foam. The main advantage of whipped evaporated milk over whipped cream is its lower cost.

Whipped Reconstituted Nonfat Dry Milk

Prepared NFDM powder can actually be whipped into a foam. This whipped milk product is very unstable, but it is much less expensive and lower in both kcalories and fat than whipped cream. It is prepared by dissolving equal parts of NFDM and cold water, chilling the mixture, and then beating until the mixture stands in soft peaks. Stability is increased by adding 1 tablespoon of lemon juice or 2 to 4 tablespoons of sugar during beating, which continues until the peaks bend over slightly on top.

STORAGE OF MILK PRODUCTS

Refrigerated

All fluid milk, except unopened, aseptic packages of UHT pasteurized milk and certain canned milk products, should be stored in the refrigerator. Milk should be removed only long enough to take what is to be used and then quickly returned to the refrigerator. Containers should be closed or covered to avoid rancidity, microbial contamination, and the absorption of odors from other foods in the refrigerator. Both oxidative and hydrolytic rancidity are potential problems in milk and milk products because of the substantial amounts of short-chain fatty acids. One should never drink milk directly from the container because bacteria in the mouth can wash back into the product. Pouring unused milk products back into the original container is also not recommended because microbial contamination may have occurred from exposure to the air or other sources. Storing milk in proper opaque containers will reduce its exposure to light, which can trigger oxidation, resulting in off-flavors and the loss of riboflavin (B_2). The shelf life of certain dairy products such as cottage cheese can be doubled with the addition of carbon dioxide, which disrupts microbial functions (29).

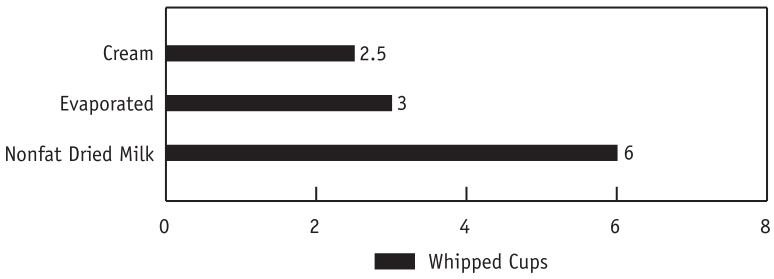
The following guidelines should be followed when storing milk products in the refrigerator:

- ***Milk.*** No more than 3 weeks.
- ***Yogurt.*** Best consumed within the first 10 days, but can last up to 3 to 6 weeks. If it separates, simply stir the liquid back into the curd before serving.
- ***Buttermilk.*** Best when used within 3 to 4 days after purchase because it will continue to sour, but it can last up to 3 or 4 weeks.
- ***Sour cream.*** Unopened, up to 1 month, but is best when used within a few days.

Dry Storage

Nonfat dry milk, ultrapasteurized milk, evaporated milk, and sweetened condensed milk are stored at or slightly below room temperature (72°F [22°C]). Nonfat dry milk should not be exposed to moisture because humidity will cause it to turn lumpy and become stale. Keeping containers tightly closed minimizes any contact with oxygen from the air. Nonfat dry milk stored in this manner will keep for about a year. Unopened cans of evaporated and sweetened condensed milks will keep up to a year in dry, ventilated areas, but double that if refrigerated. Both should be turned over every few weeks to prevent the solids from settling, thickening, and producing clots. Ultrapasteurized milk can be stored unopened at room temperature for up to 3 months. Once opened, all these milks must be treated like fresh milks and refrigerated. The sell by or pull date is the last day the item should be sold by the store, and this should always be checked before purchase.

FIGURE 10-12 Average volume yields for whipped milk products. Average yield, in cups, from 1 cup each of whipped cream, evaporated milk, and dried milk.



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PICTORIAL SUMMARY / 10: Milk

COMPOSITION OF MILK



Almost 90% of milk is water.

Lactose, or milk sugar, is the primary carbohydrate found in milk.

The predominant proteins in milk, casein and whey proteins, are of high quality.

The fat in milk is known as milk fat or butterfat.

Milk is an excellent source of vitamins A and D (depending on fortification), riboflavin (B_2), and tryptophan, which is important in the formation of the B vitamin niacin. About 80% of the calcium ingested by Americans is derived from the dairy food group.

PURCHASING MILK

USDA Grade A, the highest grade for milk, is based on the lowest bacterial count. Although grading milk is voluntary, pasteurization—the process of heating milk to kill harmful bacteria—is required for all milk (unless produced within a state that allows the sale of raw milk not transported interstate). Homogenization prevents the separation of water and fat in milk.

MILK PRODUCTS IN FOOD PREPARATION

Heat, source animal's feed, oxidation, use of copper equipment or utensils, and exposure to sunlight can all influence milk flavor.

The percentage of fat determines the mouthfeel and body of a particular milk. Milk proteins coagulate to form a solid clot when exposed to heat, acid, enzymes, polyphenolic compounds, and/or salt.

Scorching milk can be prevented by constant stirring, slow increases in temperatures, and use of a double boiler.

Liquid milk products such as cream, evaporated milk, and reconstituted nonfat dry milk can be whipped into a foam.

STORAGE OF MILK PRODUCTS

All fluid milk except unopened UHT pasteurized milk and certain canned and dry milk products should be stored in the refrigerator. Containers should be closed or covered to avoid rancidity, microbial contamination, and the absorption of odors from other refrigerated foods. Oxidation caused by exposure to air can result in an off-flavor and losses of riboflavin (B_2). Nonfat dry milk, ultrapasteurized milk, evaporated milk, and sweetened condensed milk should be stored at or slightly below room temperature (72°F [22°C]). Once opened, all these milks must be treated as fresh milks and refrigerated.



TYPES OF MILK



About half the milk produced in the United States is sold as fluid milk and cream. Much of the rest comes to market as butter, cheese, and ice cream.

Fresh Fluid Milk
- Whole
- Reduced fat (2%)
- Low fat (1%)
- Fat free (nonfat)

Nutritionally Altered
- Imitation
- Filled
- Low sodium
- Reduced lactose

Flavored
- Chocolate
- Eggnog

UHT

Dry Milk

Dairy-Based Foods
- Cheese
- Butter
- Ice cream

Plant-Based "Milk"
- Soy, rice, almond
- Hemp, grain, coconut, and other nuts

Canned
- Whole
- Evaporated
- Sweetened condensed

Cream

Cultured Milk Products
- Buttermilk
- Yogurt
- Acidophilus milk
- Kefir
- Sour cream



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The primary carbohydrate in milk is _____
   a. sucrose.
   b. glucose.
   c. lactose.
   d. fructose.

2. The enzyme most commonly used to coagulate milk is _____, which is used in the production of cheese.
   a. lipase
   b. lactase
   c. chymosin (rennin)
   d. papain

3. What is the name of the heat treatment used to kill microorganisms in milk?
   a. Pasteurization
   b. Homogenization
   c. Filtration
   d. Evaporation

4. The curdling of milk or cream that sometimes occurs when preparing dishes such as scalloped potatoes or those containing tomato products or asparagus is due to the presence of _____ in these foods.
   a. enzymes
   b. sugar
   c. alkaline ingredients
   d. polyphenolic compounds

5. What are the two main types of protein found in milk?
   a. Chymosin and albumin
   b. Whey and albumin
   c. Albumin and immunoglobulin
   d. Casein and whey

6. The ingredient in milk that contributes to a rich, creamy mouthfeel is _____
   a. protein.
   b. fat.
   c. carbohydrate.
   d. fiber.

7. What are foods with live microbial food ingredients that have a beneficial effect on human health called?
   a. Pasteurized
   b. Prebiotics
   c. Probiotics
   d. Medical foods

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

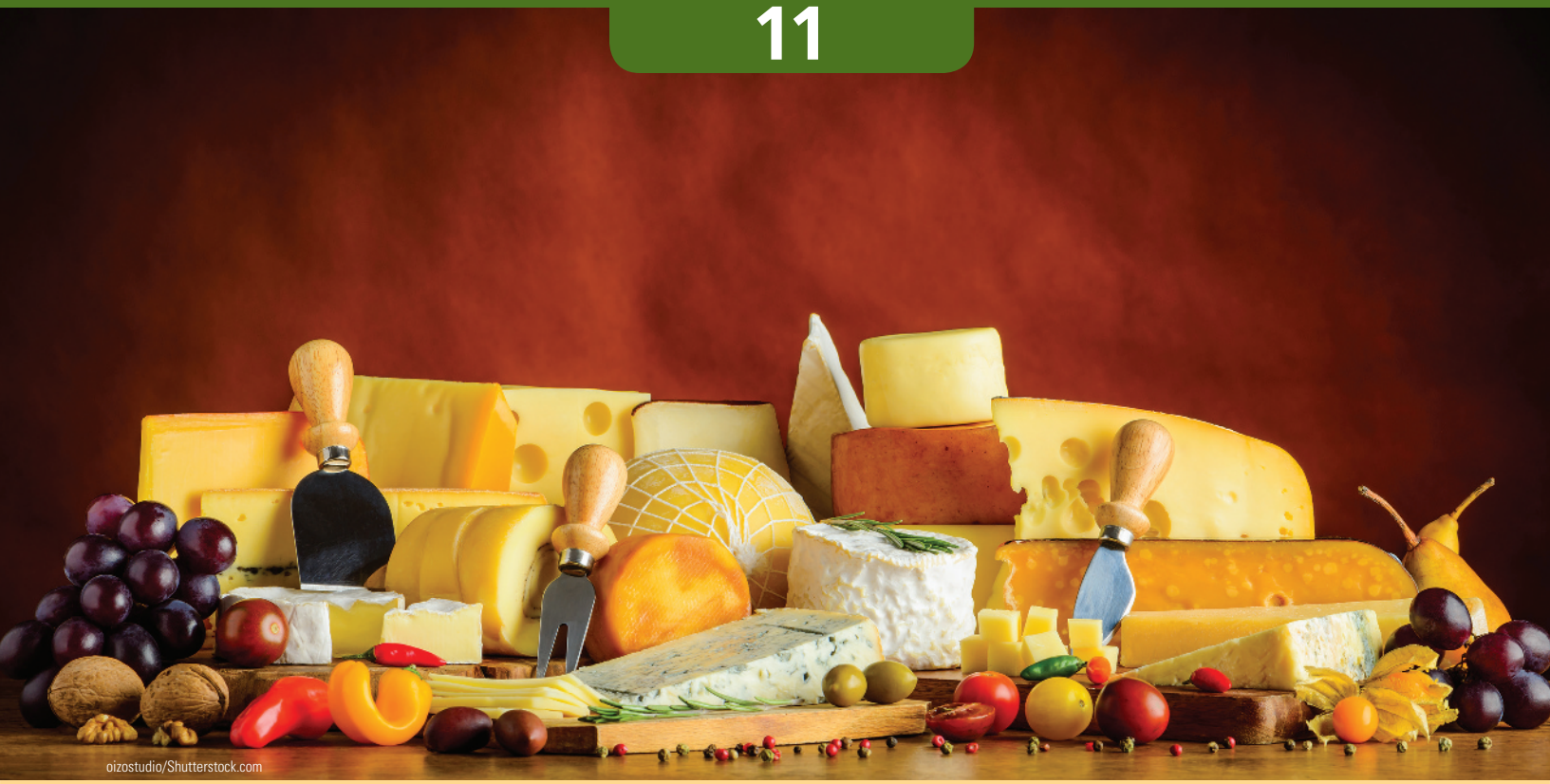
1. Describe the nutrient composition of milk, including its primary carbohydrate, its predominant proteins, and the vitamins and minerals for which it is a good source.
2. Describe the grading of milk and the process of pasteurization.
3. What is the difference between ultrapasteurization and ultrahigh-temperature processing?
4. Describe the purpose and process of homogenization.
5. Briefly describe the major characteristics of the following milk products: fluid milk, canned milk, dry milk, cultured milk products, and creams.
6. Define the following terms: *milk solids-not-fat (MSNF), agglomerate*, and *coagulate*.
7. List and explain the various ways that milk can be precipitated.
8. Discuss the effects of fat content, temperature, cream age, sugar, and whipping time on the stability of milk foams in whipped cream.
9. Exposing milk to light can trigger oxidation and the loss of which vitamin?
10. What are the recommended refrigerator storage times for fluid milk, yogurt, buttermilk, and sour cream?

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11



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Cheese

Classification of Cheeses 218
Cheese Production 219
Purchasing Cheese 229
Food Preparation with Cheese 230
Storage of Cheese 232

Cheese is a preserved food made from the curd, or solid portion, of milk. Adding certain enzymes and/or acid to any type of milk causes the casein proteins and fat to coagulate and separate from the liquid portion, or whey (see Chapter 10). No one really knows when humans first started to consume cheese, but legend links its discovery to an anonymous shepherd who decided to carry milk in a bag made from a sheep's stomach. The sun warmed the bag, activating the natural chymosin enzyme in the stomach lining and turning the liquid milk into a semisolid clump. To the shepherd's surprise, the resulting mass was quite palatable. It probably did not take long after that for people to realize how useful this natural process would be in providing a milk-based food that could be transported.

Making cheese involves removing a variable degree of moisture from the curd after the whey is drained. The curd can then be treated in a variety of ways to produce approximately 2,000 varieties of cheese, some of which are shown in Figure 11-1 and depicted at www.cheese.com. The whey also contains dissolved materials such as proteins, which can be processed to produce cheeses and other foods.

In the United States, the Food and Drug Administration (FDA) says that cheese must be "a product made from curd obtained from the whole, partly fat-free/nonfat, or fat-free/nonfat milk of cows, or from milk of other animals, with or without added cream, by coagulating with chymosin, lactic acid, or other suitable enzyme or acid, and with or without further treatment of the separated curd by heat or pressure, or by means of ripening ferments, special molds, or seasoning." This definition serves as the foundation for many different cheese varieties, but fifteen varieties now account for most of the cheese consumed today. Table 11-1 lists the commonly used cheese varieties along with their shape, flavor, basic ingredient, ripening (aging) period, and mode of serving.

This chapter discusses cheese classification, production, purchase, preparation, and storage.

CLASSIFICATION OF CHEESES

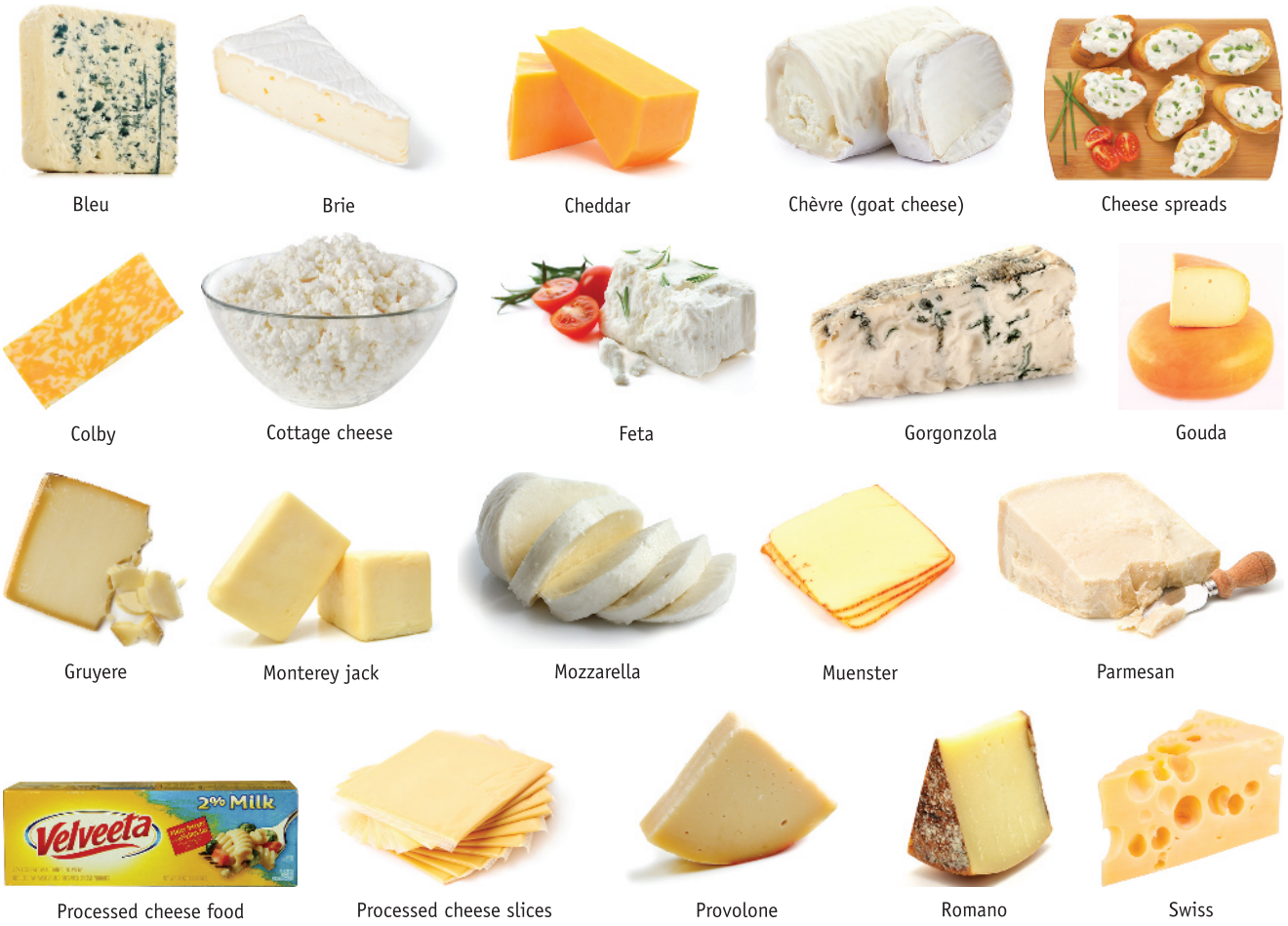
There are many ways to classify cheeses as no one method exists. Two official versions include the Food and Agricultural Organization of the United Nations that provides international standards for

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FIGURE 11-1 Common cheeses.



Bleu | Brie | Cheddar | Chèvre (goat cheese) | Cheese spreads
Colby | Cottage cheese | Feta | Gorgonzola | Gouda
Gruyere | Monterey jack | Mozzarella | Muenster | Parmesan
Processed cheese food | Processed cheese slices | Provolone | Romano | Swiss

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cheese classification (6) and the U.S. government's standards of identity for certain cheeses published in the *Code of Federal Regulations* (9). Other classifications are based on numerous differences in cheese varieties due to many variables, such as milk source (cow, sheep, goat, camel, etc.); percent moisture content; methods of pressing, sizing, and shaping; the type of bacteria utilized; appearance; mode of packaging; ripening method; and/or place of origin (23). Place of origin and moisture content are briefly discussed next.

Place of Origin

Some types of cheeses are named for the location in which they originated as shown in Table 11-1.

Moisture Content

The goal of making cheese is to remove water from the milk until a solid mass or curd remains. During this production process, the moisture content of cheese decreases, especially during aging. As cheeses age, they become drier and harder. Cheeses classified according to their moisture content are described as fresh, soft, semihard, hard, and very hard (33).

- ***Fresh***. Fresh cheeses, also called country cheeses, are soft, whitish in color, and mild tasting. They are highly perishable because their moisture content is over 80%, and they are not aged. They include cottage cheese, cream cheese, ricotta cheese, farmer's cheese, pot cheese, feta cheese, and quark (common in Europe).
- ***Soft***. Soft cheeses, such as brie, Camembert, and many Hispanic cheeses, are aged for just a short time. Water content ranges from 50 to 75%.
- ***Semihard***. Semihard cheeses contain 40 to 50% moisture. The best-known examples are Roquefort, blue, Muenster, brick, Gouda, Edam, Port du Salut, Gorgonzola, and Stilton.
- ***Hard***. The moisture content of hard cheeses ranges from 30 to 40%. Cheddar and Swiss are examples of hard cheeses.
- ***Very hard***. Parmesan and Romano are classified among the hardest cheeses. Very hard cheeses will not slice easily but are easily grated or crumbled. They are aged the longest and have a water content of approximately 30%.

CHEESE PRODUCTION

No two cheese varieties are produced by exactly the same method, which is why there are so many different types of cheese. Just think how many different types of cheddar cheese there are! However, the basic steps of making cheese—milk selection, coagulation, curd treatment (cutting, heating, salting, knitting, and pressing), curing, and ripening—are common to them all.

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TABLE 11-1 Origin of Selected Cheeses

Name	Origin	Consistency	Flavor	Normal Ripening Period
American pasteurized process	United States	Semisoft to soft; smooth, plastic body	Mild	Unripened after cheese(s) heated to blend
Asiago, fresh, medium, old	Italy	Semisoft (fresh), medium, or hard (old); tiny gas holes or eyes	Piquant, sharp in aged cheese	60 days minimum for fresh (semisoft), 6 months minimum for medium, 12 months minimum for old (grating)
Bel paese	Italy	Soft; smooth, waxy body	Moderately robust	6–8 weeks
Blue, Bleu	France	Semisoft; visible veins of mold on white cheese; pasty, sometimes crumbly	Piquant, tangy, spicy, peppery	60 days minimum; 3–4 months usually; 9 months for more flavor
Breakfast, Frühstück	Germany	Soft; smooth, waxy body	Strong, aromatic	Little or none (either)
Brick	United States	Semisoft; smooth, open texture; numerous round and irregular-shaped eyes	Mild but pungent and sweet	2–3 months
Brie	France	Soft, thin edible crust, creamy interior	Mild to pungent	4–8 weeks
Caciocavallo	Italy	Hard, firm body; stringy texture	Sharp, similar to provolone	3 months minimum for table use, 12 months or longer for grating
Camembert	France	Soft, almost fluid in consistency; thin edible crust, creamy interior	Mild to pungent	4–5 weeks
Cheddar	England	Hard; smooth, firm body, can be crumbly	Mild to sharp	60 days minimum; 3–6 months usually; 12 months or longer for sharp flavor
Colby	United States	Hard but softer and more open in texture than cheddar	Mild to mellow	1–3 months
Cottage, Dutch, Farmers, Pot	Uncertain	Soft; moist, delicate, large or small curds	Mild, slightly acidic, flavoring may be added	Unripened
Cream	United States	Soft; smooth, buttery	Mild, slightly acid, flavoring may be added	Unripened
Edam	Holland	Semisoft to hard; firm, crumbly body; small eyes	Mild, sometimes salty	2 months or longer
Feta	Greece	Soft, flaky; similar to very dry, high-acid cottage cheese	Salty	4–5 days to 1 month
Gammelost	Norway	Semisoft	Sharp, aromatic	4 weeks or longer
Gjetost	Norway	Hard; buttery	Sweet, caramel	Unripened
Gorgonzola	Italy	Semisoft; less moist than blue	Piquant, spicy, similar to blue	3 months minimum, frequently 6 months to 1 year
Gouda	Holland	Hard, but softer than cheddar; more open mealy body like Edam, small eyes	Mild, nutlike, similar to Edam	2–6 months
Gruyère	Switzerland	Hard, tiny gas holes or eyes	Mild, sweet	3 months minimum
Limburger	Belgium	Soft; smooth, waxy body	Strong, robust, highly aromatic	1–2 months
Monterey Jack	United States	Semisoft (whole milk), hard (low-fat or skim milk); smooth texture with small openings throughout	Mild to mellow	3–6 weeks for table use, 6 months minimum for grating
Mozzarella	Italy	Semisoft; plastic	Mild, delicate	Unripened to 2 months
Muenster	Germany	Semisoft; smooth, waxy body, numerous small mechanical openings	Mild to mellow, between brick and Limburger	2–8 weeks
Neufchâtel	France	Soft; smooth, creamy	Mild	3–4 weeks or unripened
Parmesan, Reggiano	Italy	Very hard (grating), granular, hard brittle rind	Sharp, piquant	10 months minimum

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TABLE 11-1 *(continued)*

Name	Origin	Consistency	Flavor	Normal Ripening Period
Port du Salut, Oka	Trappist Monasteries	Semisoft; smooth, buttery	Mellow or mild to robust, similar to Gouda	6–8 weeks
Primost	Norway	Semisoft	Mild, sweet, caramel	Unripened
Provolone	Italy	Hard, stringy texture; cuts without crumbling, plastic	Bland acid flavor to sharp and piquant, usually smoked	6–14 months
Queso blanco, White cheese	Latin America	Soft, dry and granular if not pressed; hard open or crumbly if pressed	Salty, strong, may be smoked	Eaten within 2 days to 2 months or more; generally unripened if pressed
Ricotta	Italy	Soft, moist and grainy, or dry	Bland but semisweet	Unripened
Romano	Italy	Very hard, granular interior, hard brittle rind	Sharp, piquant if aged	5 months minimum; usually 5–8 months for table cheese; 12 months minimum for grating cheese
Roquefort	France	Semisoft, pasty, and sometimes crumbly	Sharp, spicy (pepper), piquant	2 months minimum; usually 2–5 months or longer
Sap Sago	Switzerland	Very hard (grating), granular, frequently dried	Sharp, pungent, flavored with leaves; sweet	5 months minimum
Schloss, Castle cheese	Germany, Northern Austria	Soft; small, ripened	Similar to, but milder than Limburger	Less than 1 month; less intensively than Limburger
Stirred curd, granular	United States	Semisoft to hard	Similar to mild cheddar	1–3 months
Stilton	England	Semisoft to hard; open flaky texture, more crumbly than blue	Piquant, spicy, but milder than Roquefort	4–6 months or longer
Swiss, Emmentaler	Switzerland	Hard; smooth with large gas holes or eyes	Mild, sweet, nutty	2 months minimum, 2–9 months usually
Washed curd	United States	Semisoft to hard	Similar to mild cheddar	1–3 months

The yield from 10 pounds of milk is approximately 1 pound of cheese and 9 pounds of whey (31). On a smaller scale, that is equivalent to 1 cup (8 ounces) of milk providing about 1 ounce (specifically, 0.8 ounce) of cheese.

Milk Selection

The first step in making cheese, and the one that has the greatest influence on its classification, is choosing the appropriate milk. Any mammal's milk can be made into cheese, but in the United States, pasteurized cow's milk is the most common source. However, interest in specialty cheeses made from milk other than cow's milk continues to grow (14). In Europe and the Middle East, a significant amount of cheese is made from either sheep's or goat's milk. Other animals whose milk may be used for making cheese include the camel (Pakistan and Afghanistan), reindeer (Lapland), horse (Mongolia), water buffalo (the Philippines, India, and Italy), and yak and zebu (China and Tibet).

The amount of fat found in cheese is determined by the type of milk from which it is made. Whole, reduced-fat (2%), or fat-free (nonfat) milk; buttermilk; cream; whey; milk solids-not-fat (MSNF); or any combination of these can serve as the basis for cheese making. Homogenized milk is usually selected for making soft cheese because homogenization makes the casein proteins coagulate more easily, and the increased surface area of the broken-up fat results in a moister product. Homogenized milk is not used to make hard cheeses because the same trait that is desirable for softer cheeses creates a brittle texture during the long aging process (21).

Currently, the FDA requires pasteurization for all fresh or soft-ripened cheeses but allows the use of raw (unpasteurized) milk to make hard cheeses such as cheddar if they are aged at 35°F (4°C) or higher for at least 60 days (14). Cheese aged for shorter periods must be pasteurized to reduce the growth of harmful bacteria such as *Escherichia coli, Salmonella*, and *Listeria*. However, the U.S. National Academy of Science recommends that the law requiring pasteurization or a minimum 60-day aging should be replaced with standards that directly measure and limit the bacterial load allowable in cheese products (26).

Coagulation

Cheese making starts with the coagulation of the casein protein in milk. The whey, which contains most of the water in milk, is removed as the curd forms. The protein, fat, and micronutrients from milk are hence concentrated within the curd. The type of coagulation method used determines many of the characteristics of the resulting cheese. The two main methods to aid coagulation utilize the action of enzymes and the action of acid (Figure 11-2).

Enzyme Coagulation

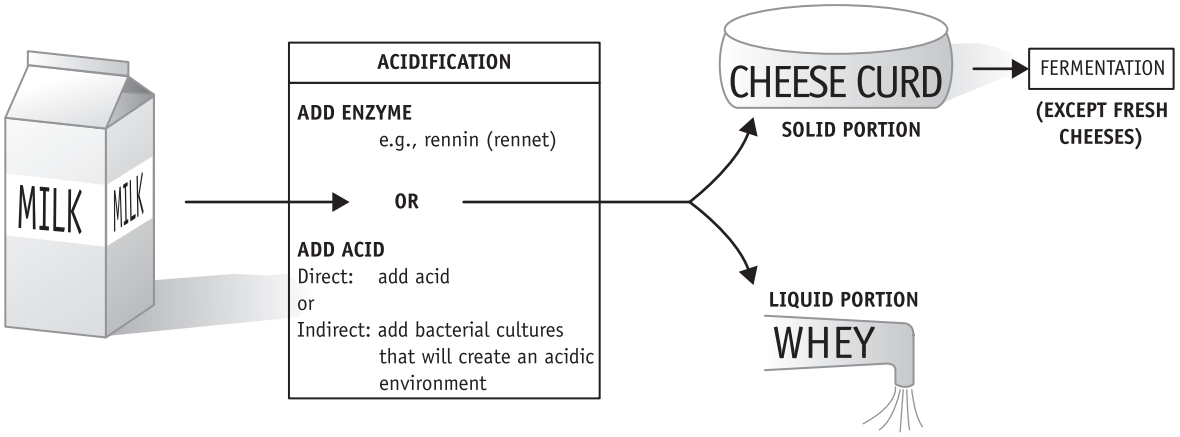
The enzyme used to coagulate milk to make cheese can come from a variety of sources—animal (calves, cows, sheep,

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FIGURE 11-2 Cheese is usually produced by coagulating (clotting) the milk with either an enzyme or acid.



goat, pigs), plant (artichoke thistle), and microbial (including genetically engineered bacteria) (10) (Chemist's Corner 11-1). The different enzymes, bacteria, molds, and/or yeasts added during coagulation influence the flavor, texture, and color developed by the cheese during ripening (41). As explained next, milk-clotting enzymes include animal stomach enzymes such as chymosin and coagulants derived from nonstomach sources.

Chymosin

The enzyme chymosin, originally obtained from milk-fed calves—specifically, their fourth stomach—has long been used to produce cheese. The name comes from the Greek word for gastric liquid, *chyme*. Infant mammals coagulate their mother's milk in their stomachs with the assistance of an enzyme (chymosin in infant cows) and stomach acid. The resultant curd is easier to digest and is essentially a natural way of making "cheese" (27).

In 1890, chymosin was renamed rennin and sold commercially as rennet (15). Confusion of the term *rennin* with *renin* (which refers to an enzyme involved in blood pressure regulation) led to the proteolytic enzyme being again called chymosin. The term *rennet* refers specifically to enzyme preparations derived from the stomachs of ruminants: calf chymosin, bovine pepsin, and porcine pepsin.

Today, the majority of enzymes used for cheese production are derived from genetically modified organisms, specifically bacteria such as *Aspergillus niger* and *Kluyveromyces marxianus var. lactis* (15). The enzyme harvested from these bacteria is known as fermentation-produced chymosin (FPC).

Coagulants

Milk-clotting enzymes derived from nonstomach sources such as vegetables and bacteria (proteases derived from *Cryphonectria parasitica, Mucor miehei*, and *Mucor pusillus*) are called "coagulants." Cheeses manufactured using coagulants are acceptable to vegetarians and adherents to kosher and halal dietary laws because they are made with enzymes from nonanimal sources.

Coagulation Process

Prior to the addition of enzymes, the milk is usually heated in large vats at temperatures from 72 to 95°F (22 to 35°C) to provide an optimal environment for enzymes and bacterial activity, which contributes to the formation of curd (Chemist's Corner 11-2). Calcium chloride may be added to speed up coagulation and strengthen the curd's consistency. Coagulation with enzymes occurs in less than an

CHEMIST'S CORNER 11-1

Milk Coagulation Mechanism

Chymosin or coagulants act on milk by hydrolyzing casein, causing the milk to clot or coagulate. The rate of this reaction depends on the pH and ionic strength or salt/NaCl concentration of the medium. Milk-clotting enzymes that cleave casein are classified as aspartic proteases because their active sites consist of aspartic acid residues.

CHEMIST'S CORNER 11-2

Caseins and Coagulation

Milk caseins may be coagulated by acid (Chemist's Corner 10-1 and 10-3) or by enzymes. The two methods are different and produce curds with different properties. Acid coagulation causes calcium to be released from the micelles, whereas in enzyme coagulation, calcium is retained in the micelles. Enzyme coagulation causes hydrolysis of kappa-casein between two specific amino acid molecules (cleavage at the Phe105–Met106 bond). This breakage results in a hydrophilic glycopeptide, which splits away from the micelles (37). The remaining κ-casein (called para-κ-casein) is hydrophobic and uncharged, and it is no longer able to stabilize the casein micelles. As a result, they aggregate and produce the coagulum that is used to make cheese (23). The optimal temperature for this reaction is about 40°F (4°C). If the milk is too hot, the enzyme is inactivated. At low temperatures, the enzyme is not activated, and the casein micelles do not coagulate. Ice-cold milk will therefore not coagulate, but if warmed to room temperature, it will begin to form clots.

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hour and creates a tough, rubbery curd. As the curd forms, the whey separates, but most of the milk's calcium remains in the curd.

Acid Coagulation

There are two methods by which acid may be used to coagulate milk proteins and thus form cheese. The first method is simply to add acid directly to the milk (7). The second and more complex method is to inoculate the milk with a bacterial starter culture that acidifies the milk by converting lactose (milk sugar) to lactic acid.

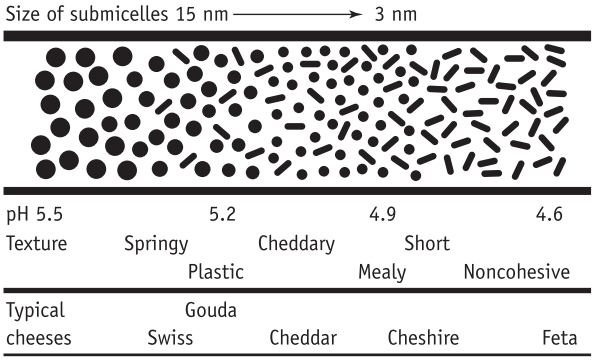
Bacterial cultures have been used for centuries to produce fermented foods, and they are carefully selected for their characteristic influences on a cheese's flavor and texture (2). Lactic acid bacteria are either added at the beginning of cheese making or are naturally present in raw milk (most milk to make cheese is pasteurized for safety purposes) (17). It takes from 4 to 16 hours to coagulate milk with acid-forming bacteria. About one-fourth to one-half of the calcium in milk is lost in the whey during this process. The curd produced by acid has a soft and spongy texture. This texture is influenced by pH, becoming more solid and compact as the acidity increases (Figure 11-3). For instance, the pH of cream cheese determines its water-holding capacity (WHC) and therefore how much moisture it retains (4). Acid-coagulated cheese is usually not aged because its high acidity inhibits the bacterial and mold growth that characterizes the aging process.

Curd Treatment

The curd may be treated to remove more whey by cutting, heating, and salting. Further optional treatment includes knitting and/or pressing. Although a few chemical tests can be used to assess the progress of the curd through each of these treatments, it is often the judgment of an experienced cheese maker that determines when it is time for the next step (20).

- ***Cutting***. Slicing the curd increases its surface area (Figure 11-4). Sometimes the curd is placed on strainers to remove even more whey.
- ***Heating***. This encourages the evaporation of whey, which allows

FIGURE 11-3 Cheese texture.



NUTRIENT CONTENT

Cheese is a very nutrient-dense food. A **pound of cheese** is equivalent in protein and fat to approximately **1 gallon of milk**. Cheeses with higher moisture levels are less concentrated in nutrients than those containing less moisture. On average, **1 ounce of cheese** (a 1¼-inch cube or a packaged slice of pasteurized process cheese) provides about **100 kcalories**, most of which are derived from fat. Overall, the primary ingredients by weight are **water, protein, and fat**; the proportions vary according to the cheese.

Fat. Fat is responsible for much of the satiety value, flavor, and texture of cheese. It is the fat content of milk, which is rather bland in taste, that is acted upon during ripening to result in a cheese with a very distinct flavor (41). Cheeses **average 9 grams of fat per ounce (primarily saturated fat)**, which is equivalent to two pats of butter. Cholesterol content averages 25 mg per ounce but ranges from 0 mg in pot cheese to 40 mg per ounce in Gouda cheese. Dietary fat from cheese can be reduced by using less cheese or choosing lower-fat forms.

Lower-Fat Cheeses. The FDA defines a **low-fat cheese** as one containing **no more than 3 grams of fat per ounce**, and a **reduced fat cheese as containing 25% less fat than their full-fat counterparts** (12). This is accomplished by starting with lower-fat milks (e.g., skim milk) to make cheese. In addition, cholesterol should not exceed 20 mg, and sodium should be below 500 mg per serving. Only a few cheeses qualify as very low in fat, at less than 2 grams per ounce. These are Gammelost, a semisoft blue cheese; sapsago, a pungently flavored, hard-textured, high-sodium cheese; and baker's, pot, or hoop cheese (29). The two most common fat-free (nonfat) milk cheeses available are ricotta and mozzarella. To create a low-fat cheese defined as 3 grams per ounce, some of the fat in cheese can be substituted with fat replacers (12). Another fat-reducing option is yogurt cheese, which contains only 1 gram of fat per ounce and is made by draining yogurt of its whey. Yogurt cheese is an excellent substitute for cheeses normally used to make cheesecake or other high-fat foods because it lowers the fat content and takes on the other ingredients' flavors.

Fat Influences Flavor. **Fat is important to texture and flavor**, so reducing the fat in cheese can result in a product with a rubbery and/or firmer texture and either no flavor or off-flavors (5). One reason that low-fat cheeses taste different is that many flavors are carried in the cheese's fat (19). The increased moisture content, resulting from decreased fat content, is more conducive to the growth of natural bacteria, which can produce compounds yielding flavors that are brothy, meaty, and bitter. Certain off-flavors such as the bitter compounds produced from protein breakdown, which are normally masked by fat, are detected when fat is reduced.

Fat Influences Texture. Many reduced-fat cheeses behave differently when heated, which sometimes makes it difficult to substitute them in recipes calling for full-fat

(*continued*)

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NUTRIENT CONTENT

cheeses. Fat also contributes to the smooth, lubricated texture of full-fat cheese by breaking up the protein matrix.

Protein. Cheese protein is complete and of high quality because it is of animal origin. One ounce of cheese contains **approximately 7 grams of protein, equivalent to that in 1 cup (8 ounces) of milk or 1 ounce of meat**. Cheese was being used as a meat substitute by monks in monasteries long before protein was recognized as an essential nutrient by food and nutrition scientists.

Carbohydrate. Cheese contains **very little carbohydrate** because most of the lactose, the primary carbohydrate in milk, is drained off with the whey, and any remaining lactose is converted to lactic acid. Because the lactose is largely gone, some people with lactase deficiency (lactose intolerance) can consume cheese with little to no ill effects. Ripened cheeses such as Swiss and cheddar are often suitable for lactase-deficient individuals (28), but process (processed) cheeses are usually not because milk or whey is frequently added to them.

Vitamins. Many of milk's vitamins are lost in cheese production. When whole milk is used to make cheese, the fat-soluble vitamins A and D remain in the curd, but many of milk's water-soluble vitamins are drained off in the whey. Only about one-fourth of the riboflavin (vitamin B_2) and one-sixth of the thiamine (vitamin B_1) remain in cheddar cheese, and much of the milk's original niacin, vitamin B_6, vitamin B_{12}, biotin, pantothenic acid, and folate drain off with the whey (30).

Minerals. Cheese has a high concentration of **minerals, specifically calcium, phosphorus, and zinc**. There are approximately 200 mg of calcium in 1 ounce of cheese, as compared with 300 mg in 1 cup of milk. Calcium content will vary depending on whether the cheese was coagulated with enzymes or acid: enzyme-coagulated cottage cheese contains twice the calcium as acid-coagulated cheese. Cheese often has a high concentration of sodium because salt is frequently added during manufacturing to aid in the process of ripening and to contribute to flavor. **Process cheese products tend to be especially high in sodium, averaging 400 mg per ounce**. The amount of salt added to cheese varies widely, and low-sodium cheeses are available.

lactic acid to build up to create a firmer, more elastic texture. Heat also destroys certain undesirable microorganisms. After heating, the curds are washed with cold water to produce softer, higher-moisture cheeses.

- ***Salting***. Salt controls the growth of bacteria and further dehydrates the curd. It also contributes to the flavor, texture, and appearance of cheese. The two major types of salting are dry salting and brine salting. Two factors influencing salting are pH and temperature—more salt is absorbed at a lower pH and higher temperature. Salted cheeses have a final salt concentration averaging 0.5 to 2%.
- ***Knitting***. Some cheeses are *knitted;* that is, the curd is united or melted into a solid mass through the use of heat.
- ***Pressing***. Pressing is another way to create a solid mass out of the curd, and the last step before ripening. Curds are physically pressed into compact masses by placing them in boxes or other containers under pressure.

Curing The aging of cheese in controlled conditions of temperature and humidity.

Ripening The chemical and physical changes that occur during the curing period.

Curing and Ripening

Cheese becomes stronger in flavor as it ages. The aging process whereby cheese is converted from a bland, tough, rubbery, fresh curd into a unique cheese with its own mature flavor, aroma, and texture is called, often interchangeably, **curing** or **ripening** (18). Depending on the variety, cheeses are subjected to different temperatures (36 to 75°F [2 to 24°C]) and humidities (higher for mold-ripened cheeses such as Roquefort and blue). Certain cheeses are treated in such a way as to develop a rind, which is simply the dried surface of the cheese. Ripening times range from 4 weeks to 2 years or longer as shown in Table 11-1. The longer a cheese ripens, the harder it becomes.

FIGURE 11-4 Cutting cheese curd.



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The U.S. Government's Code of Federal Regulations (CFR) Title 21, dictates the minimum ripening times for various cheeses such as not less than 6 months for hard grating cheeses or 10 months (up to 2 years in practice) for parmesan, which has the longest ripening time and is considered one of the hardest cheeses (9).

Cheese flavor originates from a combination of more than 300 different volatile and nonvolatile compounds that develop during curing and ripening (38). It is believed that some of these compounds originate from the milk, the activity of milk enzymes, and the starter bacteria. The skillful adjustment of curing techniques, along with the maintenance of the proper environment of temperature and humidity, creates the desired flavors, textures, and aromas of the multitude of cheeses available in our markets.

During ripening, several elements may be manipulated to affect the final product (Chemist's Corner 11-3). Added salt will draw out some of the remaining whey and inhibit bacterial growth, thereby slowing the ripening process. Bacteria, yeast, and molds contribute to the development of flavors,

CHEMIST'S CORNER 11-3

Cheese Ripening

There are three main steps in the ripening of cheese. The first is glycolysis, in which lactose is metabolized to form acetic and propionic acids, carbon dioxide, esters, and alcohols; this metabolism is initiated by the bacterial starter and other microbial agents present in milk (23). Next is lipolysis, the breakdown of fat molecules to free fatty acids, which are then further broken down to ketones, lactones, and esters by enzymes found in milk or added during manufacturing. The final step is proteolysis, the breakdown of proteins (caseins) into peptides (small protein fragments) and amino acids. This is performed by enzymes found in the milk and by microorganisms from the starter and found naturally in milk.

CALORIE CONTROL
Choosing Cheeses

Being mindful of your cheese consumption is important if you're controlling kcalories because, in addition to some important nutrients, it delivers significant kcalories:

1 ounce of cheese (size of whole thumb) = 100 kcalories and 9 grams of fat

How much is 1 ounce? Not much, because 2 tablespoons equal 1 ounce, and it takes 3 teaspoons to equal 1 tablespoon. The popular slices of American cheese weigh slightly under an ounce. Caution is recommended not only for plain cheese but also for all the foods made with cheese (pizza, calzones, cheese casseroles, etc.) and cheese dips.

Fat-Free Cheeses: Removing the fat from cheese reduces its kcalories by at least half (Table 11-2). Some of the lower-fat cheeses such as ricotta and cottage cheese are also lower in kcalories.

Limit Portions: When dishing up foods that include cheese, remember that a half cup of shredded cheese provides 228 kcalories. Doubling or tripling that amount does the same to the kcalories—456 and 684, respectively. One cheese stick is only 80 kcalories; however, four to five cheese sticks add up to 320 to 400 kcalories. Cheese can be a nutritious, delicious food, but it's best to limit portions as suggested by MyPlate: 1½ ounces of fat-free natural cheese counts as one of the three daily cups of milk recommended for adults. The Exchange Lists recognize 1 ounce of regular cheese or ¼ cup of ricotta or cottage cheese as a meat exchange.

Suggested 100-Kilocalorie Snacks:

- One plain cheese stick (80 kcalories)
- Cheese and apple or crackers: An ounce of cheese sliced up and placed on apple slices (¼ medium [3-in.] apple = 25 kcalories) or three wheat crackers (10 kcalories each)

TABLE 11-2 How Many Kilocalories Are Provided by Cheese?

Cheese			
1-Ounce Servings	**Serving***	**Kilocalories**	**Fat (g)**
• American, slice	Slice	100	9
• American, cheese spread	1 oz	82	6
• Cheddar, regular	1 oz	114	9
• Cheddar, fat-free	1 oz	40	0
• Parmesan, grated	1 oz	122	8
• Ricotta, whole	1 oz	50	4
• Ricotta, fat-free	1 oz	20	0
• Swiss	1 oz	92	7
½-Cup Servings	**Serving***	**Kilocalories**	**Fat**
• Cheddar, shredded	½ C	228	14
• Cheese stick	1 stick	80	4
• Cottage cheese, 4%	½ C	120	5
• Cottage cheese, 1%	½ C†	40	1
• Ricotta, whole	½ C†	180	12
• Ricotta, fat-free	½ C†	90	0

*Servings: oz = ounce; C = cup
†Serving Sizes = ¼ cup in the Exchange Lists

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CHEMIST'S CORNER 11-4

Bacteria and Cheese Flavor

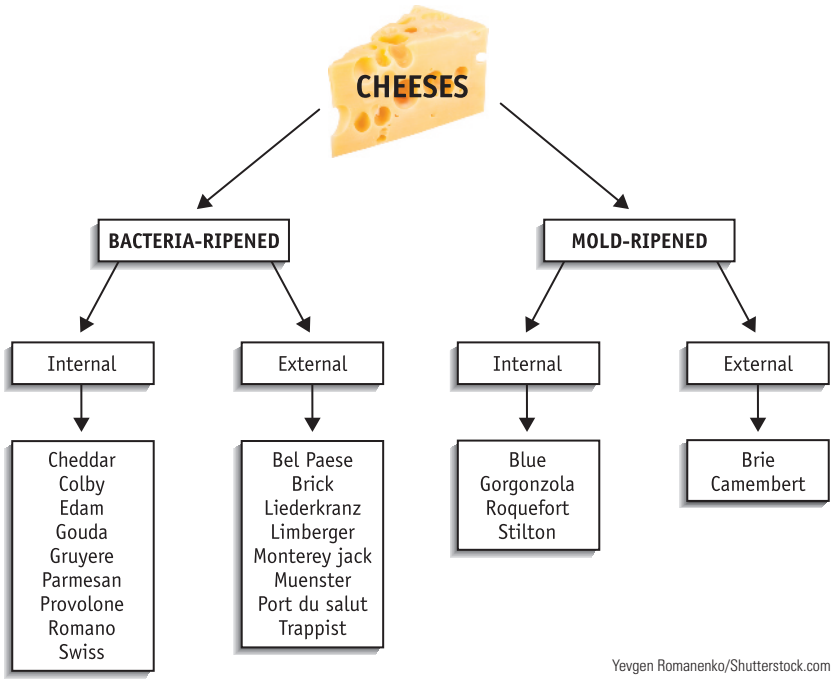
Bacteria are responsible for some of the flavors of cheese. Certain strains of bacteria produce lactic acid, which affects the degree of sharpness or mildness of cheese (25). Lactic acid–producing bacteria are believed to impart flavor to cheese by reducing the oxidation–reduction potential, hydrolyzing protein, and producing dicarbonyls. Certain dicarbonyls such as diacetyl, methylglyoxal, and glyoxal are thought to interact with amino acids via the Maillard reaction to produce flavor compounds (35). These same bacteria are present in yogurt, producing some of its flavor. Some of these "friendly" bacteria naturally produce other compounds that inhibit the growth of harmful bacteria. For instance, some strains produce a compound called "bacteriocin" that prevents the growth of the potentially infectious bacteria *Listeria* (25).

CHEMIST'S CORNER 11-5

Enzymes and Cheese Flavor/Texture

One of the major biochemical processes responsible for cheese flavor and texture development during ripening is the breakdown of proteins via proteolysis (24). The breakdown of the casein structure into smaller peptides also reduces cheese rigidity and increases its flexibility (22). Proteolytic enzymes in cheese are derived from the milk, starter bacteria, coagulant, and other microorganisms (10). The enzymes break down casein to amino acids, which can then be further broken down to various substances, giving each cheese its unique flavor (24) (Figure 11-6). Proteolysis produces pleasant flavors in cheese but also some bitter compounds (9). These various factors result in the wide variety of cheeses with different flavors.

FIGURE 11-5 Cheeses classified by their ripening methods.



Yevgen Romanenko/Shutterstock.com

aromas, and textures (Chemist's Corner 11-4 and 11-5). The choice of microorganism and whether it is internally or externally introduced during the cheese-making process will determine what kind of cheese is produced. Cheeses can be classified by the type of ripening (Figure 11-5).

The mold *Penicillium roqueforti* added to homogenized whole milk converts free fatty acids to smaller compounds, which impart the characteristic tangy flavor to blue cheese. The holes (eyes) in Swiss cheese are produced by gas (CO_2)-forming propionic acid bacteria that are active during the early part of ripening when the curd is pliable (Figure 11-7). Other processes that influence flavor during ripening include the hydrolysis of proteins to peptides (smaller protein molecules) and amino acids, the conversion of lactose to lactic acid, and the breakdown of fatty acids into shorter, volatile fatty acids (10). Feta's unique flavor is partially derived from lipase, an added enzyme that breaks down milk fat (11). This enzyme, sold in powdered form, will deliver different flavors based on its source: calf lipases yield mild flavors, while lamb lipases contribute sharper flavors.

Cheeses may exhibit different textures because they have been subjected to certain processing techniques, such as inoculation and kneading. The blue-veined cheeses have been inoculated with mold spores, whose growth within the cheese creates the blue veins. Mozzarella and provolone are ropy in texture because of kneading, which is the pulling and stretching of the curd after it has been knitted. Figure 11-8 shows that ripening is the last step in commercial cheese production.

How & Why?

Why are cheddar cheeses labeled mild, medium, or sharp?

Like wine, the finished character of these cheeses is determined not only by the original ingredients but also by the maturation process. The flavor of cheddar cheese can range from mild to sharp depending on the duration of aging. Although the time cheddar is held for aging varies by the cheese company, the general guideline is that mild cheddar is aged for at least 60 days, medium for 3 to 6 months, sharp for a minimum of 9 months, and extra sharp for at least 15 months.

Whey and Whey Products

Whey separated from its water content is low in fat and rich in nutrients. It contains the water-soluble whey proteins

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FIGURE 11-6 How some cheese flavors develop.

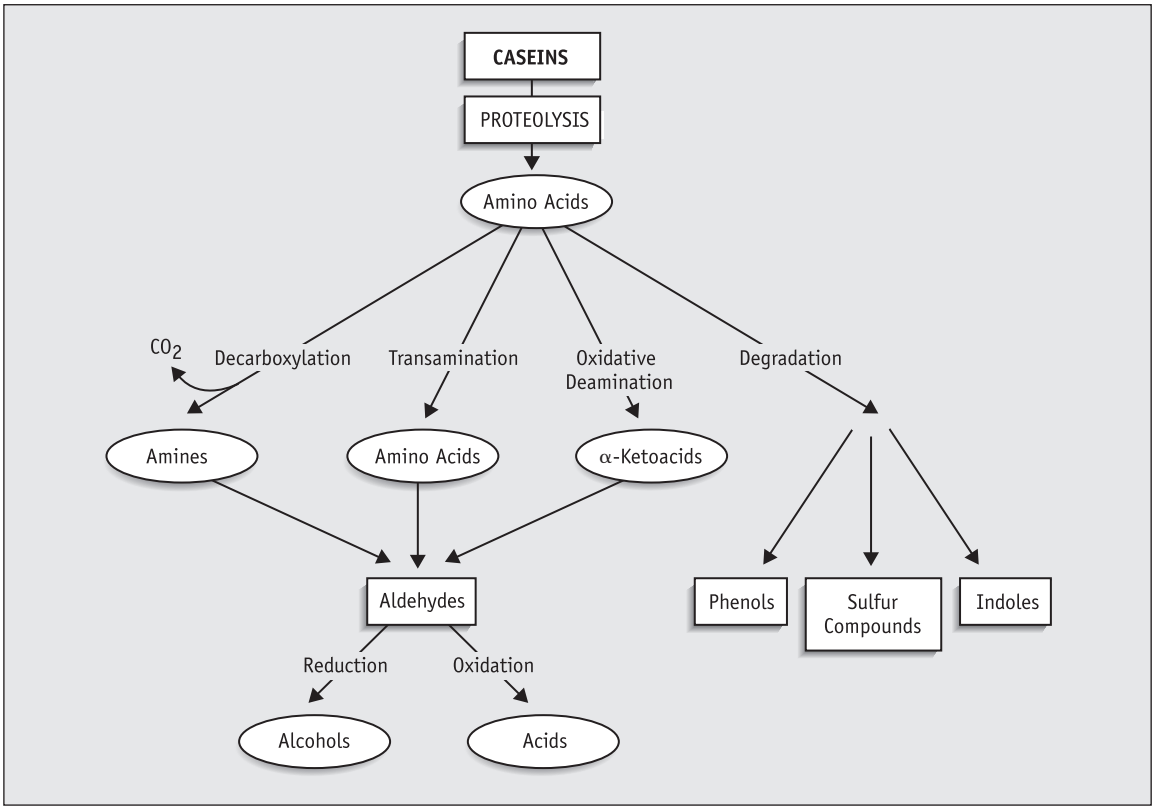


FIGURE 11-7 The eyes in Swiss cheese are generated by carbon dioxide produced by the fermentation of lactic acid (from lactose) to propionic and acetic acids.

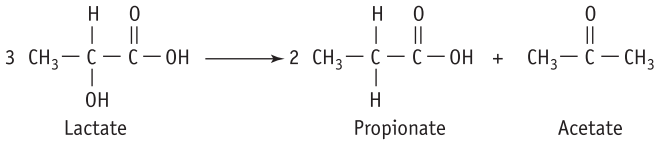
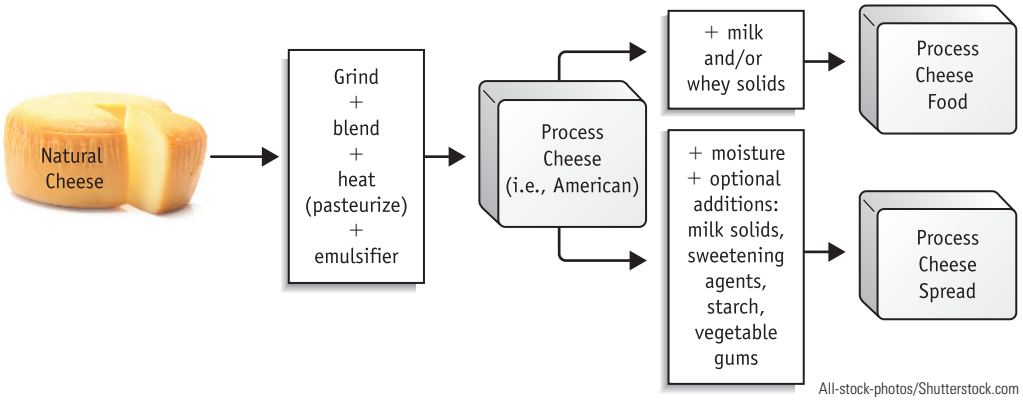


FIGURE 11-8 Commercial cheese production.



and most of the lactose, water-soluble vitamins, and minerals of the milk. Whey is highly perishable when fresh, so it is most often processed quickly into whey cheeses, dry whey, and modified whey products. In the past, the nutrient-rich whey was principally used to feed animals, but now the food industry is using pasteurized whey in a variety of products. Whey is found in baked goods, beverages, sauces, salad dressings, cheese products, canned fruits and vegetables, confections (caramels and other candies), dry mixes, frozen foods (fruits, vegetables, desserts), jams, jellies, meat, pasta, and milk products.

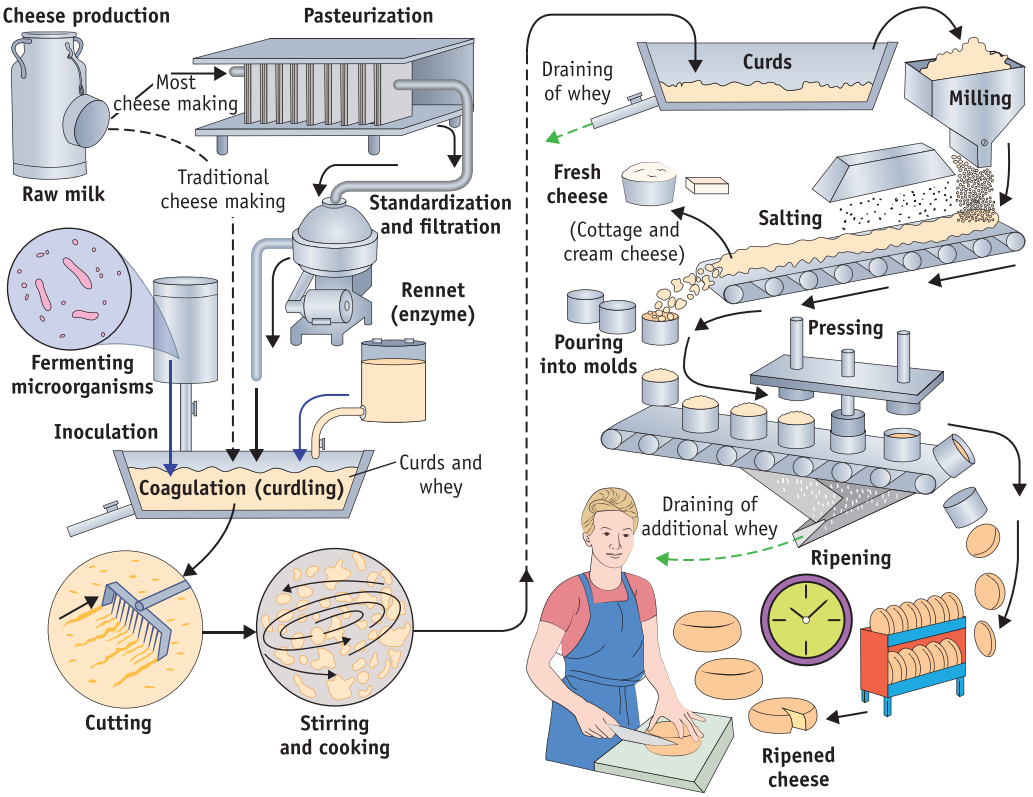
Two types of whey—sweet and acidic—are incorporated into foods (7). Sweet whey results from coagulating milk with enzymes, whereas acidic whey originates from acid-coagulated milk.

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FIGURE 11-9 The manufacture of processed (process) cheese.



Besides having greater acidity, acidic whey also contains higher mineral concentrations because the acid releases the calcium from the casein molecule, causing it to be dispersed in the whey portion.

Whey Cheeses

Scandinavian cheeses such as primost, mysost, and gjetost are very hard whey cheeses. They are made by evaporating the water until the whey is extremely concentrated. These cheeses tend to be sweet and lightly brown, a result of their lactose caramelizing in the process of water removal. Another type of whey cheese, ricotta, is produced by coagulating the whey with acid and high heat.

Dry Whey

A large proportion of the dry whey produced in the United States is fed to livestock. The remainder is used as an ingredient in processed foods such as confections, soups, beverages, imitation cheeses, dessert toppings, nondairy coffee creamers, and sports supplements.

Modified Whey Products

Condensed whey contains no more than 10% of its original water and is often used as an ingredient in process cheese food. Another product, sweet-type condensed whey, is used as an ingredient for certain candies. Whey protein concentrate is whey concentrated to a minimum of 25% protein. Removing some lactose results in a partially delactosed whey. Also available is partially and/or totally demineralized whey, which has had some or all of its minerals removed.

Process (Processed) Cheeses

Process (processed) cheese was patented in 1916 by James L. Kraft, who founded Kraft Foods (31). Process cheeses are all made from blended cheeses, but they differ on the basis of their ingredients and manufacturing methods (Figure 11-9). Approximately one-third of the cheese produced in the United States is used for the various kinds of pasteurized process cheeses. These include process cheese, cold-pack cheese, process cheese food, process cheese spread, and imitation cheese (30). These cheeses appeal to many consumers because of their uniform taste and creamy, meltable texture, longer shelf life, convenient packaging, and lower cost.

Process (processed) cheese
A cheese made from blending one or more varieties of cheese, with or without heat, and mixing the result with other ingredients.

Process Cheese

Process cheese is made by combining different varieties of natural cheese. Heating pasteurizes and stops further ripening of the cheese. Other ingredients, including emulsifying salts such as sodium citrate or sodium phosphate, are added to produce a stable, homogeneous emulsion. During the emulsifying process, powdered milk, whey, cream or butter, and water may also be added. The moisture content of the process cheese must not exceed 40%, and the fat content is similar to that of the natural cheese from which it is derived. When the mixture is partially cooled, it is formed into blocks; cut into slices, wedges, or other shapes; and packaged. American cheese made from blended cheddar cheese is a popular form of process cheese.

Cold-Pack Cheese

Cold-pack or club cheeses were developed in 1918 by Hubert Fassbender,

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who found he could blend cheddar cheese, milk by-products, and spices to create a spreadable cheese for crackers and sandwiches. Because cold-pack cheeses are blended without being heated, they must be made from pasteurized milk products. In cold-pack cheese food, the original cheese may be combined with milk (whole, reduced-fat [2%], fat-free [nonfat], or buttermilk), MSNF, cream, or whey. It also may be sold in smoked form.

Process Cheese Food

Process cheese food must be at least 51% natural cheese by weight, which is less than either process cheese or cold-pack cheese. The remaining ingredients may include milk, cream, oil, or whey (31). Process cheese food products, including Cheez Whiz™, Velveeta™, and Kraft Singles™, have a milder flavor, have a softer texture, and tend to melt more quickly.

Process Cheese Spread

Process cheese spread is a softer, more spreadable product than process cheese food, but, like cheese food, must contain at least 51% natural cheese by weight (36). Ingredients such as sugar, dextrose, maltose, and corn syrup may also be added. The higher spreadability of process cheese spread, obtained by adding more liquid and an emulsifier and reducing the amount of milk fat, makes it ideal for use in sandwiches and on crackers.

Imitation Cheese

Cheese analogues or imitation cheeses are cheese-like products in which the milk fat in natural cheese has been replaced with vegetable oil. These analogues are less expensive than natural cheese and are manufactured using a process similar to that used to make process cheese. Milk proteins such as calcium caseinate are mixed with a small amount of vegetable fat, water, salt, emulsifiers, and lactic acid before being heated to pasteurization temperatures for several minutes. The liquid is then poured into molds or formed into slices. The texture, flavor, and melting properties of imitation cheeses are similar to those of process cheese. Nutritionally, these analogues are lower in cholesterol and sodium but equivalent in fat, although it is less saturated than that from natural cheese (32).

TABLE 11-3 Selected Food Additives in Cheeses

Unprocessed Cheese—Typical Ingredients

Milk, salt, enzymes, annatto, natamycin (other additives appearing less frequently are gums, powdered cellulose, potato starch, corn starch, calcium sulfate, or potassium sorbate).

Process (Processed) Cheese—Typical Ingredients

Milk, water, whey, milk fat, milk protein concentrate, whey protein concentrate, sodium phosphate, calcium phosphate, lactic acid, sorbic acid, sodium alginate, enzymes, apocarotenal, annatto, cheese culture (process cheese food or spreads that come packed in a jar or can often contain canola oil as one of the major ingredients and sugar as a sweetener).

Food Additive in Cheese	Function
Annatto	A natural color often added to cheddar cheeses.
Apocarotenal	Natural carrot-like orange color.
Calcium phosphate	To improve texture, consistency, and spreadability of process (processed) cheese products.
Calcium sulfate	Acts as a desiccant (substance that absorbs water) to prevent caking in shredded cheese. Avoid if sensitive to sulfites.
Cheese culture	Bacteria added to produce cheese.
Enzymes	Natural enzymes used to produce cheese.
Gums (carrageenan, guar gum, locust bean gum, and xanthan gum)	Thickening stabilizers derived from plants that provide a cohesive, rubbery texture.
Lactic acid (an alternative is acetic acid, which is vinegar)	Used for pH control, flavor, and as a preservative because many bacteria are inhibited by low acidity.
Milk fat	Natural ingredient adding flavor and smooth mouthfeel.
Milk protein concentrate	Natural ingredient adding protein.
Natamycin	Mold inhibitor.
Potassium sorbate	Preservative that inhibits molds.
Sodium alginate	Extracted from seaweed; used to stabilize and thicken.
Sodium phosphate	Emulsifying, gelling, stabilizing, thickening.
Sorbic acid	Preservative that inhibits fungi.
Starch—potato starch, corn starch, cellulose	Plant products that prevent caking of shredded cheese.
Whey	Natural ingredient adding protein and lactose.
Whey protein concentrate	Natural ingredient adding protein.

Tofu and Other Nondairy Cheeses

The cheese made from soy milk is discussed in Chapter 13 under the "Legumes" section. Other types of nondairy cheese include those made from rice or almond milk. Note that some nondairy cheeses do contain some milk and/or cream.

Food Additives in Cheese

Cheese is a preserved food made from milk. As a result, several food additives are used in the manufacture of cheeses, especially process cheese. The additives in cheese will differ based on whether the cheese is unprocessed or process. Most unprocessed cheeses contain relatively few additives, including salt, enzymes, and annatto. The list of additives in process cheeses is much longer. (See Table 11-3 for a list of additives in both process and regular cheese.)

PURCHASING CHEESE

Grading

Not all cheeses are graded according to the U.S. Department of Agriculture (USDA)–defined U.S. Grades AA, A, B, and C (Figure 11-10)—but those that

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FIGURE 11-10 USDA grades of cheese.

CHEDDAR CHEESE



U.S. Grade AA
Fine highly pleasing cheddar flavor; smooth, compact texture; uniform color.



U.S. Grade A
Pleasing flavor; smooth compact texture but may have a few openings or curdy appearance; uniform color with possible white lines.



U.S. Grade B
Fairly pleasing flavor, but may contain certain undesirable flavors to a limited degree; texture may have several defects (mealy, coarse, crumbly, corky, etc.); color may possess several undesirable characteristics (dull, faded, salt spots, molded, etc.).



U.S. Grade C
May possess somewhat objectionable flavors and colors; texture may be loose; and color may be slightly bleached on the surface.

are graded are evaluated based on their variety, flavor, texture, finish, color, and appearance. Exceptions to these criteria are Colby cheese, in which color is not considered, and Swiss cheese, which is also graded for its salt level and eyes (holes) (3). Table 11-4 lists the federal standards for the maximum moisture and minimum milk fat content of various cheeses. U.S. grades have not been established for process cheese products. A Quality Approved inspection shield on the label means only that the cheese meets minimum quality standards and has been produced in a plant meeting USDA sanitary standards. An imitation cheese is defined as one that looks and tastes like the one it is intended to replace but is nutritionally inferior. Substitute cheeses resemble the traditional product and meet the nutritional equivalency comparisons (30).

Forms of Cheese

Cheese is sold in a variety of forms. The most common way to purchase cheese is in blocks that vary in shape, usually as rectangles, triangles, and circles. Food-service establishments buy cheese in large blocks (10 pounds or more) that may or may not be frozen depending on the type of cheese. Cheese that has already been shredded or sliced makes preparation easier. Individually wrapped preportioned cheese sticks provide a high-protein/fat snack under 100 kcalories. This is one of the many food products marketed under the "100-kcalorie cutoff" trend (34); the food industry, to better serve weight-conscious consumers, is packaging their products to yield individual 100-kcalorie serving units. Process cheese, sold in jars or canisters, is also available, and it can be stored on the shelf before being opened. Less frequently used by consumers are the cheese powders used widely by the food industry for seasonings and flavorings. Finally, cheese can be melted into a sauce that can be used as a dip or poured over foods such as vegetables, baked potatoes, or nachos.

FOOD PREPARATION WITH CHEESE

Cheese is most often used as an ingredient to add flavor, color, and texture in a variety of ways—on pizza; as a taco topping; and in cheese soufflés, sandwiches, casseroles, quiches, and sauces. Mozzarella, Parmesan, and ricotta cheeses are often found in Italian dishes; feta, in Greek dishes; Monterey Jack, in Tex-Mex dishes; and cheddar, in North American dishes. Numerous dishes incorporate various cheeses; the most popular cheeses purchased in the United States for these purposes, in descending order, are cheddar, process, mozzarella, cream cheese, ricotta, Swiss, provolone, Muenster, Parmesan, Neufchâtel, and blue.

The two most important rules to follow when preparing foods with cheese are: (1) select the best cheese, and (2) keep temperatures low and heating times short.

Selecting a Cheese

The chemical composition of a cheese determines its functional properties and dictates how it will be used in food preparation. Some of these functional properties include shreddability, meltability, oiling off, blistering, browning, and stretchability (3).

Shreddability

Not all cheeses shred uniformly, which may be important to food-service operations interested in cost control. On average, 4 ounces of shredded cheese are equivalent to approximately 1 cup in volume. It may be possible to use less when using aged cheeses because of their strong flavor. Grating or chopping cheese increases the surface area and thereby increases the ease and speed with which it melts.

Meltability

Cheeses with higher fat and moisture content also have greater meltability (3). Aged or ripened cheeses such as cheddar and Swiss tend to melt and blend more easily when heated than the less-ripened cheeses. Process cheeses, which contain added water and emulsifiers, can be heated

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TABLE 11-4 Federal Standards for Maximum Moisture and Minimum Milk Fat in Cheese and Cheese Products

Cheese		% Maximum Moisture	% Minimum Milk Fat
Soft, unripened	Cottage (dry curd)	80	—
	Cottage	80	4
	Cottage (low-fat)	82.5	0.5
	Cream	55	33
	Neufchâtel	65	20–33
Soft, ripened	Brie	—	27.7 ± 1.8
	Camembert	—	24.3 ± 0.6
	Limburger	50	25
Semisoft, ripened	Asiago (fresh)	45	27.5
	Blue	46	27
	Brick	44	28
	Gorgonzola	42	29
	Monterey	44	28
	Muenster	46	27
	Roquefort	45	27.5
Hard, ripened	Cheddar	39	30.5
	Colby	40	30
	Edam	45	22
	Gouda	45	25.3
	Gruyere	39	27.5
	Samsoe	41	26.5
	Swiss	41	25.4
Very hard, ripened	Asiago (old)	32	28.6
	Parmesan	32	21.8
	Romano	34	25.1
Pasta filata (plastic)	Caciocavallo siciliano	40	25.2
	Mozzarella	52–60	18
	(low moisture, part skim)	45–52	14
	Provolone	45	24.8
Skim milk or low-fat	Gammelost	52	—
	Sapsago	38	—
Pasteurized process	Cheese	43	27
	Pimento cheese	41	29
	Cheese food	44	23
	Cheese spread	44–60	20
Cold-pack	Cold-pack cheese	42	27
	Cold-pack cheese food	44	13

without the fat separating, blend more smoothly, and melt more easily than do unprocessed cheeses. Problems may result when using lower-fat cheeses because they separate more easily when exposed to high heat, and their higher protein content makes them toughen as they are heated. For these reasons, they are not always good candidates for use in cooking.

Oiling Off

One drawback to using higher-fat cheeses in cooking is their greater tendency to *oil off*, which occurs when some free fat is released and glistens on the surface.

How & Why?

Why is mozzarella cheese used on pizza?

Mozzarella cheese tends not to oil off during cooking. Because many people find a shiny sheen of oil on pizza unappetizing, this quality makes mozzarella the optimal cheese for pizza production.

Blistering

Heating cheese can sometimes cause blistering, or the formation of bubbles that may brown or pop. The number and size of the blisters that develop will depend on the cheese's age: large blisters tend to form when using excessively aged cheese, whereas numerous small blisters may be a sign that the cheese has not been aged very long.

Browning

The browning of cheeses during heating, a result of the Maillard reaction, is desirable, but only up to a certain point. Too much browning occurs if there is an excess of sugars, amino acids, or lactose in the cheese.

Stretchability

The functionality of a cheese also differs based on how well it stretches. The stretchability of a cheese depends on its concentration of calcium phosphate and its protein network structure (18). A tough, grainy texture results from the presence of too much calcium, whereas texture turns excessively soft when undergoing too much protein breakdown during aging (3).

Temperatures

Cooking temperatures for cheeses should be kept low and heating times short. High heat or prolonged cooking toughens cheese proteins and causes the fat to separate out, creating an oily,

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stringy, and inferior product. When using a microwave, it is best to use lower power settings—between 30 and 70%—for melting cheese. Cheeses used in sauces and other dishes should be added during the last stages of preparation to prevent separation. Adding a pinch of dry mustard to cheese sauces helps bring out their flavor. One way to soften cream cheese without too much heat is to enclose it in an airtight zip-top plastic bag and briefly submerge it in hot water.

Temperature is also important when serving cheese. Most semihard and hard cheeses reach their full flavor when taken out of the refrigerator and allowed to reach room temperature before serving. To prevent cheese from drying out, it is best either to cut cheese that has reached room temperature just before serving or to let people cut their own. Cream cheese, cottage cheese, and other unripened cheeses should, however, always be served chilled.

Cutting Cheese

Cheese knives come in many different shapes, each designed to be used with specific types of cheese (Figure 11-11) (12). Very hard cheeses are best cut with a strong triangular knife equipped with a short blade. A skeleton knife has large holes cut out of the middle of the blade, so that it can be used to cut soft cheeses without sticking to them. A steel string accomplishes the same purpose. The all-purpose cheese knife has a forked end that can be used to transfer individual cheese pieces to serving plates.

FIGURE 11-11 Cheese knives shaped for function.



Andrew Twort/Alamy stock photo

STORAGE OF CHEESE

Cheese must be stored properly to prevent deterioration. Most cheeses should be refrigerated; some can even be frozen. Process cheese products can be stored in a cool, preferably dark, cupboard until ready for use, although refrigeration more effectively retains desirable qualities.

Dry Storage

Many process cheese spreads, as well as dry, grated Parmesan cheese sold in cardboard containers, have long shelf storage times. Process cheese spreads may be safely stored on the shelf in jars at room temperature (70°F [21°C]) for up to 4 months, but the quality is better retained if the product is refrigerated. Packaged dry, grated Parmesan cheese, one of the hardest cheeses, and other very hard cheeses can be kept at room temperature for up to 1 year. The exception is fresh Parmesan cheese, which has such high moisture content that it is sold in the refrigerator section.

Refrigeration

Cheese should be stored in the refrigerator drawer because this is where humidity and temperature are the highest. Most cheeses are best refrigerated in their original wrappers. Once opened, the cheese should be rewrapped as tightly as possible in its original wrapping or in aluminum foil, plastic wrap, or a sealable bag. This will prevent drying and absorption of odors from other foods. Because their odor may be picked up by other foods, strong-smelling cheeses should be double-wrapped. Firm cheese and blue cheeses are best stored wrapped in wax paper followed by plastic wrap, allowing the cheese to "breathe" and preventing contact with the plastic. Soft cheeses should be stored unwrapped in a container with holes poked in the lid. When eating ripened cheese, take it out of the refrigerator at least 1 hour before serving so that it can soften and allow the full flavor to be experienced (40).

Properly wrapped cheeses are protected from the development of molds and their possible mycotoxins. Commercial efforts to inhibit mold growth include cold storage, chemical preservatives (sorbic, benzoic, and propionic acids), plant extracts (antimicrobial herbs spices, and their oils), using microbial control (competing or inhibiting microorganisms), and reducing oxygen by coating the cheeses with a wax or resinous material and wrapping them in packaging film, and or vacuum-packaging (16). In Europe, the cheese rind is sometimes coated with olive oil to protect it from bacterial contamination, and certain spices applied to the surface of some cheeses for flavor have been reported to have an antifungal effect (39).

Maximum storage time varies because no two cheeses are alike. Ripened cheeses can be stored longer than unripened, softer cheeses. Fresh cheeses such as ricotta, cream cheese, and cottage cheese should be used within a week of their sell-by date. Process cheeses can be stored up to 4 months because they have been heat-treated and contain mold inhibitors. Once opened, process cheeses should be refrigerated. Unopened Parmesan cheese stores the longest and can be kept up to a year, although the cheese may lose some of its flavor and further dry out. After being opened, Parmesan must be refrigerated. Dried-out cheeses can be salvaged by grating and storing them in the freezer for later use as toppings or in casseroles, sauces, or soups.

How & Why?

Why should moldy cheeses be discarded?

Cheese that is kept too long can become moldy and/or dry. Most molds that develop on cheese are harmless, but because there are some molds that may produce toxins, all mold should be removed. The FDA Model Codes for Food Service recommend cutting 1 inch beyond the moldy area. Although mold-ripened cheeses such as Roquefort and blue have had special molds purposely added to them, they may develop a different-looking mold on the outside edges, and this should be removed. When soft, unripened cheeses develop molds, they should be discarded because of possible permeation throughout the cheese.

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Frozen

The water content of a cheese determines whether it can be successfully frozen. Most hard natural cheeses with a low water content can be frozen for up to 2 months and process cheeses for up to 5 months, but freezing is not recommended for soft cheeses with a high water content (30). The cheeses most suitable for freezing include brick, cheddar, Edam, Gouda, Gruyere, Parmesan, provolone, and Swiss. Freezing will change the texture and flavor to some degree, but the cheese's quality should still be acceptable (31). For best results, cheese should be frozen quickly; this is best accomplished if it is in ½-pound pieces not more than 1 inch thick. Larger chunks will freeze more slowly, possibly resulting in crumbly cheese. It is best to freeze cheese in its original wrapper, but the next-best option is to use foil or plastic wrap designated for freezing. It should be wrapped tightly, and excess air should be expelled to keep it from drying out.

Just as it is important to freeze cheese quickly, it is crucial to thaw it gradually. Gradual thawing is best achieved in the refrigerator over a period of a few days, after which the cheese should be used as soon as possible. Freezing certain cheeses may cause them to develop a dry and crumbly texture, but they may still serve as a shredded or cubed ingredient in a dish even if they would be undesirable in a sandwich or on crackers.

CAREER CORNER

Judy Thompson enrolled in a health careers class and learned about registered dietitians (RDs) or registered dietitian nutritionists (RDNs). As part of the course requirements, she shadowed a dietitian at the local hospital and found the work exciting. Deciding to pursue the RD career path, Judy gained relevant experience by working as a hospital dietary aide (an entry position in a dietetics department; see Chapter 30 on careers). Nutrition-related work experience, of course, increases a student's chances of obtaining a dietetic internship—a 6- to 12-month program (or a 2-year commitment if combined with a master's degree). These internships are available after graduation from an approved Academy of Nutrition and Dietetics (AND) program (some programs combine the degree with the internship; see the list of programs at www.eatright.org).



Courtesy of Judy Thompson

Judy Thompson MPH, RD—Registered Dietitian

After graduation, Judy applied for a master's degree program that incorporated the equivalent of an internship experience. Meanwhile, she was a dietary technician at a large hospital (500+ beds), where she worked the tray line, collected menus, assisted with some of the supervisory food-service needs, and interacted with patients.

Judy finished her master's degree in public health and then passed the Registration Examination for Dietitians to become an RD. Many dietitians (about 60%) obtain their master's degree in part because of increased job opportunities. "I'm really, really glad that I also have my Certified Diabetes Educator (CDE) qualification," she says, "because it expanded my role as a dietitian and also made me more employable."

Currently, Judy is a team member in the hospital's outpatient diabetes education program, where she not only teaches group classes for patients with diabetes but also provides one-on-one patient counseling on diabetes, pre-diabetes, food allergies, weight gain, cancer risk reduction, and cholesterol or blood pressure reduction.

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PICTORIAL SUMMARY / 11: Cheese

Cheese is a preserved food made from the curd, or solid portion, of milk. One of the most nutrient-dense foods, cheese is most often used to add flavor, color, and texture to prepared foods.

CLASSIFICATION OF CHEESES

Cheeses can be classified by their origin, moisture content (fresh, soft, semihard, hard, and very hard), and milk source (cow, sheep, goat, etc.). Cheese is primarily composed of water, fat, and protein. One ounce of cheese averages:

- **7 grams of protein.** High-quality protein equivalent to that found in 1 cup of milk or 1 ounce of meat.
- **100 kcalories.** Excess cheese can quickly accumulate.
- **9 grams of fat.** A low-fat cheese is defined by the American Heart Association as one containing no more than 3 grams of fat per ounce.
- **0 grams of carbohydrates.** One of the foods low in carbohydrates.



Common cheeses

Blue
Brick
Camembert
Cheddar
Cheese foods
Cheese spreads
Colby
Cold-pack cheese food or club cheese
Cottage cheese
Cream cheese
Gorgonzola
Gouda and Edam
Limburger
Monterey Jack
Mozzarella and Scamorze
Muenster
Parmesan
Pasteurized process cheese
Provolone
Romano
Swiss

CHEESE PRODUCTION

The basic steps of cheese manufacture include milk selection, coagulation (enzyme and/or acid), curd treatment (cutting, heating, salting, knitting, and pressing), and curing and ripening. Other products from cheese manufacture are whey products and process cheeses.

PURCHASING CHEESE



A USDA Quality Approved inspection shield on the label means that the cheese meets minimum standards of flavor, texture, finish, color, and appearance. Of four USDA grades (AA, A, B, and C), Grade AA is the best. Grading is not mandatory, however, and U.S. grades have not been established for process cheese products. The most popular cheeses in the United States are mozzarella and cheddar (1).

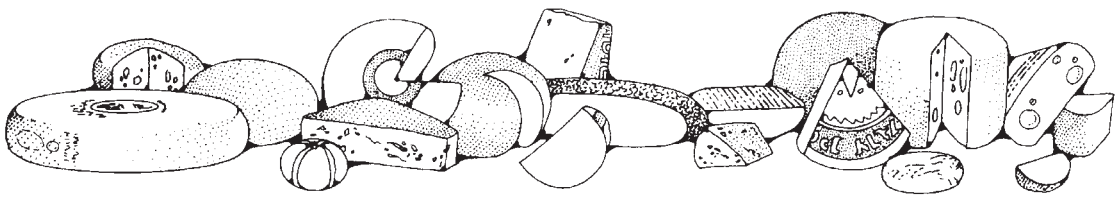
FOOD PREPARATION WITH CHEESE

Cheese can be consumed as is or as an ingredient in casseroles, pizza, soufflés, soups, salads, omelets, eggs, and other dishes. The cheese selected for preparing a particular food depends on its functional factors of shreddability, meltability, oiling off, blistering, browning, and stretchability. Ripened cheeses heat better than soft cheeses. Temperatures should be kept low, and heating times for cheeses should be short.



STORAGE OF CHEESE

Most cheeses are best refrigerated in their original wrappers. Freezing is not recommended for soft, high-water-content cheeses, but hard cheeses can be frozen for up to 2 months. Process cheese spreads packaged in jars are commonly stored on a cupboard shelf at room temperature for up to 4 months, but once opened, they must be refrigerated.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Based on their moisture content, how would Swiss and cheddar cheeses be classified?
   a. Fresh
   b. Soft
   c. Semihard
   d. Hard

2. Which of the following is the most common enzyme used to coagulate milk in cheese production?
   a. Lactase
   b. Chymosin
   c. Gorgonzola
   d. Lipase

3. What is the name for the process where cheese is exposed to controlled temperatures and humidity during aging?
   a. Curdling
   b. Boiling
   c. Curing
   d. Blistering

4. Enzymes are often used to coagulate milk, but milk can also be coagulated through the use of _____.
   a. lactose
   b. milk proteins
   c. bases
   d. acids

5. Which type of cheese is produced by blending a variety of natural cheeses (with or without heat) and then mixing them with other ingredients?
   a. Colby
   b. Cheddar
   c. Process
   d. Feta

6. Cheese averages _____ kcalories and _____ grams of fat per ounce.
   a. 50, 5
   b. 100, 9
   c. 150, 15
   d. 200, 20

7. The _____ content of cheese determines whether or not it should be frozen.
   a. carbohydrate
   b. fat
   c. protein
   d. water

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe the ways that cheese can be classified.
2. Approximately how many grams of fat per ounce are found in cheddar versus low-fat cheese?
3. What are the five steps of cheese production?
4. Describe the two methods of coagulating the casein protein in milk.
5. List and describe five methods of treating the curd.
6. Why is cheese cured/ripened, and how is it done?
7. How do the holes in Swiss cheese occur?
8. What are the two major proteins found in whey? What major food products are produced from whey?
9. What is process cheese? Briefly describe each of the following: cold-pack cheese, process cheese food, process cheese spread, and imitation cheese.
10. Cheeses differ in how they shred, melt, oil off, blister, brown, and stretch. What cheese would you select (or not select) for food preparation based on each of these characteristics?

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12



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Eggs

Composition of Eggs 236
Purchasing Eggs 238
Types of Eggs 241
Functions of Eggs in Foods 241
Preparation of Eggs . . . 244
Storage of Eggs 251

Bird eggs, long honored as symbols of fertility and life, have been part of our diet for thousands of years. All bird eggs are edible, highly nutritious, and neatly packaged in their own shells. An egg contains everything needed to sustain the life of a new chick.

The egg's nutritious contents make it susceptible to predation by other animals seeking food. Eggs were not always available or easy to find, so Americans solved this problem by breeding almost as many laying hens as there are people in the United States. Each of these laying hens produces about one egg per day.

Eggs are one of the most versatile of foods to prepare. In their most basic form, they can be cooked and eaten on their own—fried, scrambled, poached, and boiled. The unique physical and chemical properties of eggs also make them an invaluable ingredient in many prepared dishes. Among other functions, eggs are used in food preparation to do the following:

- Lend a foam structure to cakes and meringues
- Thicken custards and puddings
- Add color to lemon meringue pie and eggnog
- Emulsify mayonnaise and hollandaise sauce
- Leaven soufflés and popovers
- Bind ingredients in meatloaf and casseroles
- Coat foods prior to breading
- Glaze pastries and breads
- Clarify liquids for soups

Understanding how these various roles in food preparation are fulfilled by eggs requires a general knowledge of them. Although all bird eggs are edible, this chapter focuses on those that are most commonly consumed—chicken eggs—and their composition, purchase, functions in foods, preparation, and storage.

COMPOSITION OF EGGS

The egg has five major structural components: the yolk, albumen (egg white), shell membranes, air cell, and shell (Figure 12-1). Each of these contributes to the unique attributes and food preparation properties of eggs.

Yolk

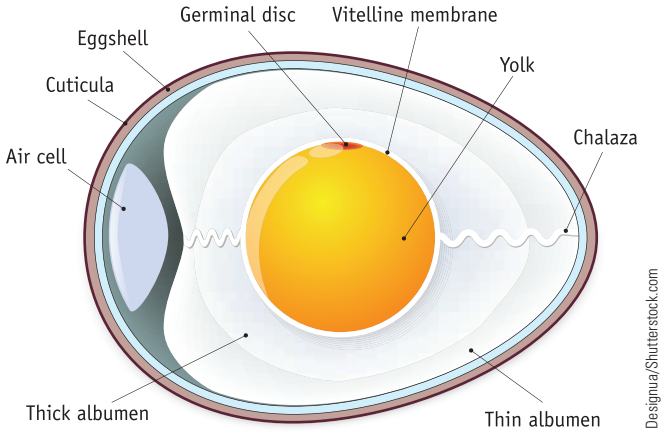
The sunny yellow yolk situated in the center of the egg constitutes about a third (30%) of the egg's weight. Dense in nutrients, the yolk serves to nourish the chick. A white, pinhead-sized germinal disc sits on the surface of the yolk. This appears darker if the egg has been fertilized but has no effect on the taste, functional

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FIGURE 12-1 Composition of an egg.



CHEMIST'S CORNER 12-1

Egg Proteins

Eggs, and especially the egg white, are composed of dozens of different proteins. Each of these proteins has its own characteristics and functions (Table 12-1). More than half of all the protein in eggs is ovalbumin, which plays an important role in egg preparation because it gels well and denatures easily when heated (4, 6). The next two proteins of any significance are ovotransferrin (conalbumin) and ovomucoid. Ovotransferrin helps protect against bacterial contamination by forming a complex with iron, thereby making it unavailable to bacteria, which need iron for growth. Ovomucoid proteins, which are resistant to denaturation, inhibit the activity of trypsin, an enzyme that breaks down specific proteins. Lysozyme, an enzyme, fights certain bacteria by lysing (breaking chemical bonds by the addition of water) the cell wall of the bacterium. Ovomucin helps protect against microbial damage by reacting with viruses. Avidin in uncooked eggs binds to the B vitamin biotin and prevents it from being absorbed by the small intestine, which is why excessive consumption of raw egg whites is discouraged. However, once cooked, the avidin is denatured and no longer inhibits the absorption of biotin. About 3 grams of protein are also found in the egg yolk in the form of lipoproteins—lipovitellin and lipovitellinin—which act as emulsifiers in food preparation.

TABLE 12-1 Protein Content of Egg White

Protein	Amount (%)*	Properties
Ovalbumin	54	Denatures easily
Conalbumin	13	Antimicrobial, complexes iron
Ovomucoid	11	Inhibits enzyme (trypsin)
Unidentified	8	Mainly globulins
Lysozyme	3.5	Antimicrobial
Ovomucin	1.5	Viscous, reacts with viruses
Flavoprotein	0.8	Binds riboflavin
Proteinase inhibitor	0.1	Inhibits enzyme (bacterial proteinase)
Avidin	0.05	Binds the B vitamin biotin (raw egg white only)

*Expressed as a percentage of the total protein content of the egg white.

properties, or nutritional value of the egg. Most eggs are screened to ensure they are not fertilized, but even if they do pass inspection undetected, fertilized eggs do not develop once refrigerated. The color of the yolk depends on the hen's diet. Pigments in the chicken feed, such as beta-carotene, cause colors ranging from pale yellow to deep red. Natural yellow-orange substances such as marigold petals are sometimes added to the chickens' feed to enhance the color of their egg yolks. Artificial color additives are not permitted.

Albumen

The albumen, or egg white, accounts for almost three-fifths (58%) of an egg's weight and is made up largely of water and protein (Chemist's Corner 12-1). Although it appears to be one mass, the egg white is actually constructed of layers differing in viscosity, alternating from thick to thin. The type and amount of proteins in various parts of the egg white determine differences in viscosity. Around the yolk is a layer of thick albumen (not to be confused with *albumin*, which refers to a class of proteins found in egg white, milk, and blood). The **chalazae** (ka-lay-zee) at the top and bottom of the egg anchor the egg yolk in the thick egg white surrounding it. They also secure the yolk to its **vitelline membrane** so it stays neatly centered in the middle of the egg.

Shell Membranes

Between the egg white and the shell are two membranes: an inner and an outer membrane. These press up against the shell and protect the egg against bacterial invasion.

Air Cell

Between the two shell membranes at the larger end of the egg is a pocket of air known as the air cell. As a freshly laid egg cools, its contents contract,

Chalaza (pl. chalazae) The ropy, twisted strands of albumen that anchor the yolk to the center of the thick egg white.

Vitelline membrane The membrane surrounding the egg yolk and attached to the chalazae.

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causing the inner shell membrane to separate from the outer shell membrane and forming the air cell. The purpose of this space is to provide the chick with some air for its first breath, which it needs to break out of the shell.

Shell

Nature's way of protecting the delicate internal contents of an egg is to surround it with a hard calcium carbonate shell (12% of an egg's weight). Eggshells are not solid but contain thousands of small pores, allowing an exchange of gases between the inner egg and the surrounding air. Shell color indicates the breed of the hen but has no bearing on the nutrient content or taste of the egg. Brown eggs tend to cost more because they usually come from larger hens, which require more food and produce fewer eggs.

The shell is protected by the **cuticle** or **bloom.** Commercially sold eggs are washed, which removes this protective cuticle. Producers compensate for this loss by applying a thin coat of edible oil onto the shell (15).

PURCHASING EGGS

In the United States, approximately 81 billion eggs are consumed each year (23). The majority (70%) are fresh eggs subject to U.S. Department of Agriculture (USDA) inspection and grading, as described below. The remaining eggs are processed (liquid, frozen, or dried eggs) for use in the food industry (food products) or food service (menu items), and their care is described more fully in the section on storage. Other egg options include egg substitutes and value-added eggs.

Inspection

The Egg Products Inspection Act of 1970 requires that egg-processing plants be inspected and that their eggs and egg products be wholesome, unadulterated, and truthfully labeled. This law is enforced by the USDA Poultry Division and applies to all eggs, whether imported or shipped intrastate or interstate.

Cuticle (bloom) A waxy coating on an eggshell that seals the pores from bacterial contamination and moisture loss.

Candling A method of determining egg quality by examining eggs placed against a light.

FIGURE 12-2 **Candling.** Eggs are automatically rolled against a light background during mass scanning, allowing checkers to remove those that have defects or that are cracked, soiled, or damaged.



Photos.com/Getty Images/Jupiterimages

Eggs Failing USDA Inspection

Eggs that do not pass inspection, called "restricted eggs," are not allowed to be sold whole to the consumer. Examples of restricted eggs are those with cracked shells—*checks*; *leakers,* which have cracked shells as well as broken membranes; *dirties,* which have at least one-fourth of their shell covered with dirt or stain; and *inedibles,* which have greenish egg whites or are fertilized, rotten, moldy, or bloody. Less than 1% of eggs have small blood spots, also known as *meat spots*. Although these are harmless, the eggs containing them are identified by electronic blood detectors during grading and removed. Inspection is intended to ensure that eggs with defects such as these are not sold to the consumer.

Grading

After eggs pass inspection, a producer can pay the USDA to have them graded for quality. The best-quality eggs are graded USDA Grade AA, followed by USDA Grade A. USDA Grade B, the lowest grade, is available to food-service establishments and not sold directly to consumers. Grades AA and A eggs, which are sold at supermarkets, have firm, high albumens and yolks that make them suitable for frying, coddling, poaching, and hard cooking. Grade B eggs have thinner whites and somewhat flattened yolks, making them better for scrambling or baking, or as ingredients in other food products.

Grading Methods

Grades are determined based on the quality of eggs, which is judged using three methods: (1) **candling,** (2) measuring Haugh (pronounced "how") units, and (3) evaluating appearance, specifically that of the shell, white, yolk, and air cell. Commercial egg grades are assigned based on both interior and exterior quality. The vast majority of eggs are graded on interior quality by candling. Grading of broken-out eggs (using Haugh units or visual examination) is reserved for research purposes or random spot checks of candled eggs. The exterior quality is determined by the cleanliness of the shell, the shape of the egg, and the presence or absence of shell irregularities such as pimples (calcium deposits) and weak shells.

Candling

As the name implies, the original method of candling involved holding an egg up to the light of a candle to view its contents. Although this is still a good way to determine an egg's inner quality and to detect defects, eggs are now mechanically rotated over lights, many at a time, by rollers (Figure 12-2).

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How & Why?

How does candling reveal whether an egg is fresh or aged?

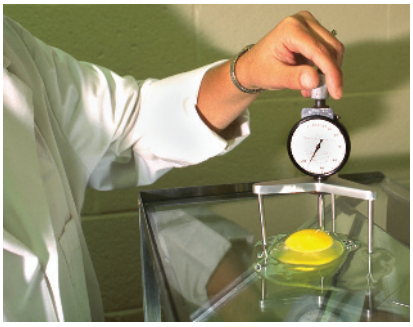
The yolk in a fresh, high-quality egg is suspended tightly by the chalazae, seen in candling only as a slight shadow. The yolks in older eggs, on the other hand, are surrounded by thinning, clearer egg whites and deteriorating chalazae. These older yolks lie closer to the shell because they are no longer suspended well by the chalazae; they are looser in consistency and cast a darker shadow. The egg's air cell, too, becomes wider or moves as the egg ages. Grade AA eggs must have an air cell depth smaller than ⅛ inch; Grade A eggs are limited to 3⁄16 inch; and Grade B eggs have no limit to the size of their air cell.

Candling is based on the principle that eggs start to deteriorate the minute they are laid, and these changes are dimly visible through an egg's shell when it is held against a light. The whites become more thin and transparent as carbon dioxide departs through the shell; and the yolk membrane stretches as the yolk absorbs water from the white, which eventually will cause the yolk to break easily when the shell is cracked.

Haugh Units

The freshness of an egg can be detected by cracking it open onto a flat surface and looking at the height of its thick albumen. Fresh egg whites sit up tall and firm, whereas older ones tend to spread out. Professional graders cannot evaluate every egg for freshness, so an egg is randomly selected and measured using a special instrument called a micrometer (Figure 12-3). The Haugh unit, a numerical value reflecting an egg's freshness, is obtained by mathematically combining the thick albumen height with the egg's weight, and then using a formula or table to convert this number into a Haugh unit. As Haugh units decrease, so does egg quality, which is reflected in grading: Grade AA is given to eggs with a Haugh unit of 72 or higher, Grade A for a measure of 60 to 71, and Grade B for a measure of 31 to 59.

FIGURE 12-3 Measuring Haugh units to determine egg quality.

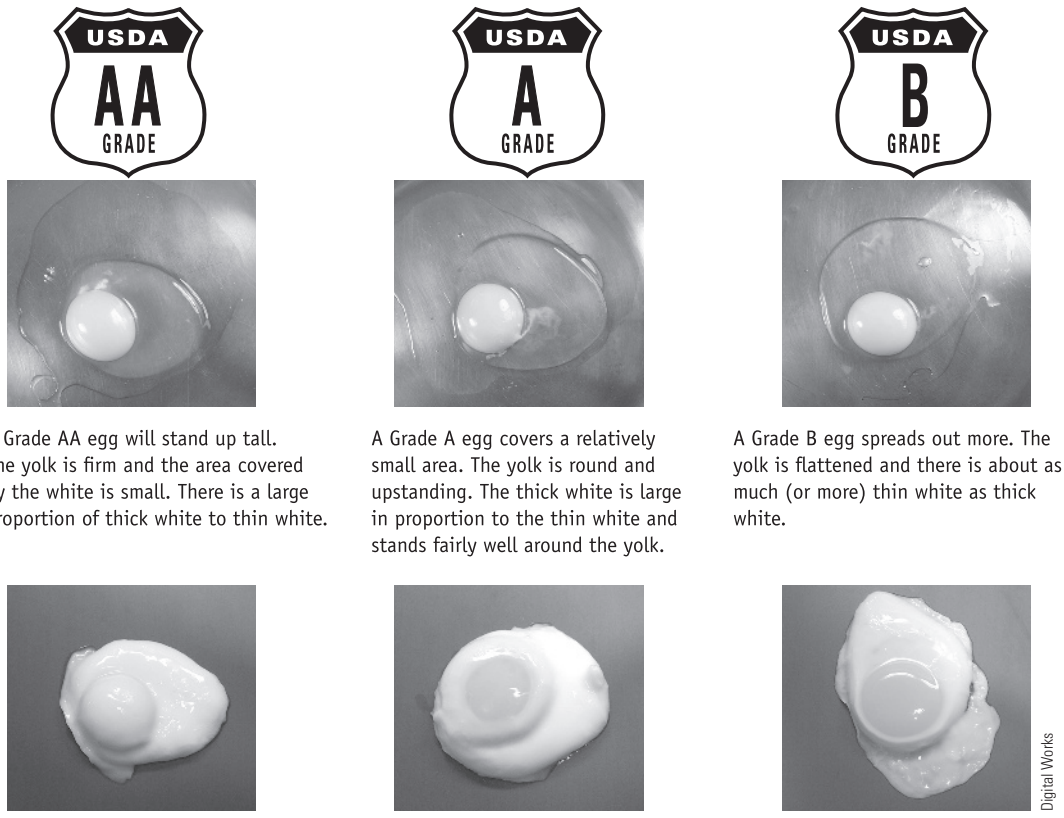


USDA

Appearance

Grading can also be based on the appearance of eggs broken onto a flat surface. Graders evaluate the quality of an egg by observing the thickness of the albumen; the prominence of the chalazae; the roundness and firmness of the yolk; and the shape, cleanliness, and texture of the shell. Figure 12-4 summarizes the characteristics of USDA Grades AA, A, and B eggs.

FIGURE 12-4 USDA grades for eggs.



A Grade AA egg will stand up tall. The yolk is firm and the area covered by the white is small. There is a large proportion of thick white to thin white.

A Grade A egg covers a relatively small area. The yolk is round and upstanding. The thick white is large in proportion to the thin white and stands fairly well around the yolk.

A Grade B egg spreads out more. The yolk is flattened and there is about as much (or more) thin white as thick white.

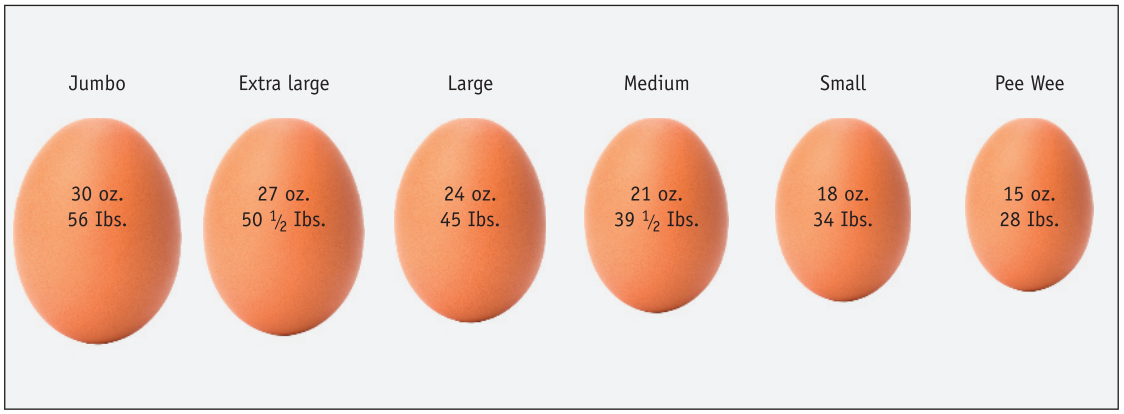
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FIGURE 12-5 Egg sizes determined by minimum weight (including shells) per dozen.



Sizing

Sizing is not related to grading in any way. Eggs are sold in cartons by various sizes determined by a minimum weight for a dozen eggs in their shells (Figure 12-5). Unless otherwise designated, recipes are based on the use of large eggs. The contents of one large egg are equivalent to approximately ¼ cup. Table 12-2 shows that four to six eggs will fill 1 cup, depending on the size of the egg. Table 12-3 shows how eggs of other sizes are used when large eggs are not available.

TABLE 12-2 Number of Eggs (Whole/Whites/Yolk) Equivalent to 1 Cup

Egg Size	Whole	Whites	Yolks
Jumbo	4	5	11
X-large	4	6	12
Large	5	7	14
Medium	5	8	16
Small	6	9	18

TABLE 12-3 Egg Equivalents: Number of Eggs Used to Replace Eggs of Other Sizes

Jumbo	X-Large	Large	Medium	Small
1	1	1	1	1
2	2	2	2	3
2	3	3	3	4
3	4	4	5	5
4	4	5	6	7
5	5	6	7	8
9	10	12	13	15
18	21	24	27	28
37	44	50	56	62

Egg Substitutes

Consumer demand for products lower in cholesterol has created a market for liquid egg substitutes, made by either omitting egg yolks, replacing egg yolks with vegetable oils, or removing some of the cholesterol in egg yolks (18). One drawback to egg substitutes is that they may be higher in sodium than regular eggs. On the positive side, egg substitutes are ultrapasteurized, packaged, and then refrigerated, preparing them for a 10-week shelf life (5). Pasteurization makes them ideal for use in uncooked foods such as eggnog, mayonnaise, and ice cream, in which raw eggs would pose a food safety risk. The ingredients and cholesterol contents of two brands of egg substitutes are listed in Table 12-4.

TABLE 12-4 Substitutes Compared to Standard Egg

	kcalories	Fat (g)	Cholesterol (mg)	Protein (g)	Sodium (mg)
Standard large egg (one)	75	5	215	6	65
Better'n Eggs™ (56 g)	30	0	0	6	120
Ingredients: 98% egg whites, water, natural flavors, sodium hexametaphosphate, guar gum, xanthan gum, color (includes beta-carotene).					
Egg Beaters™ (46 g)	25	0	0	5	90
Ingredients: 99% egg white, less than 1%: vegetable gums (xanthan gum, guar gum), color (includes beta-carotene), salt, onion powder, natural flavor, spices.					

Sources: www.allwhiteseggwhites.com/products/product.cfm?prid=2#data, www.eggbeaters.com/egg-substitute-products/original

Value-Added Eggs

Some eggs on the market are produced with the health of both the consumer and the laying hen in mind.

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NUTRIENT CONTENT

Eggs are an excellent source of many nutrients—**protein, fat, vitamins, minerals**, and water—and possibly beneficial nonnutrients—**choline, lutein, and zeaxanthin**—although they contain **very little carbohydrate or fiber**. An average large egg provides about **75 kcalories**, primarily from fat and protein.

Protein. One large egg contains approximately **7 grams** of complete, life-sustaining **protein**—4 grams from the white and 3 grams from the yolk. The quality of the protein in eggs is so high that it has become the standard by which researchers rate that of all other foods. As a result, egg protein is often used as a **reference protein**.

Fat. One egg yolk contains approximately **5 grams of fat**, predominantly in the form of triglycerides, phospholipids, and cholesterol. The fat is approximately 47% monounsaturated (2 grams), 37% saturated (slightly under 2 grams), and 16% polyunsaturated (slightly under 1 gram). Also available are eggs that are high in omega-3 (polyunsaturated) fatty acids, which are widely considered to be beneficial in the prevention of a variety of medical conditions, including heart disease and inflammatory disorders.

Cholesterol. Egg yolks are **high in cholesterol, averaging 186 mg in a large egg** (24). Though in the past, the American Heart Association recommended limiting dietary cholesterol to reduce heart disease risk, it has more recently concluded that there is insufficient evidence to determine whether reducing dietary cholesterol reduces blood cholesterol (16).

Vitamins and Minerals. Eggs are one of the few foods containing **all the fat-soluble vitamins—A, D, E, and K**. Certain **water-soluble B vitamins**, found primarily in the white, are also supplied by the egg in relatively high Reference Daily Intake (RDI) percentages: 25% of vitamin B_{12} and biotin, 15% each of riboflavin (vitamin B_2) and biotin, 12% of folate, and 11% of pantothenic acid.

In addition, eggs are a source of several **minerals, especially selenium, iodine, zinc, and iron**. Unfortunately, the iron in egg yolks is not very available because it binds to phosvitin, an egg protein that inhibits absorption.

Value-added eggs have special attributes because of their nutrient content or the conditions under which the hens are raised. For instance, eggs containing less cholesterol, more omega-3 fatty acids, or 300% more vitamin E can be achieved by special feeding practices. Other types of value-added eggs include those that have been laid by hens that are free roaming, cage free, or fed natural grains without animal products—a plus for animal-friendly egg eaters (13). Note, however, that these are marketing terms without official definitions.

TYPES OF EGGS

All poultry produce eggs. Although chicken eggs are frequently used in the preparation of foods, many other types of eggs—including quail, duck, goose, turkey, and ostrich eggs (Figure 12-6)—are usable and available. It's important to remember that these other egg varieties should always be well cooked because they are more apt to contain harmful bacteria.

FUNCTIONS OF EGGS IN FOODS

Eggs are often combined with other ingredients. Their unique ability to flavor, color, emulsify or thicken, bind, foam, interfere, color, coat, leaven, clarify, and prevent crystallization makes them nearly indispensable in cooking (Figure 12-7). They are often used for these purposes in prepared foods such as snacks, entrées, and processed meats (20). Some of these unique qualities of eggs are discussed next.

Emulsifying

Lecithin, found in egg yolks, is a natural emulsifying agent: one end of the molecule attracts water, while the other end is drawn to fat (1). Eggs thus help keep fat and water or other liquid compounds from separating, so they are often used to thicken and stabilize foods such as salad dressings, hollandaise and béarnaise sauces, mayonnaise, ice cream, cream puffs, and certain cakes.

Binding

The high protein content of eggs makes them excellent binders. Fish, chicken, vegetables, and other foods are often dipped in beaten egg and then rolled in breading, batter, flour, or cereal. During cooking, heat coagulates the eggs' protein, which then acts as an adhesive, binding the other ingredients to the surfaces of the cooked material. Egg also binds together mixtures such as meatloaf, meatballs, lasagna, and manicotti. When the mixture cooks, the egg proteins firm and stabilize, providing structural strength. Too much egg, however, can cause foods to become overly firm and dry.

Foaming

The capacity of egg whites to be beaten into a foam that increases to six or eight times its original volume is invaluable in food preparation (8). Egg-white foams are used to aerate and leaven a number of food products, such as puffy omelets, soufflés, angel food cake, sponge cake, and meringues.

The best eggs to use for an egg-white foam are fresh eggs because they have thick egg whites, which contribute to a stable foam. Older eggs have thinner whites, which beat to a larger volume but are less stable and may collapse during heating. Some food-service establishments use dried egg whites to achieve consistency when preparing egg foams.

Reference protein A standard against which to measure the quality of other proteins.

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FIGURE 12-6 Types of eggs.

CHICKEN EGGS

Standard Eggs
Most eggs sold to consumers are white-shelled chicken eggs that have not been fertilized. Brown-shelled chicken eggs are also available. The type of hen breed determines the color of the shell. Shell color does not influence the egg's quality, flavor, or nutrient value.

Fertile Eggs
Only fertilized eggs, usually identified by a red spot on top of the inner contents, can hatch into chicks (if incubated). Refrigeration stops the growth process. Fertilized eggs are not more nutritious than nonfertilized eggs. Fertilized eggs are actually removed from the eggs commonly sold to the consumer. Their disadvantage is that they are more costly to produce and do not store as well.

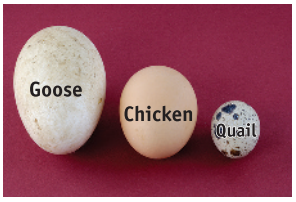
Free-Range Eggs
The USDA has no standard definition for "free-range" eggs except that the hens must "have access" to outdoor areas. One reason that these eggs are more expensive is because eggs from penned hens are easy to harvest, whereas more labor is required to obtain eggs from free-range birds that, like all birds, instinctively hide their eggs.

Organic Eggs
Commercial food for egg-laying hens cannot contain growth hormones. As a result, organic eggs are defined as those obtained from hens fed food ingredients that were grown without pesticides, herbicides, fungicides, or commercial fertilizers.

NON-CHICKEN EGGS



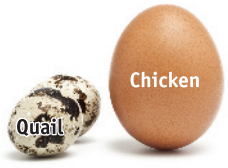
Duck Eggs
Because ducks need water, they are not as easily housed as chickens. As a result, harvesting of duck eggs does not lend itself well to mass-production techniques. Their eggs are also richer due to more than triple the cholesterol (619 g) and double the fat (10 g) content as compared with chicken eggs (186 mg cholesterol; 5 g fat). Historically, duck eggs are more commonly consumed in Asian than North American cuisine. Salted duck eggs and "1000 year old eggs" (a traditional Chinese delicacy of preserved eggs not more than 100 days old) are examples.



Goose Eggs
Larger and more flavorful than either duck or chicken eggs, goose eggs are also much higher in cholesterol (1,227 mg) and fat (19 g).



Ostrich Eggs
The largest of all eggs weighs about 3 pounds and is equivalent to about a dozen chicken eggs. Approximately 6 inches long and 5 inches wide, individual ostrich eggs are more a novelty than a common source of food for consumers.



Quail Eggs
These dainty, delicate eggs are often hard-boiled. They are used most often as gourmet garnishes or salad ingredients.



Turkey Eggs
Turkey eggs are bigger than chicken eggs but not as popular (primarily because of cost). The cost of turkey egg production is much higher because (1) the average chicken bred to produce eggs lays about an egg a day, whereas turkeys usually lay 1 egg every 3 days; (2) turkeys do not start laying eggs until they are about 10 weeks older than chickens are when they begin producing eggs; (3) chickens weigh only about 3½ pounds and eat less than turkeys, which weigh about 15 pounds; and (4) turkeys require more room.

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FIGURE 12-7 The functions of eggs in food preparation.

Food	Functions of Eggs
Cereal, grains, and pasta	
Noodles, pasta	Color, flavor, nutrition
Pancakes, crepes, waffles	Flavor, coagulation
Desserts	
Cakes, pastries	Foaming, coagulation, color
Candy	Inhibition of crystals
Custards, puddings	Coagulation, flavor
Doughnuts, croissants	Texture, flavor
Ice cream	Emulsification, texture
Egg dishes	
Meringues, soufflés	Foaming
Omelets, scrambled, poached	Coagulation, flavor
Fish products and meat	
Fish products (surimi)	Binding by coagulation
Meat (patties, sausages)	Binding by coagulation
Salad dressings	
Mayonnaise, salad dressing	Emulsification

The formation and stability of egg white foams also depend on a number of other factors: beating technique, temperature, type of bowl, careful separation of yolks and whites, and whether or not sugar, fluid, or acid have been added (26).

How & Why?

Why do beaten egg whites make a stable foam?

Vigorous beating or whisking of egg whites breaks the links between protein molecules, causing the protein molecule coil to unwind (to become denatured). A foam structure is created when the unfolded proteins rearrange to construct films around the air cells (3). When the airy foam is heated, its air cells further expand, after which the egg proteins coagulate, solidifying the egg protein to create a firm, stable structure, higher in height than the same food made without egg-white foam.

Beating Technique

Egg whites are best beaten with an electric mixer, but a wire whisk or a double-bladed rotary eggbeater can also be used. Whichever device is used, the key is to whip the egg whites into very fine, delicate bubbles. Figure 12-8 shows the consistency of the foam at the various stages of foam formation—foamy, soft, stiff, and dry.

At first, beating speed should be moderately slow and even. The foamy stage consists of very large air bubbles, but as the foam thickens, smaller, finer bubbles begin to appear. When the egg whites are half whipped and beginning to hold their shape, the beating speed should be increased to medium or fast.

Testing for Doneness

Testing for doneness consists of stopping, lifting the beaters or whisk out of the foam, and observing how the egg-white peaks form. Initially, the egg-white foam forms soft, shiny peaks that droop over without holding their shape, and the whipped foam slides around in the bowl. Beating should continue until the peaks are stiff and shiny but not dry. Whipping is complete at the stiff peak stage when the peak tips fall over slightly but keep their shape, and the whipped foam sticks to the side of the bowl. Perfectly beaten egg whites will pass the inverted bowl test; that is, they will cling to the inside of a bowl turned upside-down.

Avoiding Overwhipping

Excessive beating of egg whites results in peaks that stand tall, are dry, and are no longer shiny. In addition, the protein films surrounding the air cells rupture, creating bubbles that are too large and unstable. It is important to beat egg whites to the correct stage because both overbeaten and underbeaten foams will eventually collapse and separate into liquid pools at the bottom of the bowl.

Temperature

The bowl, beater, and eggs should be at room temperature. The decreased

FIGURE 12-8 Stages of foam formation.



(a) Foamy



(b) Soft peaks



(c) Stiff peaks



(d) Dry peaks

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surface tension of room-temperature egg whites allows them to whip more easily and to a larger volume than cold eggs. However, the stability of the foam deteriorates with continued exposure to room temperature. In addition, leaving eggs out for more than 30 minutes risks *Salmonella* growth. Eggs can be briefly submerged in a bowl of warm water before whipping, but this strategy is not highly recommended.

Bowl Selection

Deep bowls with rounded bottoms sloping up into the sides are best because they allow the egg whites to be picked up by the beater. Plastic bowls should be avoided because their porous surface may harbor a thin film of grease from previous usage, which could interfere with foam formation (12). Even the smallest amount of fat will interfere significantly with an egg white's ability to foam.

How & Why?

Why were copper bowls once commonly used to whip egg-white foams?

It was long a common chef's practice to use copper bowls made specifically for beating egg whites. A unique reaction between the copper and the egg whites occurs: trace amounts of copper from the bowl combine with an egg-white protein, conalbumin, allowing the air bubbles in the foam to expand to a larger size as they are beaten. Although copper bowls do improve the whipping properties of eggs, they are no longer recommended because of toxicity risks associated with excess dietary copper.

Separation of Eggs

Although fat contamination can come from plastic bowls or utensils, or from traces of cream, oil, butter, or other foods, the most common source is the egg yolk itself. Careful separation of the egg yolk and the white is imperative. Eggs can be separated using an egg separator, a small cup centered in a round frame. The central cup catches the yolk while slots around the frame let the white slip through to a container underneath (Figure 12-9). Another method is to break the egg into a clean funnel, which allows the white, but not the yolk, to run through. Egg yolk fragments are sometimes removed by using the egg's shell, which has an affinity for picking up traces of yolk remaining in the egg white; however, this method is not recommended because eggshells are a possible source of microbial contamination. For the same reason, eggs should not be separated by passing the yolk back and forth between the two shell halves.

FIGURE 12-9 Egg separator.



Lanzelot/Shutterstock.com

Additives

Sugar

Sugar stabilizes egg-white foam, but it also inhibits the mechanical coagulation of proteins necessary for foam formation. Therefore, it is best to add sugar near the end of the whipping time so volume is not compromised. One teaspoon of granulated or superfine sugar per egg may be added only after soft white peaks have formed. Egg white sweetened with sugar is less likely to be overbeaten and has a very fine texture with a smooth, satiny surface.

Fluid

Adding fluid to egg whites increases the foam volume up to 40% but decreases its stability.

Salt

Salt decreases the stability and volume of egg-white foam, so it is rarely added to egg whites.

Acid

Normally, whole eggs are relatively neutral in pH (7.0 to 7.6), but egg whites by themselves tend to be alkaline (about 8.4 pH). In fact, alkalinity increases with age as the loss of carbon dioxide increases the pH of the egg whites (up to 9.7) (2). Egg whites whip more easily into a stable foam when their pH is lowered slightly. Adding acid in the form of lemon juice or cream of tartar (the salts of tartaric acid) decreases the pH of egg whites, causing the egg proteins to become unstable and more likely to denature and whip into a foam. Adding too much acid, however, results in delayed foam formation and a much less stable foam. Proper acidity can be achieved by adding 1 teaspoon cream of tartar per cup of egg white, ⅛ teaspoon cream of tartar per egg white, or ⅛ teaspoon of lemon juice or white distilled vinegar per egg white.

Interfering

Eggs are often used in the preparation of frozen desserts such as ice cream because they interfere with the formation of ice crystals. Similarly, in some candies, eggs are used to block the formation of large sugar crystals to create a smoother, more velvety texture.

Clarifying

Egg whites are often used to **clarify** liquids by dissolving egg proteins, especially egg whites (albumen), in cold liquid, which is then heated. This causes the proteins to solidify, to attract other particles that may be clouding the liquid, and to rise with them to the surface for removal. This food preparation technique is used to make clear soups (see Chapter 15).

Color

An egg's yolk contributes a golden brown color to yellow cakes, cookies, pastries, and even rolls, breads, and egg-containing noodles.

PREPARATION OF EGGS

Eggs are extremely versatile and can be prepared alone or in combination with other foods (Figure 12-11). When eggs are the primary ingredient in a dish, it is best to use the highest quality (Grade AA or A) and those packed within 28 days of laying (19). Countless recipes that include eggs can be cooked by either dry-heat or moist-heat methods. Before these are discussed, a brief overview of the changes that can occur in prepared eggs is presented.

Clarify To make or become clear or pure.

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CALORIE CONTROL
Eggs—It's What You Serve with Them

- **Eggs Alone.** Eggs are relatively low in kcalories—only 75 for a large egg. That drops to 15 kcalories for the egg white if the yolk, with its 60 kcalories, is removed.
- **Portions Count.** Most people have at least two eggs at a time, and that adds up to 150 kcalories. A three-egg omelet would be 225 kcalories.
- **Breakfast Choices.** It's the foods consumed with eggs that really contribute to the total kcalorie count (Figure 12-10). Lower-kcalorie options include vegetable omelets, fresh fruit, and/or a small glass of vegetable or fruit juice with breakfast.

FIGURE 12-10 Kilocalorie content of three breakfast options.

Breakfast #1 = 526 kcalories

Danish (Large, 7 inches)



Breakfast #2 = 783 kcalories

Two eggs, sausage, and hash browns

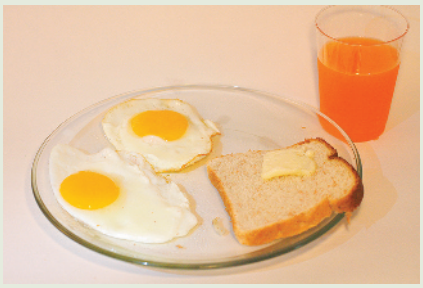
2 eggs = 180 kcalories (includes fat to fry)
2 sausage = 133 kcalories
1 cup hash browns = 470 kcalories



Breakfast #3 = 386 kcalories

Two eggs, toast, butter, and orange juice

2 eggs = 180 kcalories (includes fat to fry)
1 slice whole-grain toast = 60 kcalories
1 pat butter = 36 kcalories
1 cup orange juice = 110 kcalories



Courtesy of Amy C. Brown

FIGURE 12-11 Food preparation with eggs.

Eggs Prepared Alone:	
Fried	Waffles
Baked	Egg soup
Simmered	Cream puffs
Coddled	Mayonnaise
Poached	Quiche
Omelet	Fritatas
Scrambled	Popovers
Foods Prepared with Eggs:	
Eggs Benedict	Cake
Meringue	French toast
Deviled eggs	Egg sandwich
Pudding	Cream pies
Pancakes	Salad dressing
Egg salad	
Mousse	
Eggnog	
Soufflé	
Crepe	
Egg foo young	
Custard	

Changes in Prepared Eggs

Effects of Temperature and Time

The key to cooking eggs is to keep the temperature low and/or the cooking time short. Heating eggs at high temperatures and/or for long periods of time diminishes their texture, flavor, and color. Overheated proteins become tough and rubbery and shrink from dehydration, which is why overcooked scrambled eggs look curdled and feel dry and rubbery.

Coagulation Temperatures

Egg whites and yolks coagulate at different temperatures. Egg whites first start to coagulate at about 140°F (60°C) and become completely coagulated at 149 to 158°F (65 to 70°C). Slightly warmer temperatures of about 144 to 158°F (62 to 70°C) are needed for the egg yolks to start coagulating. This difference allows eggs to be cooked so their whites are firm, but the yolks remain soft. An egg may be cooked at 142°F (61°C) for an hour and still have a soft yolk. In addition, beaten eggs coagulate at a slightly higher temperature (about 156°F [69°C]).

Effects of Added Ingredients

Adding other ingredients to eggs changes their coagulation temperature. For example, incorporating milk into whole eggs in a custard dish increases the coagulation temperature to about 175°F (79°C). Sugar also increases the coagulation temperature, whereas the addition of salt and/or acid lowers it. Eggs can curdle if too much of an acidic ingredient, such as tomato or vinegar, is added.

Color Changes

Undesirable color changes may occur during egg preparation. Sometimes when eggs are overcooked or heated at too high a temperature, the sulfur in the egg white may combine with the

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iron in the yolk, the cooking water, or other iron sources to form ferrous sulfide, a green-colored compound with a strong odor and flavor. To eliminate the problem of "green yolk," it is best to use stainless steel equipment and low cooking temperatures, to avoid overcooking, to cool hard-cooked eggs quickly in cold water, and to serve them immediately. Another change in heated eggs, which is more difficult to prevent, is the slight browning that results from the Maillard reaction, in which egg proteins react with the few carbohydrates contained in the egg.

Dry-Heat Preparation

Dry-heat preparation of eggs primarily involves frying and baking. Egg dishes that are commonly fried are fried eggs, scrambled eggs, and omelets. Baked egg dishes include shirred eggs, meringues (both soft and hard), and soufflés.

Frying

A frying pan, a sauté pan (omelet pan), or even a griddle can be used to fry eggs. Cast iron pans work best for eggs if the pans are **primed** or **seasoned.** Priming is accomplished by rubbing a clean frying pan with a thin layer of vegetable oil and setting it on moderate heat, which is then briefly increased to high. Then it is removed from the heat and allowed to cool. Washing the frying pan with soap or cooking anything but eggs in it removes the primed surface. Nonstick pans do not need to be primed or seasoned. Frying is used to prepare fried and scrambled eggs and omelets.

Fried Eggs

For each fried egg, about 1 teaspoon or less of butter, margarine, or oil is added to a hot pan. Clarified butter can also be used; it will not burn like regular butter. To cut down on fat, a bit of fat may be spread on the pan's surface with a paper towel or waxed paper, or a vegetable spray may be applied to its surface before heating. Too little fat causes sticking, but excessive fat will result in greasy eggs. The fat should be hot enough to prevent the eggs from running, but not so hot that it toughens the egg proteins. The temperature is just right when a drop of water dropped into the pan sizzles instead of either rolling around or instantly vaporizing into the air.

Yolks are less likely to break open when the eggs are cracked if the eggs are allowed to warm very briefly in a bowl of hot water. Broken yolks can also be avoided by using fresh eggs and/or by first breaking the eggs into a bowl or other container rather than dropping them directly from the shell into a frying pan or griddle. Then, after the pan and the fat have been heated to the right stage, the eggs should be slid from the bowl, no more than two at a time, onto the pan or griddle. The heat should be lowered immediately to medium-high.

Coagulation is then allowed to occur according to the following "cook-to order" stages:

- ***Sunny-side up.*** The egg is cooked until the white is set and the yolk is still soft. The egg is not flipped. Sunny-side up eggs may not be sufficiently cooked to eliminate bacteria, and thus some state health departments do not allow them to be served to the public. Covering the pan with a lid during cooking gives the yolk a rather opaque appearance but eliminates any risk of an undercooked egg.
- ***Over easy.*** The eggs are flipped over when the whites are 75% set. Cooking continues until the whites are completely cooked, but the yolks are still soft.
- ***Over medium.*** The same as over easy, except that the yolks are partially set.
- ***Over hard.*** The same as over easy, except that the yolks are completely set.

Scrambled Eggs

Scrambled eggs are beaten while raw until well blended and may be seasoned with salt and pepper or other seasonings. Liquid in the form of milk, cream, or water may be added to impart more body and/or flavor and a soft, creamy texture. The added liquid, a tablespoon or less for each egg, creates steam during cooking, which lifts the eggs and makes them lighter and fluffier. Too much liquid makes the eggs watery and forms small, tough, curd-like masses.

The beaten egg mixture is poured onto a heated surface, the heat is reduced, and the eggs are gently stirred as soon as they begin to coagulate. Too much stirring will break the egg into too many small pieces, so it is better to lift the cooked egg repeatedly with a spatula so the undercooked portions may slide underneath rather than literally to stir them. Scrambled eggs are finished cooking when they are set, yet still soft and moist. Like most egg dishes, they are best when served immediately. In restaurants or when cooking for large crowds, it is recommended that scrambled eggs be prepared in small batches, generally 3 quarts or less at a time (19).

Omelets

When eggs are beaten, cooked, and rolled into a cigar shape or folded into a flat half circle, the resulting dish is called an omelet. Both plain (French or American-style) and puffy (fluffy) omelets can be prepared with or without fillings. Omelet preparation is considered so important by chefs that it is not unusual for a job applicant to be asked to chop an onion and make an omelet as part of the interview process.

Plain omelets consist of whole eggs, beaten, seasoned as desired, and poured into a prepared pan heated to medium-high. After the mixture is in the pan, the heat is lowered to medium, and the mixture is not stirred. Uncooked portions are allowed to cook by lifting just the edges of the omelet with a spatula so the runny mixture flows underneath. When the top is firm, the omelet can be folded in half, rolled and folded over itself, or rolled and slid onto a dish (Figure 12-12). If fillings are to be added, they are placed on top of the omelet just before it is folded.

There are many opinions about how French and American omelets differ, but here are four basic differences:

- French omelets are never allowed to brown, whereas American omelets may have some color.
- French omelets never have texture lines, whereas an American omelet may have a few.
- Folding a French omelet occurs in three steps (fold left over center, fold right over center, and then turn the omelet out onto the plate folded side down) or complete rolling (like a rug), whereas American omelets are simply folded in half.
- The center of a French omelet is soft, whereas American omelet centers are fully cooked.

Prime (season) To seal the pores of a pan's metal surface by coating the pan with a layer of oil and then heating it.

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FIGURE 12-12 Omelet preparation.



(a) With wire whisk, beat eggs with salt and water just until well mixed but not too frothy.



(b) Slowly heat a 9-inch skillet or omelet pan to medium heat. Temperature is correct when drops of cold water sizzle and roll off the pan's surface. Add butter and heat until it sizzles but is not yet brown. Gently pour the egg mixture into the heated pan.



(c) As egg mixture begins to set, use a spatula to push mixture back and allow unset egg to run onto pan's surface.



(d) Continue loosening and tilting until omelet is almost dry on top and golden-brown underneath.



(e) Add filling ingredients, and fold omelet over itself.



(f) Tilt the pan, and use the spatula to slide omelet onto a plate.

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The fluffiness of puffy omelets is achieved by separating the yolks from the whites and whipping each portion separately. Seasonings and liquid, if added, are incorporated into the whipped yolks. The egg whites are whipped until stiff but not dry and then gently folded into the yolks. This mixture is poured into a preheated omelet pan or suitable frying pan with sloping sides, and the heat is reduced to medium. When the omelet is browned on the bottom, it is placed in a 350°F (177°C) oven for 5 to 10 minutes to allow additional rising and further coagulation of the surface proteins. The omelet is finished cooking when the top springs back from a gentle touch of the finger.

Baking

Shirred Eggs

Whole eggs that are baked and served in individual dishes are called shirred eggs. The egg is cracked, gently placed into a cup from which it can be rolled into a container coated with butter or margarine, and then baked in an oven at 350°F (177°C) until cooked to order.

Meringues

A meringue is an egg-white foam used in dessert dishes as a pie topping, a cake layer, or a frosting. It may also serve as a dessert on its own or be combined in other ways with dessert ingredients. Meringues are made by whipping egg white into foam and adding sugar; the amount of sugar determines whether the meringue is soft or hard.

Soft meringues are made with about 2 tablespoons of granulated (preferably superfine because it dissolves faster) sugar per egg white and are often used as pie toppings (e.g., in lemon meringue pie). The sugar is gradually added to the egg whites—three will cover an average pie—in the later stages of whipping the mixture to the soft peak stage. The meringue is then spread immediately over the still-warm filling. A warm filling is necessary so the egg-white proteins can coagulate and bind to it. The whole pie with the meringue is then baked in the oven at between 325°F (163°C) and 350°F (177°C) for about 15 minutes. A temperature that is too low dries the meringue; a temperature that is too high shrinks it.

Some problems that can occur when preparing soft meringues are shrinking, **weeping** and **beading:**

- ***Shrinking.*** To prevent the meringue from shrinking back and leaving an unsightly gap around the outside edges of the pie, it should be spread to slightly overlap the entire perimeter of the crust.

Weeping (syneresis) Extraction of liquid from a gel. An example is the escape of liquid to the bottom of a meringue or the formation of pores filled with liquid within a meringue.

Beading The formation of tiny syrup droplets on the surface of a baked meringue.

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- ***Weeping.*** Also known as **syneresis,** weeping may be caused by underbeating the eggs, which leaves unbeaten whites on the bottom of the beating bowl, or by undercoagulation, created, for example, by placing meringue on a cold pie filling. A meringue can be protected from weeping by adding a teaspoon of cornstarch to the sugar before beating it into the egg whites.
- ***Beading.*** Undissolved sugar is the main cause of beading, but overcooking (overcoagulation) also contributes to this phenomenon. Beading can be avoided by using shorter cooking times and increasing the temperature up to 425°F (218°C).

Hard meringues are usually baked as cookies, but they can also be formed into different shapes and used as decorations on puddings or other desserts. They are prepared with twice the amount of sugar used in soft meringues, about 4 tablespoons (¼ cup) per egg white. Confectioner's sugar is preferred over granulated sugar for use in hard meringues because it is more evenly distributed through the beaten egg whites, lacks a gritty texture, and results in a lighter meringue. Egg whites are beaten to the stiff stage, the sugar is beaten in, and the resultant meringue is shaped, placed on a parchment-covered baking sheet, and baked at the low temperature of 225°F (107°C) for about an hour or longer, depending on the size of the individual portions. When the meringue is delicately browned and the end product firm, the oven is turned off, the door left open, and the meringue left in the cooling oven for at least 5 minutes. After the meringue is removed from the oven, the remainder of the cooling period should occur in a warm place free of drafts.

Soufflés

A soufflé is actually a modified omelet. The main ingredients of a soufflé are a thick base generally made from a **white sauce** or pastry cream, an egg-white foam, and flavoring ingredients. Initially, the egg yolks and whites are separated. A thick white sauce or pastry cream is prepared and combined with the egg yolks. Stiffly beaten egg whites are folded into the thick egg yolk mixture.

When combining beaten egg whites with a heavier mixture like this one, it is best to pour the heavier mixture onto the beaten egg whites. Then gradually, using a spoon or rubber spatula, combine the ingredients with a downward stroke into the bowl, across, up, and over the mixture. Come up through the center of the mixture about every three strokes, and rotate the bowl during folding (Figure 12-13). Fold just until there are no streaks remaining in the mixture. Avoid stirring, which will force air out of the egg whites.

For a main-dish soufflé, flavoring ingredients such as diced or grated cheese, cooked meat, cooked seafood, and/or vegetables and seasonings are added to the egg mixture. Dessert soufflés will include sweet ingredients such as sugar, chocolate, or fruit, but the process is the same. Whichever the type of soufflé, the entire combination is gently poured into a lightly greased soufflé dish or other deep baking dish, placed in a larger pan of hot water, and baked in a moderate (350°F [177°C]) oven for 50 to 60 minutes or until delicately browned and firm to the touch. Small, individual soufflés will take less time. The oven door should not be opened during baking until time to check for doneness because it creates a draft that can cause the soufflé to fall. Doneness is determined by gently shaking the oven rack. If the center jiggles, even slightly, more baking time is required.

FIGURE 12-13 Folding egg whites.



Duffas, Marcel/AGE Fotostock

White sauce A mixture of flour, milk, and usually fat.

Moist-Heat Preparation

Eggs can be prepared by moist heat using a variety of methods. Most common among the resulting dishes are "boiled" eggs, coddled eggs prepared in a cup, poached eggs, a variety of custards, and eggs that are prepared using the microwave. In all cases, eggs are cooked at simmering temperatures (see Chapter 5). Each of these methods and some of the egg dishes produced are discussed in more detail next.

Hard or Soft "Boiling"

Although the term *hard-boiled egg* is commonly used, eggs should actually be simmered and never boiled because they will become tough and rubbery if so treated (11). The high heat of boiling also transforms the iron in the egg yolk into ferrous sulfide, causing the greenish-black color and unpleasant flavor found in the yolk of overcooked hard-boiled eggs (Chemist's Corner 12-2).

There are two methods for hard-cooking eggs: hot start and cold start. Each has advantages and disadvantages, and each produces acceptable products.

Hot-Start Method

In the hot-start method, the water is heated to boiling, and then the eggs

CHEMIST'S CORNER 12-2

Yolk Color in Boiled Eggs

The green "ring" around the yolk is from the sulfur in the egg. Egg whites contain sulfur in the form of hydrogen sulfide gas. When eggs are overcooked or under the high pressure of boiling, this gas moves from the egg white to the yolk. There it combines with the iron in the egg yolk to form ferrous sulfide, resulting in a greenish ring around the yolk and a characteristic off-odor. Under reduced pressure, however, the gas moves away from the yolk toward the shell. The green discoloration in hard-cooked eggs can thus be avoided by dipping them in cold water immediately after boiling; the rapid temperature drop lowers the pressure within the egg, and the hydrogen sulfide gas does not enter the yolk.

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are completely immersed in the boiling water. The heat is immediately reduced to simmer, and the eggs are cooked for 3 to 15 minutes, depending on the desired doneness:

- **Soft:** 3 to 4 minutes
- **Medium:** 5 to 7 minutes
- **Hard:** 12 to 15 minutes

The cooked eggs are drained and then rinsed under cold running water to stop further cooking from residual heat. The extreme temperature change from hot to cold also helps loosen the egg's membrane from the shell, making it easier to peel. To further ease peeling, the first crack should be made at the air cell located at the larger end of the egg, and then the egg rolled gently between the hands to break the shell all over. Peeling under cold running water also makes the job easier. Fresher eggs are harder to peel because the air cell is smaller and the membrane is tight against the cell wall. Older eggs, in contrast, are easier to peel because of their larger air cell and higher pH, but they also tend to break more easily during heating.

The benefits of using the hot-start method are greater temperature control, eggs that are easier to peel, and a shorter total cooking time. A drawback is that lowering the eggs into boiling water may cause them to crack.

How & Why?

Why do boiled eggs sometimes crack?

Eggs crack because the pressure created by fast-heating water pops the shell. Although simmering hard-cooked eggs makes them prone to cracking, this can be avoided by first warming eggs to room temperature in a bowl of warm water. Another way to reduce the chances of cracking is to push a sterilized pin or needle through the large end of the shell where the air cell is located. To reduce cracking still further, a spoon or other utensil may be used to place the eggs gently in the water.

Cold-Start Method

In the cold-start method, the eggs are placed in a saucepan with enough cold water to cover them by at least an inch. The water is brought to a boil, then immediately lowered to a simmer, and the eggs are then cooked to order:

- **Soft:** 1 minute
- **Medium:** 3 to 5 minutes
- **Hard:** 10 minutes

Another way to prepare hard-cooked eggs from a cold start is to remove the pan from the heat as soon as the water boils, cover it tightly, and let it stand for 20 minutes.

The advantages to the cold-start method are that less attention to the process is required, the eggs are easier to add to the water, and they are less likely to crack during cooking. On the other hand, starting eggs out in cold water may cause the egg white by the shell's surface to be more rubbery, and there is a greater chance of a greenish tint forming on the egg white.

How & Why?

Why is vinegar added to boiling water when cooking eggs?

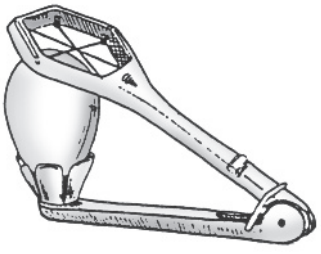
Vinegar is often added to the water used to hard-boil eggs. There are two reasons for this. First, the acid in the vinegar dissolves the external surface of the shell, making it easier to peel away. Second, if the egg cracks while boiling, the vinegar will encourage the egg white to harden, preventing the entire egg from leaking out into the water.

Once cooked, eggs can be cut into slices or wedges using the equipment shown in Figure 12-14. Dipping the knife in hot water before slicing keeps the hard-cooked eggs from falling apart. To tell a hard-cooked egg from a raw one, spin the egg on its side. A smoothly spinning egg is hard cooked, while one that wobbles out of balance is not.

FIGURE 12-14 Egg-cutting tools.



Slicer A device that cuts a hard-cooked egg into neat slices with one swift stroke.



Wedger Similar to a slicer, but it cuts the egg into six equal wedges rather than into slices.

Coddling

Coddled eggs are prepared by breaking an egg into a small cup, called a coddler, made of porcelain or heat-proof glass with a screw-on top, and submerging the whole coddler in simmering water until the egg is cooked. The coddler should be buttered or greased before adding the raw egg. Cream or other flavorings such as ham or bacon are sometimes added before cooking. Once done, the egg is eaten directly out of the coddler.

Poaching

Eggs are poached by being cracked into and simmered in enough water to cover the egg by at least twice its depth. Fresh USDA Grade AA eggs are best to use for poaching because the whites are firmer and less likely to spread out in the water and create *streamers*, floating strands of partially cooked egg whites. Salt (½ teaspoon per cup) and/or vinegar (1 teaspoon per cup) may be added to the water to speed coagulation and help to maintain a compact, oval shape of the egg. On the other hand, salt or vinegar will give the cooked egg a shinier, tougher, and, perhaps, more shriveled surface than one cooked in plain water. Poached eggs are cooked for 3 to 5 minutes, removed with a slotted spoon, drained, trimmed of any streamers, and served immediately. The well-poached egg should have a firm yolk and compact white. Poached eggs are commonly used for eggs Benedict, which consists of an English muffin layered with a slice

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of ham or Canadian bacon, followed by a poached egg, and topped with a dollop of hollandaise sauce.

Custards

Custards are mixtures of milk and/or cream, sweeteners (sugar, honey), flavorings (vanilla, nutmeg, etc.), and eggs or egg yolks. Custards are thickened by the coagulation of egg proteins during cooking. These egg proteins denature when heated and recombine to form a network that sets or coagulates, at the right temperature, to form the solid gel of a custard. All custard dishes are very susceptible to microbial contamination and should be covered and refrigerated as soon as possible after preparation.

Custards are distinguished by whether they are sweet or savory, as well as by their preparation method: stirred or baked.

Sweet and Savory Custards

Sweet custards are served as desserts in the form of puddings or as fillings for éclairs and pies. Savory (nonsweet) custards are used for dishes such as quiches. A popular quiche made with bacon and Swiss cheese is known as quiche lorraine.

Stirred Custard (Soft Custard or Custard Sauce)

The ingredients of this custard are stirred while being heated on the range over low heat or in a double boiler. The mixture retains a smooth, creamy, fluid consistency. Stirred custard is often eaten as a pudding; however, it may provide the base for many frozen desserts; be served as a sauce for cake, fruit, and other desserts; or be used to replace eggnog. The repeated stirring prevents the formation of a gel, so the custard mixture thickens rather than gels.

Baked Custard

Baking a custard is, in fact, an example of dry-heat preparation. Stirred and baked custards begin with the same ingredients; they are simply heated differently. Baked custard mixes are poured into ungreased custard cups that are placed in the oven, usually in a water bath (bain-marie), where they sit undisturbed and gel during baking. A water bath is made by filling a large, low-sided pan with 1 inch of hot water into which the cups containing the custard mix are placed. The layer of water insulates the cups and prevents the outside of the custard from cooking to completion before the inside has had a chance to coagulate.

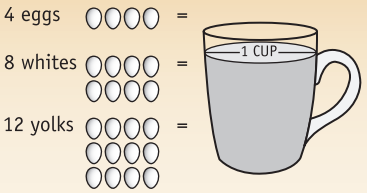
The internal temperature of custards should never be allowed to rise above the point of coagulation of the egg–liquid mixtures (185°F [85°C]). Overheating causes the egg proteins to shrink, allowing liquid to be released from the egg and producing a product with a curdled, weepy, porous appearance. Another problem with baked custards is that they tend to have a runny texture, which makes them unsuitable for making solid pie fillings. As a result, custards to be used as pie fillings are often thickened with starch in the form of cornstarch or flour.

Custards should be baked at 350°F (177°C) until a knife inserted in the middle of the cup comes out clean—about 23 to 25 minutes for custard cups and 35 to 40 minutes for a casserole-size dish. Just before it is completely done, the custard is removed from the oven and placed on a rack. Some additional cooking will inevitably occur during cooling but can be minimized by using a cooling rack. If the custard overcooks, the cups can be set in ice water to stop further coagulation. Undercooking should likewise be avoided because it will prevent the custard from setting properly.

How & Why?

How many large eggs in a cup?

FIGURE 12-15 How many large eggs are in a cup?



Microwaving

Eggs cook extremely rapidly in a microwave oven, so special caution should be taken to avoid overcooking. Manufacturer's instructions should be followed for microwave egg cooking. Whole eggs with intact shells should never be microwaved because steam expanding within the shell can cause them to burst. The same principle applies to whole eggs out of the shell because the vitelline membrane around the egg yolk traps steam and will burst if not punctured with a toothpick or the tip of a knife prior to going into the microwave.

Fried

A browning dish is required to fry an egg in a microwave and should be preheated on full power for 2 minutes, plus 1 additional minute for each egg being fried. About ½ teaspoon or less of fat per egg is melted in the dish before adding the cracked eggs from a bowl into the dish. The yolk membrane is punctured, and the dish is covered with plastic wrap, then microwaved on high for 45 seconds per egg or until the desired doneness is reached.

Shirred

Shirred eggs are cooked in individual containers and thus ideal for cooking in a microwave oven. The egg is placed in a custard dish, the yolk is punctured, the dish is covered, and the egg is heated on medium for 45 to 60 seconds. It should be rotated a quarter turn at the half-minute mark.

Scrambled

To prepare for scrambling, 1 teaspoon of butter is melted in a 2-cup glass measure by setting the microwave very briefly on high. The beaten eggs are placed in the measuring cup and microwaved on high for 20 seconds. The egg mixture is then stirred, and the heating and stirring process is repeated one or two more times. Microwaving is completed when the eggs are just past the runny stage. They should be allowed to stand 1 or 2 minutes if a firmer set is desired.

Poached

To poach an egg, ¼ cup of water, with a dash of vinegar and salt, is heated to a boil in a custard dish or 1-cup glass measure. The egg is dropped into the hot water, and the yolk is pierced with a toothpick. The dish is partially covered with plastic wrap and then heated at 50% power for 1 minute, plus or minus 15 seconds. Allowing the cup to stand 2 to 3 minutes and gently shaking back and forth help to set the egg whites.

Omelet

Omelets can be prepared in the microwave by using a browning dish or 9-inch pie plate. Enough butter is added to

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slightly coat the bottom of the dish. It is melted on high and then spread evenly by tilting the container. The combined eggs, liquid, and seasonings are then poured into the container, covered with plastic wrap, and cooked on medium for 2 to 3½ minutes, or until the omelet is almost set. After the omelet is removed from the oven, any fillers are added, and the omelet is folded over with a spatula. Puffy omelets are prepared in the same manner. An omelet cooked in a microwave will not brown unless a browning dish is used.

Quiche

A quiche dish or pie shell is filled with cooked vegetable and/or meat ingredients. Cream (preheated, unlike the cream in conventionally cooked quiches) is added to the beaten eggs, and the egg mixture is then poured over the vegetables and baked according to the manufacturer's guidelines.

STORAGE OF EGGS

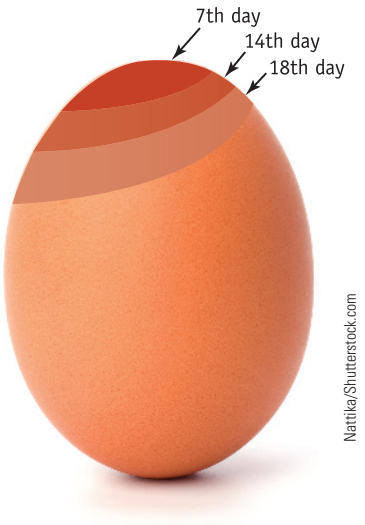
Eggs begin to deteriorate as soon as they are laid and lose quality very rapidly at room temperature. In fact, an egg will age more in 1 day at room temperature than in 1 week in the refrigerator. To ensure the freshness of whole or liquid eggs, they may be refrigerated, frozen, or dried. Proper storage is critical for eggs because they contain all the nutrients necessary to support the growth of a bird—or a microbe. Their nutrient content, especially water and protein, is ideal for bacterial growth and for this reason, eggs should always be stored properly.

Refrigerator

Whole Eggs

An eggshell is not airtight. There are as many as 17,000 tiny pores over the shell's surface, so keeping eggs in the carton and refrigerated helps retain their freshness. Several signs distinguish fresh from aged eggs. Changes in proteins over time cause egg whites to thin. Fresh eggs also have more prominent, viscous chalazae on either side of the yolk than older eggs. In the process of aging, the vitelline membrane weakens, and the yolk migrates or breaks (10). The size of an egg's air cell provides another indication of its age (Figure 12-16). The air cell gap between the membranes increases in size as the egg ages because moisture and carbon dioxide escape through the porous shell.

FIGURE 12-16 The size of the air cell sac increases as eggs age.



Proper refrigeration of eggs helps to delay these changes and protects them from microbial growth, thus helping to maintain their quality. Many home refrigerators have built-in egg containers, but eggs retain their moisture better and keep longer if stored in the carton. It also helps prevent flavors and odors from being absorbed through their porous shells. Eggs should be stored in dry conditions, so damp cartons should not be used. Individual eggs should sit in the carton with their large ends up to prevent the air cell from moving toward the yolk (19). Washing eggs is not recommended because this will remove the oil coating applied by the processor to prevent microbial growth and moisture loss.

Shelf Life of Refrigerated Eggs

Refrigerated whole eggs should stay fresh for about 1 month even though the recommended storage time is 1 week. Separated egg yolks may be stored submerged in water in the refrigerator but should be used within 2 days. Egg whites kept tightly covered in a glass container will last up to 4 days. When multiple cartons of eggs are purchased, the eggs should be used according to the "first in-first out" method—meaning that the oldest eggs are used first (19).

Storage Eggs

Restaurants, food-service institutions, and other food manufacturers must be especially careful about storing eggs because they purchase such large quantities. **Storage eggs,** available to commercial food-service establishments but not sold at the retail level, are usually used within a month but can be stored for up to 6 months. Storage eggs have a coating of oil or plastic that prevents microbial invasion and any loss of moisture or carbon dioxide.

Pasteurized Eggs

USDA regulations require that all liquid, frozen, or dried eggs be pasteurized or otherwise treated to protect against *Salmonella*. Commercial outlets frequently use refrigerated liquid eggs that have been pasteurized. Typical processed food products that may incorporate pasteurized liquid egg whites include baked goods, candies, and chilled or frozen desserts. After they are pasteurized, the advantages of liquid eggs over whole eggs or even frozen egg blends are convenience, consistent quality, microbial safety, and costs savings in terms of space, labor, and freezing (22). New to the market are eggs pasteurized in their shells that are being marketed to the consumer (14).

Frozen

Freezing a whole egg is not possible because the expanding liquids will cause it to crack. Food manufacturers solve this dilemma by breaking the eggs open at the processing plants, where the contents are frozen whole (whites and yolk mixed together) or separated as whites or yolks. Prior to being frozen, the liquid whole eggs are usually pasteurized (140 to 143°F [52 to 55°C] for 3½ minutes). Egg whites by themselves denature if pasteurized, so prior to this process, they are often combined with a small amount of lactic

Storage eggs Eggs that are treated with a light coat of oil or plastic and stored in high humidity at low refrigerator temperatures very close to the egg's freezing point (29 to 32°F [−1.5 to 0°C]).

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CHEMIST'S CORNER 12-3

Egg Pasteurization

Aluminum sulfate is sometimes added to egg whites prior to pasteurization to stabilize conalbumin, an egg protein that is labile (unstable) to heat at pH 7.0. Most of the other egg proteins are stable to heat at this pH.

acid and aluminum sulfate (Chemist's Corner 12-3). There are several drawbacks to using frozen pasteurized eggs: they are costly to freeze and keep frozen, they must be thawed, they are cumbersome to portion, and they have lowered functional quality (9).

Fortunately, separated egg whites are not adversely affected by freezing. Some commercially frozen egg whites have added stabilizers and whipping aids to improve their ability to form large, stable foams. For separated yolks, about 10% (by weight) sugar, corn syrup, or salt is added to prevent them from becoming viscous and rubbery when thawed. Salt is used in frozen eggs only if they will be incorporated into sweet foods that will partially mask the salty taste. When freezing eggs at home, 1 tablespoon of sugar (corn syrup) or ½ teaspoon of salt is added for every cup of blended eggs. Raw egg whites can be frozen with no special measures taken.

Dried

Drying eggs is a simple process. Whole eggs or separated yolks are spray-dried to create a fine powder, which is mixed with anticaking substances to prevent clumping. Egg whites are dried in different ways to form granule, flake, or milled textures. Dried eggs sometimes brown because of the Maillard reaction, but this can be prevented by removing glucose from the eggs before drying with the aid of an enzyme (glucose oxidase) or by yeast fermentation. Once dried, eggs can be stored in the refrigerator for up to a year, but they must be kept in tightly closed containers to prevent the clumping that can result from moisture accumulation.

Dried eggs, used extensively by food manufacturers, are particularly advantageous when storage and refrigeration space is limited. The major disadvantage of using dried eggs is that they lose many of the functional and sensory qualities of eggs and are highly susceptible to bacterial contamination. Therefore, they should be used only when the end product will be thoroughly heated.

Rehydrating Dried Eggs

Dried eggs are used in food preparation by adding them to water or by sifting them with dry ingredients. One egg can be reconstituted by sprinkling 2 tablespoons plus 1½ teaspoons of sifted egg powder over an equal amount of lukewarm water and beating until smooth. Combining ½ cup each of sifted egg powder and water produces the equivalent of three eggs. The mixtures should be used within 5 minutes. Table 12-5 lists the amount of frozen, refrigerated, or dried eggs needed to substitute for regular large eggs.

Safety Tips

The chances of an egg being internally contaminated are relatively low, less than 1 in 10,000 commercial eggs (17). It is more common for contamination to occur during handling and preparation after the egg has been removed from its shell. Even so, eggs are an excellent breeding ground for microbes and can become internally contaminated from a hen with a *Salmonella enteritidis* infection in her ovary or oviduct (27), or by absorbing bacteria through the pores. The latter can occur if the eggs are boiled and then cooled in the presence of infected water or an infected food handler. Externally, the eggs may also be exposed to *Salmonella enteritidis* by fecal contamination during egg laying. The Centers for Disease

TABLE 12-5 Substituting Frozen, Refrigerated, or Dried Eggs for Regular Large Eggs

Frozen or Refrigerated Liquid Eggs	Weights	Volume
Whole large eggs:		
1	1¾ oz	3 Tbsp
10	1 lb 1¾ oz	2 C
12	1 lb 5½ oz	2½ C
25	2 lbs 13 oz	1 qt 1¼ C
50	5 lbs 8 oz	2 qt 2½ C
Yolks:		
10	7¼ oz	¾ C
12	8½ oz	¾ C 2 Tbsp
22	1 lb	2 C less 2 Tbsp
Whites:		
10	11½ oz	1¼ C 2 Tbsp
12	14 oz	1½ C 2 Tbsp
14	1 lb	2 C less 2 Tbsp

Dried Eggs (whole, large)	Weight/Volume	Water (to reconstitute dried eggs)
6	3 oz (1 C)	1 C
12	6 oz (2 C)	2 C
24	12 oz (1 qt)	1 qt
50	1 lb 9 oz (2 qt and ⅓ C)	2 qt and ⅓ C
100	3 lb 2 oz (2 qt and ⅔ C)	1 gal and ⅔ C
150	4 lb 11 oz (6 qt and 1 C)	6 qt and 1 C
200	6 lb 4 oz (2 gal and 1⅓ C)	2 gal and 1⅓ C

Source: American Egg Board

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Control and Prevention identifies eggs as the major source for *Salmonella enteritidis* outbreaks (27), and there is an increasing possibility that *Listeria monocytogenes*, which can grow at refrigerator temperatures and has already been observed on whole eggs, may also contribute to future outbreaks (21). This section describes the many precautions recommended by the FDA that can be taken to prevent foodborne illness from eggs (7).

Purchase

- Only buy refrigerated eggs. Refrigerate promptly after purchase or during preparation.
- Open the carton to make sure eggs are clean and not cracked.
- Store eggs in their original container.
- Use within 3 weeks for best quality.

Preparation

- Cook eggs until no visible liquid egg remains, especially when preparing French toast, scrambled eggs, poached eggs, and omelets.
- Do not add raw egg to already scrambled eggs, a practice sometimes used in food-service operations to increase the moisture content of dried scrambled eggs.
- Use an egg separator rather than passing the yolk back and forth between the two shell halves or fingers.
- Ensure that eggshells are not left in food products, as this can be potentially hazardous (19).
- Bake egg dishes such as quiches, baked custards, and most casseroles until an inserted knife comes out clean.
- Hold scrambled eggs served via cafeteria and buffet lines at appropriate temperatures.
- Be extra cautious when preparing lightly cooked egg dishes such as mousse, meringue, and other similar dishes because they may not be sufficiently cooked to eliminate possible bacteria.
- The USDA recommends that consumers heat all egg dishes to 160°F (71°C). The Food and Drug Administration (FDA) suggests that commercial food establishments heat eggs to a final temperature of 145°F (63°C) for at least 15 seconds.

Consumption

- Serve cooked eggs immediately after cooking.
- Never leave cooked eggs out more than two hours, or more than 1 hour if temperatures are above 90°F (32°C).
- Raw eggs or undercooked eggs should never be consumed; this holds especially true for people who are very young, very elderly, or immunocompromised (by conditions such as AIDS, cancer, etc.).
- Use pasteurized egg products or eggs treated to destroy *Salmonella* in recipes that call for eggs that are lightly cooked or not cooked at all, such as Caesar salad dressing, uncooked hollandaise or béarnaise sauce, and homemade items such as mayonnaise, eggnog, and ice cream (25).

Storage

- Always store eggs in the refrigerator, never at room temperature. Meringue-covered pies and other egg-containing foods should be refrigerated until served.
- Unopened liquid egg products can be stored for up to 7 days. Once opened, they should be used or discarded within 3 days.
- Dried egg mix should be used within 7 to 10 days of opening and should be stored at a temperature of less than 50°F (10°C) (19).
- Cold egg dishes should be stored below 40°F (4°C); hot dishes should be kept above 140°F (60°C) for up to ½ hour, or 1 hour on a buffet, according to the USDA (19).

The USDA provides more information about egg safety online (www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/egg-products-preparation/egg-products-and-food-safety/CT_Index and www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/egg-products-preparation/shell-eggs-from-farm-to-table/CT_Index).

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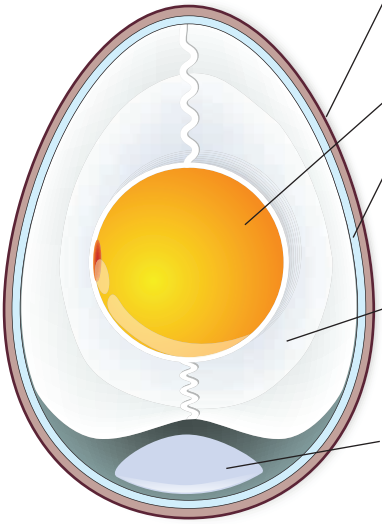
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PICTORIAL SUMMARY / 12: Eggs

As a life-sustaining protein, egg protein is so high in quality that it has become the standard (reference protein) by which researchers rate all other food proteins. The versatility of eggs, whether prepared alone or in combination with other foods, makes them nearly indispensable in cooking.

COMPOSITION OF EGGS



Shell: 12% of the egg's weight; porous calcium carbonate.

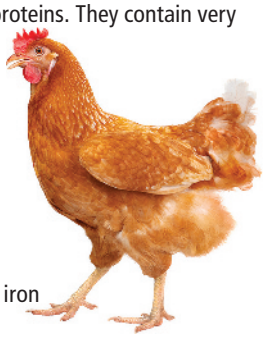
Egg yolk: 30% of the egg's weight; dense in nutrients.

Shell membranes: inner and outer membranes protect the egg against bacterial invasion.

Albumen (egg white): 58% of the egg's weight; four layers, composed largely of water and protein.

Air cell: located between the two shell membranes at larger end of the egg; becomes larger as egg ages.

Nutrient Content: Eggs are one of the very few foods containing all the fat-soluble vitamins (A, E, D, and K) and large amounts of certain water-soluble vitamins. Eggs contain all the essential amino acids, making them a good source of complete proteins. They contain very little carbohydrate or fiber.



A large egg contains:

- Kilocalories: 75
- Protein: 7 grams
- Fat: 5 grams
- Cholesterol: 186 mg
- Vitamins: A, D, E, K, and several B vitamins
- Minerals: selenium, iodine, zinc, iron

PURCHASING EGGS

Inspection of processing plants producing egg products is mandatory. Candling, Haugh units, and appearance are used to determine quality grades. Size, unrelated to grading, is determined by the weight of a dozen eggs.



TYPES OF EGGS

Chicken egg forms include standard (unfertilized white or brown), fertile, free-range, and organic. Non-chicken eggs include duck, goose, ostrich, quail, and turkey.

FUNCTIONS OF EGGS IN FOODS

When combined with other ingredients, eggs have a unique ability to flavor, color, emulsify or thicken, bind, foam, interfere, and clarify.

- **Emulsifying:** Lecithin, found in egg yolks, keeps liquid compounds (e.g., fat and water) from separating, thus thickening and stabilizing foods such as sauces and salad dressings.
- **Binding:** The abundant protein in beaten eggs can act as an adhesive when cooked. Examples are egg used with breaded, fried foods and the addition of eggs to bind meatloaf.
- **Foaming:** Egg whites beaten into a foam increase their original volume six to eight times and aerate and leaven food products such as soufflés and meringues. The best egg-white foam is made from fresh eggs at room temperature.
- **Interfering:** Because they interfere with the formation of crystals (ice, sugar), eggs are used to create a smooth, velvety texture in ice cream and candy.
- **Clarifying:** Egg whites are used to make clear soups.

PREPARATION OF EGGS

To preserve the egg's texture, flavor, and color, it is best to keep the cooking temperature low and the heating time short. Eggs can be prepared in a great variety of ways, using either dry-heat or moist-heat methods.



Dry-Heat Methods

- Fried, scrambled, omelets
- Baked (shirred, meringues, soufflés, baked custards)

Moist-Heat Methods

- Simmered
- Coddled
- Poached
- Stirred (custards)
- Microwaved

STORAGE OF EGGS



Eggs begin to deteriorate as soon as they are laid, but they can be preserved through refrigeration, freezing, and drying. Refrigerated eggs retain more moisture and keep longer when they are left in the carton.

The chances of an egg being internally contaminated are relatively low, but external bacterial contamination is possible, and certain precautions can be taken to reduce this risk.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The white of an egg is also referred to as the _____.
   a. albumen
   b. beta-carotene
   c. yolk sac
   d. air cell

2. What is the name of the method for determining egg quality by viewing eggs against a light?
   a. Ripping
   b. Sizing
   c. Candling
   d. Emulsifying

3. In terms of food preparation, eggs are very functional for _____.
   a. emulsifying
   b. binding
   c. foaming
   d. all of the above

4. As eggs age, what happens to the air cell?
   a. It increases in size.
   b. It decreases in size.
   c. It stays the same.
   d. It disappears.

5. What type of eggs should not be cooked in a microwave?
   a. Scrambled
   b. Poached
   c. Shirred
   d. Whole

6. What type of eggs should never be served to the very young, the elderly, or immune-compromised (by HIV, cancer, etc.) individuals?
   a. Dried
   b. Pasteurized
   c. Liquid
   d. Raw

7. One large egg contains approximately
   a. 50 kcalories, 15 g of protein, 10 g of fat, and 150 mg of cholesterol.
   b. 75 kcalories, 7 g of protein, 5 g of fat, and 186 mg of cholesterol.
   c. 100 kcalories, 10 g of protein, 10 g of fat, and 250 mg of cholesterol.
   d. 150 kcalories, 15 g of protein, 15 g of fat, and 300 mg of cholesterol.

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. List and describe the five components of an egg's structure.
2. Describe the protein, fat, cholesterol, vitamin, and mineral contents of eggs.
3. List the USDA quality grades for eggs, and describe the methods used to grade eggs.
4. Describe the following functions of eggs in food preparation: emulsifying, binding, interfering, and clarifying.
5. Explain how the following affect the quality of whipped egg whites: beating technique, temperature, bowl type, separation of eggs and whites, sugar, fluid, salt, and acid.
6. Describe the difference in rate of coagulation for egg whites and yolks, and explain how added ingredients change the coagulation temperature.
7. Discuss how undesirable color changes may occur during egg preparation, and explain what can be done to prevent this.
8. Briefly describe the process of preparing the following types of egg dishes: over easy, shirred, soufflé, and poached.
9. What is a meringue? Describe the potential causes of weeping and beading.
10. List at least six precautions that may be taken to prevent foodborne illness from eggs.

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13



Vegetables and Legumes

Classification of Vegetables 256
Composition of Vegetables 256
Purchasing Vegetables 263
Legumes 273
Preparation of Vegetables 275
Storage of Vegetables 280

Webster's dictionary defines vegetables as "any plant" whose parts are used as food. In practice, a vegetable is the edible part of a plant (raw or cooked) accompanying the main course of a meal. Imagine a meal consisting of just meat, dairy products, and a starch. It is the vegetables and fruits (discussed in the next chapter) that impart color and sometimes unique flavors and textures to meals. This chapter focuses on vegetables, specifically their classification, composition, purchase, preparation, and storage.

CLASSIFICATION OF VEGETABLES

One method of classifying vegetables is to define them by the part of the plant from which they originated. For example, Figure 13-1 shows that vegetables may be derived from almost any part of a plant: roots (carrots, beets, turnips, and radishes); bulbs (onions and garlic); stems (celery and asparagus); leaves (spinach and lettuce); seeds (beans, corn, and peas); and even flowers (broccoli and cauliflower). In addition, there are foods that are routinely called vegetables and used as vegetables, but they are actually fruits. Botanically, fruits are the part of the plant that contains its seeds—specifically, the mature ovaries of plants. If it derives from a flower, then it is usually a fruit. The fruits most often seen masquerading as vegetables include tomatoes, squash, cucumbers, avocados, okra, eggplant, olives, water chestnuts, and peppers. Although many of the principles discussed in this chapter, such as composition and color, apply to both vegetables and fruits, the main focus here is on vegetables.

COMPOSITION OF VEGETABLES

Structure of Plant Cells

Cell Wall

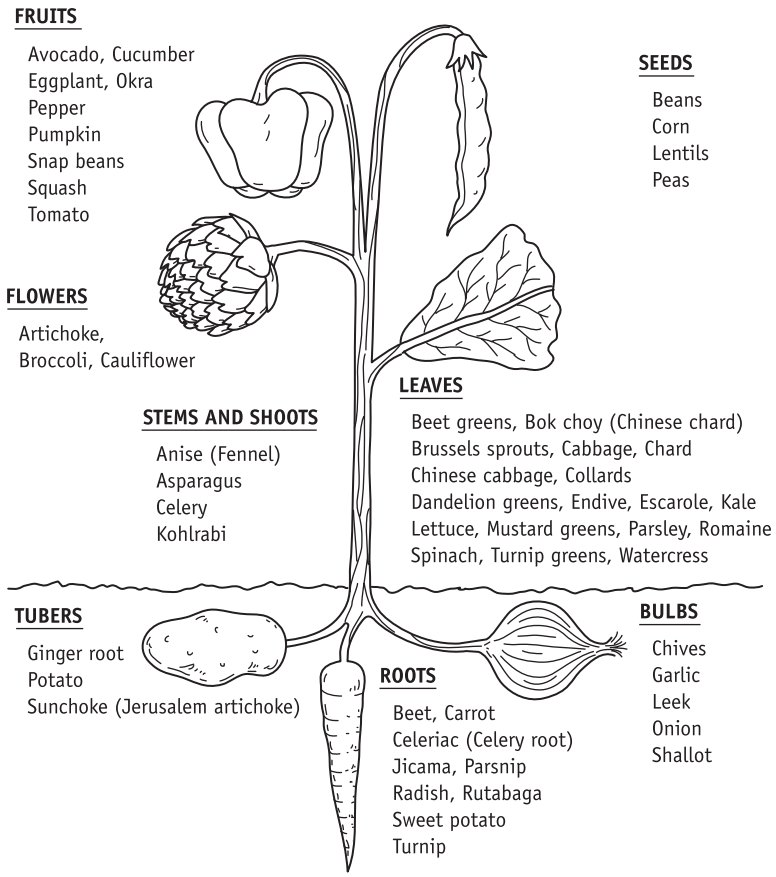
Cells are the building blocks of both plant and animal organisms. One of the major differences between the two types of cells is that only plant cells have cell walls. Because plants lack the skeletal structure that provides support in animal organisms, each plant cell gains

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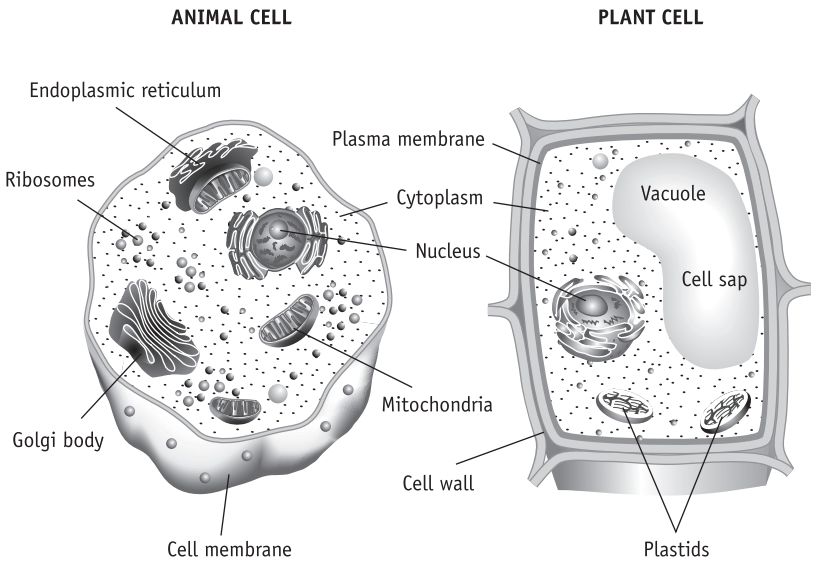
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FIGURE 13-1 Classification of vegetables.



its structural support from the sturdy wall that surrounds it (Figure 13-2). Contributing to the strength of these cell walls are several fibrous compounds that are indigestible by humans. Fiber includes, but is not limited to, cellulose, pectic compounds, hemicellulose, lignin, and gums. Humans are unable to digest fiber because they lack the enzyme necessary to break down cellulose to the glucose molecules that the body can use.

FIGURE 13-2 The structural differences between animal and plant cells.



Two indigestible fibers are pectic compounds and hemicellulose. These substances, found within and between cell walls, serve as a type of intracellular and intercellular cement, giving firmness and elasticity to the tissues (10). The outer layer of the skin, peel, or rind has a higher proportion of cellulose and hemicelluloses than the inner, thinner layers do. The surface cells of these protective layers secrete a waxy cutin, a water-impermeable coat that protects the plant.

Lignin is one of the few types of fiber found in foods that is a noncarbohydrate compound (it is made from polymers of phenolic alcohols). As vegetables mature, their lignin concentrations increase. This is why spinach stems and the inner cores of carrots, asparagus spears, and broccoli become tougher with age and do not soften when heated (47). Other fibrous compounds found in plants include gums, which are polysaccharides with a unique ability to absorb water and swell to several times their original volume. They are often added to processed foods such as ice cream, candies, and salad dressings to increase their viscosity. Examples of food gums derived from plants include algin, carob bean gum, carrageenan, gum arabic, guar gum, locust bean gum, gum tragacanth, and gum karaya.

Storage Structures in Parenchyma Cells

The most common type of cell in vegetables and fruits is the parenchymal cell. Within the jelly-like cytoplasm of these cells are the compounds responsible for the plant's starch content, color, water volume, and flavor. Several of the substances in parenchymal cells, such as starch and pigments, are stored in organelles called *plastids*. There are three types of plastids: leucoplasts, chloroplasts, and chromoplasts.

Leucoplasts

Leucoplasts store starch and some water. Starch stored by parenchyma cells serves as the major digestible portion of the plant. Many vegetables and fruits are consumed for their starch content and the energy it provides.

Chloroplasts and Chromoplasts

Certain plastids contain pigments responsible for the colors of many vegetables and fruits. The chloroplast plastids contain the chlorophyll that is essential for carbohydrate synthesis and

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provides the green color of plants. The orange-yellow colors of certain vegetables and fruits are derived from the chromoplast plastids that contain the carotene or xanthophyll pigments.

Vacuoles

Another function of the parenchymal cells is to store water and other compounds in sacs called "vacuoles." The size of the cell is often related to the amount of liquid it holds, which determines the juiciness of the vegetable or fruit. The degree of juiciness ranges from very low in potatoes and bananas to very high in tomatoes and watermelon. The optimal water content provides **turgor** and crunchiness to leafy vegetables such as lettuce and spinach. Heat or humidity reduces turgor in plants. Other substances found in the cells' vacuoles besides liquid are the red-blue pigments known as anthocyanins (discussed next) and an array of flavor compounds such as saccharides, salts, and organic acids. Organic acids found in the cell contribute to its pH and to the food's flavor and acidity. Most vegetables have a pH of about 5.0 to 5.6, with tomatoes slightly lower (pH 4.0 to 4.6) and corn, peas, and potatoes slightly higher (pH 6.1 to 6.3).

Intercellular Air Spaces

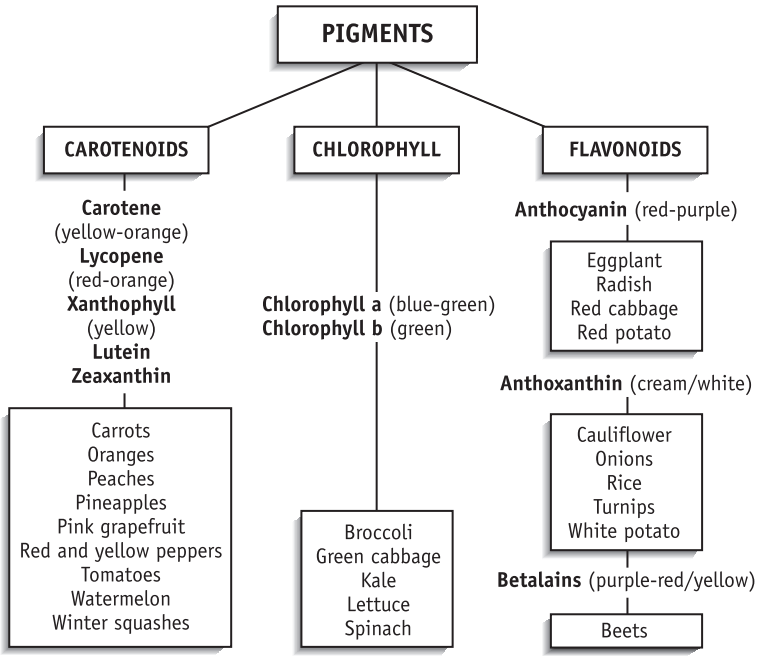
Plant cells do not fit tightly next to each other, so intercellular spaces—the spaces *between* cells—fill with air, adding volume and crispness to vegetables and fruits. The distance between cells influences the texture—specifically, the crispness—of fruits and vegetables. For instance, air spaces account for 20 to 25% of the volume of an apple, 15% of a peach, and only 1% of a potato. Without the air, both vegetables and fruits would be soft and flaccid.

Plant Pigments

Vegetables (and fruits) are clothed in all the colors of the rainbow, and so they brighten meals that would otherwise look bland with only meat, dairy products, grains, and bread on the table. The selection of fruits and vegetables is often based on the way they look, and color is an important attribute of a meal's appearance.

Turgor The rigid firmness of a plant cell resulting from being filled with water.

FIGURE 13-3 Three classes of plant pigments.



Plant pigments fall into three major groups: carotenoids, chlorophylls, and flavonoids (Figure 13-3). Carotenoids and chlorophylls are found in plastids and are fat-soluble. Flavonoid pigments are water-soluble and tend to be lost in cooking water.

Carotenoids

Carotenoids (α-, β-, and γ-carotenes), along with lycopenes and xanthophylls, account for most of the yellow-orange and some of the red color of fruits and vegetables. Carotenes lend reddish-orange hues to carrots and winter squashes. Lycopenes, which are a deeper red, provide the bright color of tomatoes. Light yellow xanthophyll pigments color pineapples.

Heat affects the color of vegetables, most likely because it modifies the pigments' chemical structure. Exposure to oxygen also causes oxidation of pigments and a resulting loss in color (9). Vegetables containing β-carotene should not be overheated because this pigment not only contributes to color but can also be converted to vitamin A; therefore, its destruction would be doubly undesirable (24) (Chemist's Corner 13-1).

Chlorophyll

Chlorophyll, the pigment responsible for the green color of plants (Chemist's Corner 13-2), also makes possible the essential process of photosynthesis, in which leaves capture the sun's light energy to convert carbon dioxide and water to carbohydrates. It is not surprising that plants rich in chlorophyll include most of the leafy green vegetables such as lettuce, spinach, broccoli, green cabbage, and kale.

In older plants or those picked and exposed to sunlight, chlorophyll is degraded, causing underlying pigments to show. This is why leaves may turn yellow in fresh parsley or broccoli florets left too long on the produce stand (11, 54). The process is similar to what happens to tree leaves in autumn, when the nongreen colors, which have been there all along but are masked by the darker, green chlorophyll, are allowed to show as the chlorophyll diminishes with the changing light and cooler temperatures.

CHEMIST'S CORNER 13-1

Vitamin A Carotenoids

The carotenoids with vitamin A activity include β-carotene, α-carotene, and β-cryptoxanthin (42). Beta-carotene can be split into two molecules with vitamin A activity (50).

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CHEMIST'S CORNER 13-2

Types of Chlorophyll

There are two types of chlorophyll, and each produces a specific color in green plants. *Chlorophyll a* is blue-green, whereas the more common *chlorophyll b* is green. These chemical compounds differ in color because of their different structures—the *chlorophyll a* molecule has a methyl group ($-CH_2$) attached to one of its carbons, whereas *chlorophyll b* has an aldehyde group (–CHO).

Blanching Enhances Green Color

Chlorophyll may be hidden by the air between the cells in fresh vegetables. Sometimes the green color can be enhanced by blanching the vegetable, which causes the air to bubble away so that it no longer clouds the colors. After blanching, the vegetables are then "shocked" in cold water or ice water to stop carryover cooking. The brighter green seen in frozen vegetables is caused by blanching them before freezing. Raw vegetable platters prepared by caterers are often more brilliant in color because the vegetables have been blanched and then dipped quickly in cold water.

Chlorophyll, a fat-soluble pigment, is not as stable as carotenoid pigments. Color changes in green vegetables can be minimized by keeping heating times short, adding a small amount of sugar, and heating the food uncovered for the first few minutes to allow volatile organic acids to escape. Avoid heating green vegetables in a pan with the lid on because this causes the natural acids in the vegetables to concentrate and destroy the chlorophyll. A more alkaline cooking medium converts the chlorophyll pigment to a water-soluble form, which is what turns the cooking water green.

Flavonoids

Flavonoid pigments include anthocyanins (red-blue), anthoxanthins (creamy to white), and betalains (purplish-red).

Anthocyanins

Most of the red, purple, and blue colors seen in fruits and vegetables derive from anthocyanin. Although numerous fruits contain this pigment, it is found in only a few vegetables—red cabbage, eggplant, radish, and red potato (58). The color of the anthocyanins in these foods is affected by several factors, including changes in pH that may occur during simmering. Acidic tap water intensifies the red color of anthocyanins; alkaline water changes the reddish-blue hue first to an unappetizing blue and then to green. The latter process is sometimes observed in red cabbage and can be prevented by adding acidic ingredients such as apple, lemon juice, or vinegar.

How & Why?

Why do greens become duller in color when cooked?

Although heating green vegetables causes them at first to turn a sharp, bright green, longer heating periods such as those required for canning cause them to turn a dull olive brown—the color often seen in canned spinach or peas (48). This heat-induced color change occurs when membranes that previously separated acids and pigments are disrupted, allowing acids to come in contact with chloroplasts. Hydrogens from the acids replace the magnesium in the chlorophyll, which results in an olive-brown compound known as pheophytin.

Anthoxanthins

Anthoxanthins are actually a composite of compounds known as flavones, flavonols, and flavonones. They contribute the cream or white color of cauliflower, onions, white potatoes, and turnips. Further whitening can be achieved by adding acidic ingredients such as cream of tartar or vinegar. Anthoxanthins turn an undesirable yellow color in alkaline water, and can even change to blue-black or red-brown under excessive heating or in the presence of iron or copper.

How & Why?

Why does red cabbage sometimes turn purplish-blue when cut with a knife?

If a nonstainless metal knife is used to cut red cabbage, the anthocyanin pigment will react with the metal ions in iron, tin, or aluminum and create off-colors. Stainless steel and glass are consequently the best choices for the preparation and storage of foods rich in anthocyanins.

Betalains

Betalain pigments (red betacyanins and yellow betaxanthins) give beets their deep purplish-red color. It is important to leave beets unpeeled until after they are cooked in order to prevent their rich color from bleeding out into the water. For the same reason, 1 or 2 inches of stem should be left at the top during cooking. Acidic ingredients such as vinegar convert the purplish-red hue of beets to a brighter red. In an alkaline medium, the red color shifts to yellow.

Plants as Functional Foods

Research indicates that fruits and vegetables carry a vast array of **phytochemicals** that may function to protect health as antioxidants, phytoestrogens, and anti-inflammatory agents and through other mechanisms (49). Phytochemicals from foods, rather than manufactured supplements, are the preferred source. The **cruciferous** vegetables, as well as tomatoes, strawberries, pineapples, and green peppers, contain phytochemicals that appear to inhibit cancer in laboratory animals (Chemist's Corner 13-3).

Phytochemical A nonnutritive component ("chemical") in plants ("phyto") considered to have positive health benefits.

Cruciferous A group of indole-containing vegetables named for their cross-shaped blossoms; they are reported to have a protective effect against cancer in laboratory animals. Examples include broccoli, brussels sprouts, cabbage, cauliflower, kale, mustard greens, rutabaga, kohlrabi, and turnips.

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CHEMIST'S CORNER 13-3

Phytochemicals and Cancer

Although human studies are variable in their results with regard to phytochemical consumption and reduced risk for cancer, laboratory animal (in vivo) and cultured cell studies (in vitro) are more supportive (5). Several mechanisms are suggested, including, but not limited to (1) the prevention of chemical carcinogens in the digestive tract, (2) oxidative damage protection, (3) improved cellular damage protection, and (4) induced cell death (apoptosis) of cancerous cells. Some of the phytochemicals studied include flavonoids, isoflavonoids, carotenoids, lignans, isothiocyanates, tocopherols, folate, protease inhibitors, and others (36).

Lycopene is the compound responsible for the red color of tomatoes and some fruits, such as watermelon. It is a powerful antioxidant (Chemist's Corner 13-4), and a high intake of lycopene is linked to decreased risk of prostate (20) and digestive tract (25) cancers. Luteolin is a compound found in broccoli, celery, cabbage, spinach, green pepper, and cauliflower. In laboratory studies, luteolin has been shown to decrease the growth of cancer cells and have anti-inflammatory properties; however, many plant extracts have been reported to have similar properties. High dietary levels of soy are linked to a decreased risk of breast and uterine cancers. Genistein, a compound in soybeans, is thought to be responsible for some of these effects. Epidemiologic evidence suggests that increased intake of dietary fiber, of which vegetables are an excellent source, decreases the risk of colon cancer (6). Vitamins, including A, E, and C, have antioxidant and anti-inflammatory effects (21).

Legumes Members of the plant family *Leguminosae* that are characterized by growing in pods. Vegetable legumes include beans, peas, and lentils.

NUTRIENT CONTENT

With the exception of starchy vegetables, most fresh, unprocessed vegetables are naturally **low in kcalories, cholesterol, sodium, and fat**. Most vegetables are good sources of **carbohydrates (including fiber), vitamins, and minerals—vitamin C, β-carotene, certain B vitamins, calcium, and potassium**. It has been suggested that this nutrient combination, in addition to other nonnutritive compounds found in a plant-based diet of vegetables, fruits, whole-grain foods, and **legumes** (especially soy products), contributes to a **reduced risk for certain cancers** (25, 22).

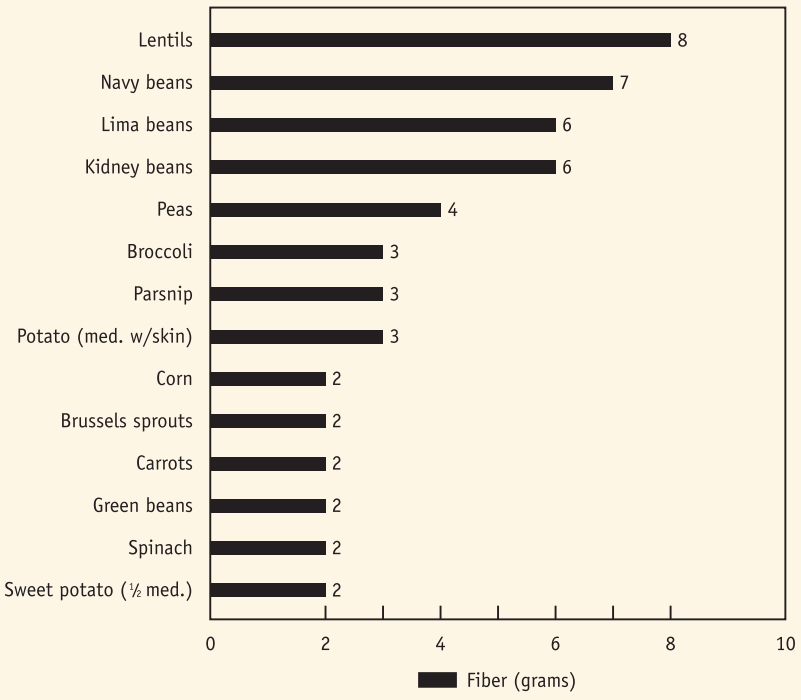
Cholesterol. Only organisms with a liver (animals) are capable of manufacturing **cholesterol, so plants contain none**. Peanuts, for example, are high in fat but do not contain even a trace of cholesterol. However, cholesterol may be added during processing of a plant-based food item.

Fat. Unprocessed vegetables contain **little or no fat**. The only vegetable foods high in fat are the processed vegetable oils derived from plant seeds—corn, peanut, rapeseed, cottonseed, safflower, and others.

Carbohydrates. Some vegetables are so **high in complex carbohydrates** that they can substitute for grain-based starches. Potatoes, legumes, and corn fall into that category. During the ripening process, vegetable sugars convert to starch for storage. Corn, carrots, and peas taste sweeter when harvested early because their sugars have less time to convert to starches. In fruits, the opposite occurs; starches convert to sugars, which explains why a ripe melon tastes sweeter than an unripe one.

Fiber. Many, but not all, vegetables are rich in dietary fiber. **Fiber content varies a good deal among plant foods**, as shown in Figure 13-4. For example, iceberg lettuce contains only 1 gram of fiber per cup; one would have to consume 28 cups of lettuce to obtain the **28 grams of daily fiber recommended for a 2000-kcalorie diet**, whereas only 1½ to 2 cups of kidney beans would have to be eaten to obtain a similar amount.

FIGURE 13-4 Vegetables high in fiber (½ cup cooked unless otherwise noted).



(continued)

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Protein. Vegetables lack certain essential amino acids and therefore are **not a source of complete protein**. The most complete sources of protein in the plant kingdom are the legumes, which nevertheless tend to be low in the essential amino acid methionine (61). Most vegetables average only about 3% protein and are far from complete, so various combinations of legumes and cereals serve as a complete protein and act as a dietary staple for much of the world's population (33).

Vitamins and Minerals. Vegetables are usually higher in vitamins and minerals than fruits. Sprouted beans are high in vitamin C and riboflavin (vitamin B_2). Dark green, leafy vegetables are good sources of riboflavin, β-carotene, vitamin C, and iron. Although **80% of the calcium in an average North American diet is derived from dairy sources**, the next most important source is green vegetables such as broccoli. However, compounds called oxalates, found primarily in certain green vegetables such as spinach, can bind to the calcium, zinc, or iron in these vegetables and may decrease their absorption in the body (7). **Green vegetables are excellent sources of vitamin K and folate, a B vitamin**, the need for which almost doubles during pregnancy.

Fruits and vegetables also contain electrolytes such as potassium and sodium, although the amount of sodium in fresh produce is of negligible significance in the human diet. Canning often increases the sodium content, but lower-sodium versions of many processed foods and beverages are now available.

CHEMIST'S CORNER 13-4

Cancer and DNA Damage

One of the ways that cells become cancerous is to sustain damage to their genetic material, or DNA. This damage can be caused by free radicals, which are highly reactive molecules that interact with and harm DNA. Certain metals, ultraviolet radiation, or chemicals such as cigarette smoke can form free radicals inside of cells. Antioxidants prevent the formation of free radicals by binding to these harmful chemicals or metals and by activating proteins within cells that eliminate free radicals (20). By eliminating free radicals, antioxidants may help prevent DNA damage and possibly reduce the risk of certain cancers.

Studies linking an eating pattern high in plant foods with lower cancer risk have prompted the American Cancer Society to recommend an increased daily intake of fruits and vegetables to at least 2.5 cups per day (22).

Additives

Fresh vegetables generally have few or no additives. Silicon dioxide may be used as an ink diluent for marking fruits and vegetables. Some vegetables, such as cucumbers, are coated in wax to prevent moisture loss. Canned vegetables may contain the preservative EDTA (ethylenediaminetetraacetic acid), as well as flavoring agents including salt and sucrose. Sodium bicarbonate (baking soda)

CALORIE CONTROL
Vegetables (1 cup cooked or 2 cups raw)

Nonstarchy Vegetables: Average 50 kilocalories (range: 25–100 kcals)
Relatively low in kcalories. These vegetables make great snacks as they help you feel full (they are usually high in fiber and low in sugar), deliver lots of healthy phytochemicals, and keep kcalories and carbohydrates low (Table 13-1).

Starchy Vegetables: Average 230 kcalories (range: 130–330 kcals)
These provide three to four times the kcalories of nonstarchy vegetables because of their higher carbohydrate content (Table 13-1). On the other hand, for those who want to gain weight, starchy vegetables are an excellent kcalorie source that is low in fat (unless it's added).

Recommended Intake: The recommended daily intake of vegetables varies according to your caloric needs, the type of vegetable, and whether the vegetables are eaten cooked or raw. For instance, the U.S. Department of Agriculture (USDA) ChooseMyPlate website recommends:

- 2.5 cups vegetables per day (for a 2000-kcalorie diet)
- Including dark green (1.5 cups), red and orange (5.5 cups), legumes (1.5 cups), and starchy (5 cups) vegetables each week

Meat Substitute (Dietary Guidelines): 1 ounce of meat can be substituted with the following:

- ¼ cup cooked dry beans or tofu
- 1 Tbsp peanut butter
- ½ ounce nuts or seeds

Limit Servings of Starchy Vegetables. Too much of a good thing, even if it's vegetables, can still contribute to an excess of kcalories. It would be difficult to get too many kcalories from greens; however, the kcalories from starchy vegetables can add up quickly.

1 cup dried beans, creamed corn, or cassava = about 230 kcalories
2 cups = about 460 kcalories

(*Continued*)

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TABLE 13-1 Estimated Kilocalories in Nonstarchy and Starchy Vegetables (Based on 1 Cup Cooked or 2 Cups Raw; Kilocalories Provided in Parentheses)

Nonstarchy Vegetables (0–100 kcalories)

0–25 Kilocalories	25–50 Kilocalories	50–100 Kilocalories
Bamboo shoots (14)	Asparagus (43)	Artichoke and artichoke hearts (95)
Cucumber (16)	Broccoli (44)	Bean sprouts (65)
Eggplant (28)	Cabbage (23)	Beets (slices) (75)
Gourd (20)	Cauliflower (29)	Brussels sprouts (64)
Greens (collard, kale, mustard, turnip) (15)	Celery (19)	Carrots (70)
Lettuce (iceberg, shredded) (10)	Chayote, fruit or leaves (40)	Corn on the cob (7 inches) (77)
Spinach (7)	Green beans (44)	Mixed vegetables (90)
Salad greens (all types) (9)	Green onions (40)	Onions (90)
Tomato (25)	Leeks (32)	Pea pods (67)
Watercress (3)	Mushrooms (42)	Peppers (green) (52)
	Okra (33)	Rutabaga (66)
	Onion (55)	Vegetable juice (12 oz) (71)
	Pumpkin (49)	Water chestnuts (slices) (120)
	Radishes (28)	
	Seaweed, Kombu, Nori (27)	
	Squash (summer) (36)	
	Swiss chard (35)	
	Turnips (33)	
	Zucchini (29)	

Starchy Vegetables (100–300+ kcalories)

100–200 Kilocalories	200–300 Kilocalories	300+ Kilocalories
Corn (132)	Beans, plain (240)	Baked beans, Boston (340)
Parsnips (125)	Cassava (221)	Hummus (398)
Peas (121)	Corn, creamed (213)	
Potato (1 med, 1 C) (160)	Lentils (230)	
Squash (winter) (115)	Plantain (1 med, 1 C) (218)	
Taro corm (192)		
Yam or sweet potato (1 med, 1 C) (185)		

Limit Fried Food. French fries are potatoes submerged in heated fat. Anything breaded and fried signals "loaded with fat and kcalories":

Food	Serving Size	kcalories	Fat (grams)
French fries	Medium, 4 oz	**360**	18
Baked potato	4 oz	105	0
	Medium	160	0
Onion rings (breaded, fried)	4 rings	**230**	12
Onion	1 cup	55	0
Zucchini			
Breaded, fried	4 oz	**277**	16
Stir fried, little fat	4 oz	20	1

Tips for Eating More Vegetables

- **Snacks.** Keep cut-up vegetables in a bowl of water in the refrigerator (or in an aerated bag) and include baby carrots, broccoli florets, pepper (green, yellow, red) strips, and cauliflower. Use low-kcalorie dressings as a dip, but limit the amount to 1 tablespoon.
- **Vegetable soup.** Making homemade vegetable soup on the weekend can yield a cup of soup for every day of the week.
- **Frozen vegetables.** Prepared as needed and/or cut into bite-size pieces and mix in with sautéed onions, green peppers, and tomatoes.
- **Daily salad.** Increase greens by adding romaine lettuce and spinach, and increase fiber by topping the greens (usually low in fiber) with shredded carrots, cauliflower, beans, peas, broccoli, green pea pods, and corn.
- **Vegetable juice.** A 12-ounce (1½ cups) can of vegetable juice delivers only 70 kcalories, as compared with the usual 150 kcalories found in sodas.
- **Green and orange.** Certain green vegetables are higher in folate (B vitamin), and certain yellow-orange vegetables are rich in vitamin A.

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is used to clean vegetables and to absorb excess acid in some canned products such as soups, and it may also be used, along with sorbic acid, in pickled vegetables. BHT (butylated hydroxytoluene) and BHA (butylated hydroxyanisole) are preservatives and antioxidants that are used in dried potato flakes, cereals, and other processed foods.

PURCHASING VEGETABLES

Grading Vegetables

Because most fresh produce deteriorates too quickly to grade, most grading is at present voluntary; it is based on ripeness, color, shape, size, uniformity, and freedom from bruises and signs of decay. Labeling laws include USDA U.S. Grade Standards for selected fresh vegetables (56, 57). USDA grades are shown in Table 13-2.

TABLE 13-2 USDA Grades for Vegetables and Fruits—Processed and Fresh

USDA Grade	What the Grade Means
Processed: Canned and frozen.	
U.S. Grade A (or Fancy)	This is the highest grade for canned and frozen vegetables. They are the most tender, succulent, and flavorful, and they have the best color for type.
U.S. Grade B (Choice for fruits or Extra Standard for vegetables)	The majority of canned and frozen vegetables. They are not as tender or as well colored as U.S. Grade A.
U.S. Grade C (or Standard)	These canned and frozen vegetables are usually more mature, less tender, and not uniform in shape or color. They are an excellent buy when cost, but not appearance, is important. U.S. Grade C vegetables are frequently utilized for soups, stews, and casseroles.
U.S. Grade D (or Substandard)	Lowest marketable quality.
Processed: Dried or dehydrated fruits. Fruit and vegetable juices (canned and frozen). Also includes preserves, jams, jellies, peanut butter, honey, ketchup, and tomato paste.	
U.S. Grade A	Very good flavor and color, and few defects.
U.S. Grade B	Good flavor and color but not as uniform as A.
U.S. Grade C	Less flavor than B, color not as bright, and more defects.
Fresh: The grade is more likely to be found without the shield.	
U.S. Fancy	Premium quality; only a few fruits and vegetables are packed in this grade, so they are rarely seen by most people. U.S. Fancy is the highest grade used in judging the quality of fresh vegetables and is based on appearance and uniform shape.
U.S. No. 1	This is the most common grade for fresh vegetables and is given for those that appear fresh and tender, have good color, and are relatively free from bruises and decay.
U.S. No. 2	Intermediate quality between No. 1 and No. 3.
U.S. No. 3	Lowest marketable quality.

Selecting Vegetables

Vegetables come from living plants that grow in cycles with the passing seasons. Thus, the season of the year is the most important consideration when selecting vegetables (Figure 13-5). Not all vegetables are in season at the same time. Specific tips on selection for each of the vegetables are discussed in alphabetical order (53).



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Artichoke

The artichoke is the immature flower head of a thistle. The edible "leaves" are actually petals (Figure 13-6). The furry center, known as the choke, must be removed before consumption. Occasionally, baby artichokes are sold; they are tender throughout and may be eaten whole. Overmature artichokes are detected by separating leaves and a woody texture. The edible portion of the artichoke includes the stem, the base (or heart), and the thicker bottom section of the leaves. Mature artichokes are usually trimmed as shown in Figure 13-7 prior to preparation. The most common variety is Green Globe. Selection varies according to season, with the

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FIGURE 13-5 Seasons for vegetables.



(Continued)

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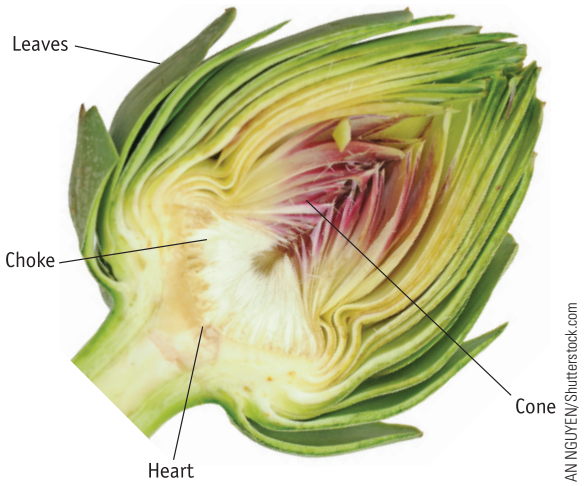
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FIGURE 13-5 Seasons for vegetables. (*continued*)

Seasons for Vegetables

Vegetable	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
Radicchio	■	■	■	■		■	■	■	■	■	■	■
Romaine	■	■	■	■	■	■	■	■	■	■	■	■
Rutabagas									■	■	■	■
Salsify	■	■	■	■						■	■	■
Scallions								■	■			
Spinach	■	■	■	■	■	■	■	■	■	■	■	■
Squash, acorn									■	■	■	■
Squash, baby							■	■	■	■	■	
Squash, butternut									■	■	■	■
Squash, cheese									■	■	■	■
Squash, crookneck							■	■	■	■		
Squash, dumpling									■	■	■	■
Squash, straight neck									■	■	■	■
Squash, patty pan							■	■	■	■		
Squash, spaghetti									■	■	■	■
Sunchokes	■	■	■	■	■						■	■
Tomatoes						■	■	■	■	■	■	
Tomatoes, cherry							■	■	■	■	■	
Turnips	■	■	■	■	■	■	■	■	■	■	■	■
Watercress	■	■	■	■	■	■	■	■	■	■	■	■
Zucchinis				■	■	■	■	■	■	■	■	

FIGURE 13-6 The major edible portion of an artichoke is the fleshy ends of the "leaves" attached to the plant. The heart is also edible and considered a delicacy. It is reached by lifting out the cone and cutting out the choke (core).



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FIGURE 13-7 Preparing an artichoke.



Fabrizio Esposito/Shutterstock.com

Trim away both ends of the artichoke.



Steve Cukrov/Shutterstock.com

Use scissors to cut away the barbs from the ends of leaves.

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best-flavored artichokes available in the winter, when the artichokes are heavy, compact, plump, and have bronze-tipped leaves (winter-kissed) from a light frost. Spring artichokes are globe-shaped, green, and have tight leaves. The shape becomes conical in the summer and fall, with the leaves becoming lighter in color and weight.



Asparagus

Tenderness is the key consideration when selecting asparagus. Tight, compact buds and fresh, firm stalks that break with a crisp snap are desired. Opened buds and flattened or angular stalks are signs of tougher, less sweet asparagus. The size and thickness of the stalk or spear is not related to tenderness. The two main types of asparagus available in North America are the more popular dark green and the less often purchased white or light green.



Beans (Green Snap, Green, Wax, and Yellow Wax-Pod Beans)

Select sturdy, crisp pods with no sign of wrinkling, pitting, or bulging in the skin due to overmaturity. Green (green snap beans) and yellow (wax) are the two most common types of beans.



Beets

Select beets that are smooth, firm, and free of any sign of dryness. Leaves should be fresh, tender, and clean.



Broccoli

In fresh broccoli, the bud clusters should be firmly closed, and the head should be dark green to purple in color. Stems should be light green and not pale, woody, hard, or dry. The signs of decay in broccoli are subtle, but avoid broccoli with florets that are starting to open or have an uneven, yellow-green color. Calabrese is the most common variety, but others include Emperor, Premium, Futura, Green Duke, Harvester, Atlantic, Topper 430, Gem, Medium Late 423, and Medium Late 145.



Brussels Sprouts

Select those with compact leaves and clean stalk ends. Brussels sprouts with wilted, yellowish, puffy, or soft leaves are poorer in texture and flavor. Varieties such as Citadel, Lunet, Rampart, and Valiant differ in their bud-bearing characteristics.



Cabbage

Look for cabbage with leaves firmly attached to the stem. The stem should be solid, hard, and heavy in relation to the head. The cabbage surface is usually smooth (except savoy cabbage), evenly colored, and free from any signs of dehydration. The most common variety is domestic cabbage, but others include Danish, the yellow-colored savoy, and red cabbage. Bok choy is Chinese mustard cabbage; it has large, sturdy, white stems and leaves, and a unique, mild flavor that enhances salads, stir-fry dishes, and soups.



Carrots

Most carrots are sold by length and range from 2 to 8 inches long. The surfaces should be smooth, firm, and free from cracks, and the tops should be free from any sprouting green shoots, which would indicate an older carrot. The darker the orange color, the more β-carotene the carrot contains. Pre-peeled carrots are also available. "Baby-cut" carrots are really just mature carrots cut and trimmed to represent young carrots (27).



Cauliflower

Cauliflower, like broccoli, is a head of flowers. A fresh cauliflower head will not have started to bloom, spread, or look "ricey." The color ranges from white to creamy white. Lime-green is the color of broccoflower, a hybrid between broccoli and cauliflower. The jacket leaves at the cauliflower's base should be green and crisp. Popular varieties include Early Snowball, Super Snowball, Snowdrift, Pearl, Danish Giant, and Veitch Autumn Giant.



Celery

The first thing to check for in celery is clean, smooth, tender-looking inner stalks. They should snap when broken and have a straight, solid cone in the center. Celery with signs of stringiness or roughness may be tough and should not be purchased. The leaves on top should be fresh, green, and free from signs of dehydration (wilting, color changes) or decay.

The green variety is the most popular, although Pascal, a lighter color variety, is growing in popularity because of its special flavor and lack of stringiness and toughness.



Corn

Corn on the cob is relatively easy to select because the husks, the stem ends, the silk strands on top, and the kernels can all be checked for freshness. Healthy husks and stems are a vibrant green and show no signs of discoloration or drying out. The stem ends are moist and not wilted or decayed. Many stores prefer that shoppers not rip open corn ears because it causes the kernels to dry out and degrade, but when it is possible to do this, the husk should resist being pulled back and the kernels should be plump, even sized, and ripe-colored. Any indentations in the kernels or large or dark-yellow kernels indicate older, tougher, less flavorful corn. There are more than 200 varieties of corn, but the major type found commercially is Yellow Hybrid Sweet Corn.



Cucumbers

The three types of cucumbers that are available include slicing or table, pickling, and greenhouse. Slicing cucumbers are found in most supermarkets and are best selected based on their firmness and fairly straight-sided oblong shape. The skin should be free from any soft spots or shriveling, and evenly colored, with no yellowing, a sign of aging. Typical supermarket varieties are heavily waxed to protect the fruit. Varieties include Ashley, Cherokee 7, Gemini, Hybrid Ashley, High Mark II, Long Market, Marketer, Palomar, Poinsett, and Straight Eight. Hothouse or greenhouse

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cucumbers are elongated, seedless cucumbers with a mild flavor and no bitterness. European cucumbers are long and slender and usually come wrapped in plastic. Small- to medium-size cucumbers are used to manufacture pickles (see Chapter 28).



Eggplant

Select the heaviest eggplant with at least a 3- to 6-inch diameter. Freshness in eggplants is judged by the condition of the skin. It should be smooth, firm, and glossy, with a deep purple, almost black color. Eggplants are also available in white and striped varieties; in these, any sign of yellow indicates aging. Flabbiness, softness, or dark bruise-like discolorations indicate poor quality. Chinese eggplants (also called Asian or Japanese eggplant) have a thinner skin and are long and thin, averaging 1 or 2 inches in diameter. American varieties include Black Beauty, Florida High Market, Florida Market, Myers Market, New Hampshire, and New York Purple.



Exotic Vegetables

The expanding global economy and improved transportation methods have introduced more exotic vegetables into cuisines around the world (Figure 13-8):

- ***Adzuki bean***. Compared to other beans, adzuki beans have a slightly sweet flavor.
- ***Amaranth***. A boiled leafy green vegetable prepared like spinach. Although not well known in the United States, amaranth is consumed extensively throughout Africa, Asia, the Caribbean, and Latin America. The greens are of considerable nutritional value (vitamins A and C, calcium, magnesium, and iron).
- ***Chayote***. Pronounced "chy-o-tay," this native Mexican squash has a flesh that is crisp like a water chestnut. The chayote can be eaten raw in salads, or stuffed and baked.
- ***Daikon***. This Japanese radish is gaining in popularity. Although frequently pickled in Japan, it serves as a good addition to green salads.
- ***Jicama***. Pronounced "hee-ka-ma," this legume grown in Mexico is consumed fresh or is used like a radish in salads.



Garlic

Roman gladiators ate garlic, believing it would make them stronger and capable of great feats, and even today many people believe it has curative powers against a host of ailments. Garlic is sold in whole heads. Select firm, well-filled cloves with skins that are not overly dry. Avoid those that are sprouting or have dark or rotted areas. Garlic can be peeled and minced by using a garlic press, or the clove can be crushed on a cutting board under the side of a chef's knife or heavy object such as the side of a can.

Garlic ranges in color from white to dark maroon, and varieties include Argentina White, California Early, California Late, Mexican Purple, and Mexican White. Elephant garlic, which is much larger, milder, and sweeter than regular garlic, is gaining in popularity. It is capable of reaching 6 inches in diameter and weighing up to 12 ounces.

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FIGURE 13-8 Exotic vegetables.



Chinese long beans
- Grow up to 18" long
- Steam or stir-fry



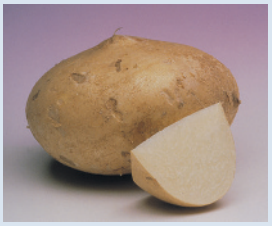
Jerusalem artichoke
- Root of sunflower plant
- Nutty, sweet, mild flavor



Breadfruit
- Not used to make bread
- Used like a potato (if unripe)



Kohlrabi
- Sweeter and crisper than turnips
- Flavor of broccoli stems



Jicama
- Pronounced "hee-ka-ma"
- Sweet, starchy taste



Belgian endive
- Mild, bitter flavor
- Used in salads or soups



Calabaza
- Variety of squash
- Dark orange flesh



Chayote
- Pronounced "chy-o-tay"
- Flavor similar to zucchini/cucumber

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Ginger

This vegetable, often used as a spice in Asian, Indian, Moroccan, and Caribbean dishes, is selected by looking for a smooth, nonwrinkled skin with a fresh sheen and filled-out flesh. Choose ginger root that breaks cleanly with a snap and has the least number of knots.



Greens

Greens are leafy vegetables that include collards, dandelion greens, kale, mustard greens, beet greens, endive, Swiss chard, and others (Figure 13-9). These excellent sources of vitamin A should be fresh, crisp, tender, and free from any drying, insect damage, or decay. Top varieties for each of the greens are as follows:

- ***Collards***. Georgia, Louisiana Sweet, Morris Heading, and Vates.
- ***Dandelion***. Arlington Thick Leaf, Improved Thick Leaf, and Thick Leaf.
- ***Kale***. Two types of kale frequent the market: 1) bright green, curly more tart kale, and 2) darker, flatter leafed, more nutty-flavored kale. Cooking releases the bitterness as well as soaking the leaves in an acid-based dressing such as vinegar, lemon, or lime.
- ***Swiss Chard***. Burpee's Rhubarb Chard, Dark Green, White Ribbed, Fordhook Giant, Giant Lucullus, and Rhubarb Chard.



Leeks

This mild-flavored member of the onion family is traditionally used in soups and French dishes. Select leeks with tender leaves that are not too fibrous or coarse. Varieties include American Flag (London Flag), Blue Leaf, Carentan (Winter), and Musselburg.



Lettuce

Lettuces are leafy vegetables that serve as the foundation for salads and as an ingredient in sandwiches or tacos (Table 13-3). Select lettuce with fresh, crispy leaves and no signs of withering or dehydration. Iceberg lettuce can be easily cored by holding the head core-down and rapping it against the counter. This motion forces the core into the head, and it can then be easily twisted and removed. The lettuce head is then rinsed core-up so that the cold running water will spread through the leaves. All moisture should be removed after lettuce is washed to slow decay.



Mushrooms

Mushrooms are actually a type of fungus that lacks chlorophyll. Select mushrooms with firm, smooth caps that are free of slime, mold, wilting, or bruises. The appearance of gills underneath the umbrella can indicate aging, although they are always visible in some varieties. If present, the gills should be clean, not too dark, and unbroken. Once purchased, mushrooms are often not washed but instead stemmed and cleaned with a damp cloth or paper towel or scraped clean with a paring knife. They are very absorbent, so exposing them to water may ruin their flavor and texture, although many individuals subject them to a quick rinse just prior to preparation. There are quite a few varieties of mushrooms from which to select (Figure 13-10). "Wild" mushrooms should not be picked from fields, forests, or any other location because even

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FIGURE 13-9 Leafy greens.



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TABLE 13-3 Major Varieties of Lettuce

Variety	Characteristics
Iceberg	Iceberg lettuce accounts for almost 10% of the entire produce market. Leaves are crisp and consistently mild in flavor, and have a high moisture content.
Boston or Bibb	Also known as butterhead, this lettuce has a very mild taste and pliable, soft leaves. Varieties include Bibb, Big Boston, May King, and White Boston.
Endive	Curly leaf ends distinguish this lettuce from the rest. The edges tend to be more bitter than the center.
Escarole	These crumpled-looking leaves, relatively fibrous and somewhat bitter tasting, are usually available in the Full Heart Batavian variety and are often served cooked or in soups.
Leaf lettuce	This lettuce has a crunchy texture not unlike iceberg lettuce, but it has more flavor.
Romaine or Cos	The darker green, sometimes reddish-tinged, flimsy leaves and stronger flavor differentiate this lettuce from iceberg. The pale, crisp cores, or hearts, of romaine are often sold for Caesar salad.

mushroom identification experts have been reported to make mistakes and get extremely ill.



Okra

Okra consists of edible pods filled with seeds. The pods should be young and tender, ranging from 1 to 3 inches in length. Fresh pods snap and puncture easily, whereas older ones are dry, fibrous, have a dull color, and contain hard seeds. Okra pods are usually green, but white and purple varieties are also available. Popular varieties of okra include Clemson Spineless, Dwarf Long Pod, French Market, and Perkins Spineless.



Onions

The most common onion varieties are yellow, white, red, and green (Figure 13-11). The yellow onion, which is the general all-purpose onion, should feel firm; the skin should be dry and papery, and the stem small. The skin should be free of any green sunburn marks, mold, or blackish decay spots. Well-selected onions emit a typical fresh onion odor. Onion flavor ranges from pungent to sweet. Vidalia onions are known for their distinctive taste, which is sweeter and milder than other onions because of their higher sugar and water contents. This type of onion is preferred for onion rings, omelets, pizzas, marmalades, sautéing, or any other dish in which a distinctive sweet onion flavor is desired. Varieties include Vidalia (small, sweet yellow), Texas 1015 (large yellow), White Boiler (small white), Medium White (large white), and Red. Only onions from specific counties in the state of Georgia may legally carry the Vidalia name.

Other types of onions and their relatives are as follows:

- ***Green onions***. Also known as scallions, green onions are "onions to be" that have been harvested while the bulbs are still small and the leaves still growing. For scallions, tender, succulent, small to medium bulbs with springy leaves that hold their

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FIGURE 13-10 Varieties of cultivated mushrooms.



Button mushrooms are the most common variety sold; they are somewhat nutty and creamy when raw and become earthy and rich when cooked.



Cremini are a darker variety of the standard button mushroom; they're firmer, with a much more intense flavor.



Enoki mushrooms have a mild, pleasant flavor that isn't particularly distinctive, but they often used in Asia cuisine, especially soups.



Oyster mushrooms have a subtle flavor that's best paired with other simple ingredients.



Portabella mushrooms are simply cremini grown to gargantuan proportions; their flesh is denser and usually more fibrous.



Shiitakes have a distinct, slightly smoky flavor that adapts well to other strong flavors; they're commonly used in Asian cooking.

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FIGURE 13-11 Onion varieties.



WHITE
- Pungent odor
- Sharp flovor
- Stews (Boiling)

YELLOW
- All-purpose
- Medium-strong flavor

RED
- Best used raw; salads
- Tangy flavor



VIDALIA
- Salads
- Cooking
- Sweet flavor



PEARL ONIONS
- Soups and casseroies
- Regular onions whose growth has been stunted

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shape are preferred. Green onions are commonly used in salads, in Mexican dishes, for stir-frying, and alone as a garnish.

- ***Shallots***. Although related to the onion family, their large cloves more closely resemble garlic, and, in a similar fashion, they are predominantly used for flavoring.
- ***Leeks***. A type of onion (discussed previously).



Parsley

The two kinds of parsley—Italian (flat leaf) and Chinese (cilantro or coriander)—differ quite a bit in taste. Cilantro leaves are wider, droop more, and have a very distinctive fragrance. These herbs (not a vegetable) are best consumed raw, rather than cooked, and are used throughout many cuisines in the world, especially Asian, Indian, Middle Eastern, African, Caribbean, and Latin American. Fresh cilantro imparts flavor to guacamoles, salsa, ceviche, and tacos.

Chimichurri is a very flavorful mixture that can spread over grilled steak or chicken and consists of chopped parsley, garlic, lemon zest, and seasonings mixed with oil and vinegar.



Parsnips

These long, tapered vegetables look like bleached-out carrots but are not eaten raw. They are excellent for soups.



Peas

Green peas have a bulging pod, snow pea pods are flat, and sugar snap pod diameters range somewhere between green and snow peas. Unlike green peas, snow and sugar snap peas are consumed with their pods. All should be fresh, tender, and sweet. Avoid those that are in an advanced stage of maturity, which is signaled by grayish specks, yellow streaks, a darker color, dryness, and wrinkling.



Peppers, Hot

Chili peppers come in a variety of colors, shapes, and degrees of "heat." Green, red, yellow, and black are the predominant colors (Figure 13-12). The skins of fresh chilies should always be bright, shiny, firm, and unwrinkled. Several of the more common types of chili peppers (Mexican varieties) include jalapeño, Anaheim, yellow chile, chile de arbol, poblano (ancho or pasilla), serrano, and habeñero, which is the hottest of all hot peppers. Figure 13-12 lists the chili peppers in order of heat (pungency – sharp taste) according to the Scoville scale, a ranking system that measures how much capsaicin is present in each chili.



Peppers, Sweet

Sweet peppers are available in many colors—green, red, yellow, orange, purple, and brown. As peppers ripen, they become sweeter because of their increasing sugar content. Those with a bright, smooth, glossy color and thick, filled-out walls and a good solid weight are recommended, whereas those that are pitted, dull-looking, or shriveled should be avoided. Those bell peppers that are more square or rectangular in shape are the easiest bell peppers to cut up. California Wonder is the most common variety of pepper, and others include Early Cal-Wonder, Burlington, Chinese Giant, Harris Early Giant, Neapolitan, and Yolo Wonder. Other sweet peppers include the round cherry, pimento, Holland, sweet Hungarian, Cubanelles, Italian, bull horn, and sweet banana wax.



Potatoes

Numerous potato varieties are cultivated in South America, but, in North America, three basic types are found in the market: russet/Idaho, white, and red (Figure 13-13).

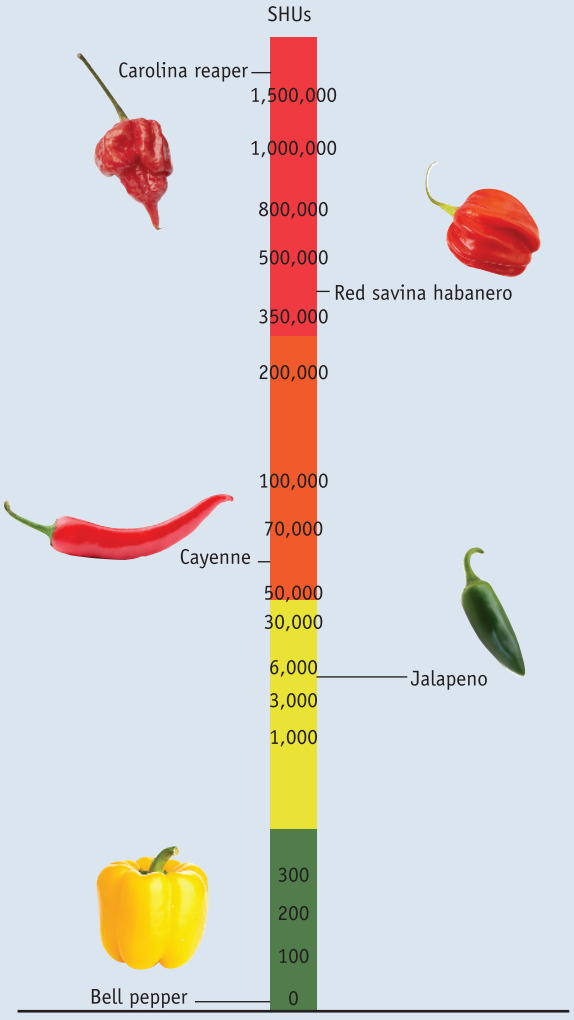
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FIGURE 13-12 Chili peppers on the Scoville heat unit (SHU) scale.



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Russets are considered starchy potatoes and are preferred for baking; whites are best suited for roasting with meats or poultry; and reds, known as waxy potatoes, have the least starch and are good for simmering. New potatoes are immature, smaller versions of any mature potato variety. They have a delicate skin and waxy flesh that is ideal for simmering and for salads because they hold their shape. When selecting potatoes, look for those that are firm to the touch and that have few eyes, good color, unshriveled skin, and a round or oblong shape (irregular shapes result in more waste during peeling). They should all be about the same size to ensure even cooking. Russets should have a net-like texture on their skins with no hint of green coloration, which indicates exposure to sunlight and possible presence of the toxin solanine. The varieties of each of the potatoes are as follows:

- ***Russet***. Burbank, Centennial, and Norgold.
- ***White***. Available in either long (White Rose) or round (Atlantic, Katahdin, Kennebec, Superior).
- ***Red***. Norland, Red LaSoda, and Red Pontiac.
- ***Others***. Varieties such as Yukon Gold, a medium-starchy all-purpose potato, and a wide array of small, fingerling potatoes are becoming increasingly available in the market.



Radishes

Radishes are classified by shape: globular, oval, turnip-shaped, oblong, and long. The Red Globe type is the most popular and is selected based on a bright red color; smooth, firm skin; healthy roots; and crisp, white flesh. Avoid those that are cracked open, withered, spongy, and dry- or rough-looking. The leaves should be fresh and vibrant with no signs of decay. The daikon is a white, sweet, and elongated radish from Asia that is shaped like a carrot. Some markets also sell the large black radish, which is black on the outside and white on the inside.



Rutabagas

Looking much like a turnip, rutabagas are more purple/beige in color, have a yellowish flesh, and have leaves that are thicker and smoother. The three most common varieties are American Purple Top, Laurentian, and the Thomson Strain of Laurentian. Like cucumbers, rutabagas are often sold heavily waxed.



Spinach

Fresh, dark green spinach leaves with good turgor are preferred over those that are wilted, decaying, straggly, slimy, or have large, rough stalks. Spinach leaves may be wrinkled (savoy), flat, or semi-savoy, which is a combination of wrinkled and flat (sold for fresh and processed purposes). Young, tender leaves are somewhat lighter green and best used for salads, while the darker, more mature leaves are preferred for cooking. Varieties include dark green Bloomsdale, Bloomsdale Long Standing, Old Dominion, and Virginia Savoy.



Sprouts

All seeds can be sprouted, but not all should be consumed. The two dominant types of sprouts on the market are alfalfa and mung bean, but other available sprouts include, but are not limited to, legumes (clover, lentil, pea, soybean), cereals (wheat, rice, corn, barley, quinoa, amaranth, buckwheat), and oilseeds (sesame, peanut). The greenish-topped, white-stemmed alfalfa sprouts are selected based on very little breakage of the stems and freedom from wilting or slime. The sprout heads should be full, vibrantly

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FIGURE 13-13 Choosing the right potato.

Selecting the right type of potato:



RED POTATOES

- Boiling
- Microwaving
- Salads
- Soups
- Steaming



RUSSET/IDAHO POTATOES

- Baking
- Boiling
- Casseroles
- Mashing
- Microwaving
- Pan-frying
- Sautéing
- Frying



WHITE POTATOES

- Braising
- Boiling
- Casseroles
- Frying
- Mashing
- Microwaving
- Pan-frying
- Salads
- Sautéing

Different kinds of potatoes:



Bintje



Austrian Crescent



Blue Pride



Ozette Indian



Ruby Crescent



Red Thumb



Rote Erstling



French Fingerling



Russian Banana



Yukon Gold

© PhotoDisc

green, and provide an overall nut-like flavor. Bean sprouts grown from mung beans are long, ivory-colored strands of uniform length with a crisp, snappy texture. Signs of decay include darkened roots, sliminess, and a musty odor.



Squash

There are two categories of squash: summer or soft-skinned types and winter or hard-shell types (Figure 13-14).

Summer Squash

Summer squash include zucchini, yellow crookneck, yellow straightneck, chayote, cucuzza, scallopini, and sunburst. Look for small squash with a shiny skin and no bruises or scars. The smaller the squash is, the more tender its flesh, seeds, and skin. Pits in the skin are caused by chilling, whereas dull skin or discoloration may indicate old age.

Winter Squash

It is difficult to determine the eating quality of winter squash because of the hard outer rind. Examples of winter squash include acorn, butternut, pumpkin, spaghetti, banana, turban, Hubbard, delicata, sweet dumpling, kabocha, and golden nugget. Select those that are dull and heavy for their size; as winter squash age, they become lighter in weight, indicating a dry and stringy texture. When selecting a pumpkin, look for a clean, uncracked surface with a bright orange color. Avoid those that show scarring, excess wrinkling, fading color, or soft spots on the rind.



Sweet Potatoes

There are two types of sweet potatoes: soft-fleshed, which tend to have a more orange flesh and are soft, moist, and sweet when cooked; and firm-fleshed, which are lighter in color and dry and mealy when cooked. Select sweet potatoes that have large,

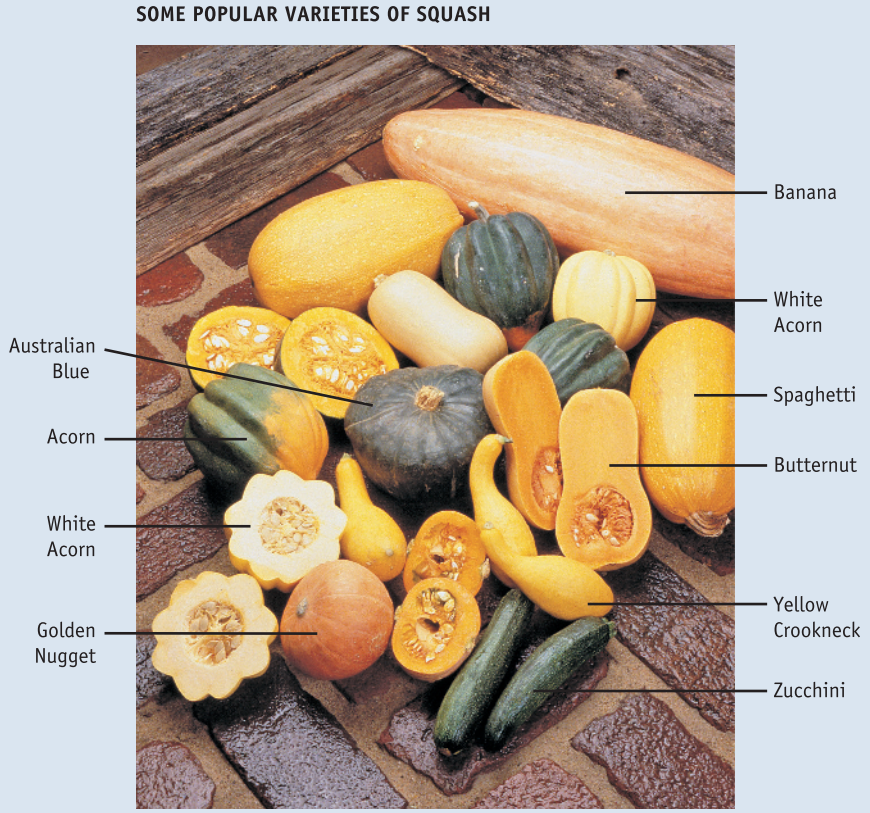
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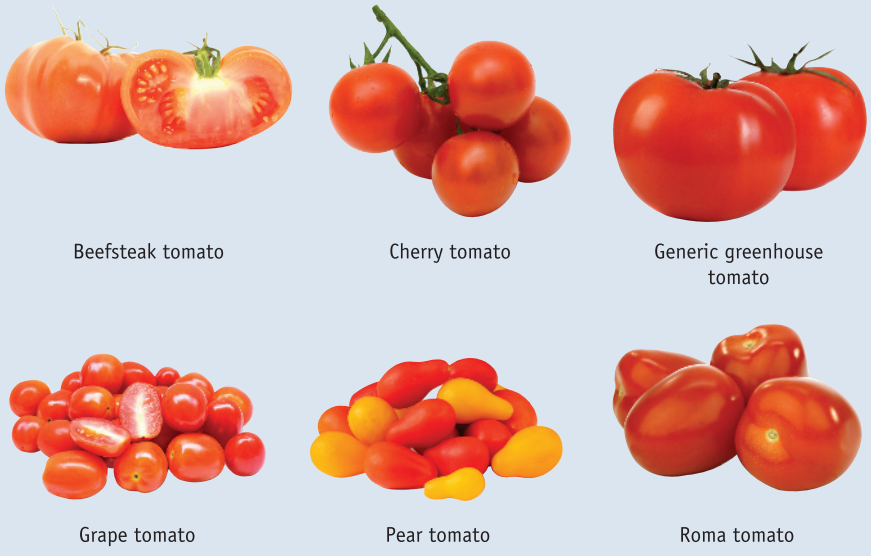
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FIGURE 13-14 Squash selections.



Vincent Lee

FIGURE 13-15 Selected varieties of tomatoes.



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uniform shapes with no signs of discoloration, wrinkling, or drying. If they are too tapered or pointed at the ends, they may be difficult to peel. Prominent sweet potato varieties include Beauregard, Jewel, Garnet, and Hernandez.



Tomatoes

Tomatoes are often sold unripe because they are easily bruised during transportation (16). The color changes from green to bright red or reddish-orange as tomatoes ripen. Once ripe, they should give to gentle palm pressure; a watery consistency or slippery skin is a sign of being overly ripe. A sweet, delicate aroma often accompanies ripeness. Sometimes cutting the tomato open is the only way to determine whether it is ripe enough for consumption.

There are several common types of tomatoes: mature green, which are best for slicing or garnishes; vine-pink/vine-ripe, suited for stuffed tomato entrees or salad wedges; Romas, which are elongated in shape, meaty, and flavorful, making them ideal for salads and sauces (see Figure 13-15); and cherry tomatoes, ranging from marble size up to ping-pong-ball size, which are excellent for salads, garnishes, or salad bars. Cherry tomatoes soften at a slower rate than other tomatoes, allowing them to be harvested at a later date, after they have had more time to ripen.



Turnips

Soups and stews are the main dishes to which turnips are added. A firm, well-rounded turnip, free from shriveling or rough skin, is preferred. Common varieties include Amber, Golden Ball, Purple Top, Yellow Aberdeen, White Egg, and White Globe.

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LEGUMES

Beans, peas, and lentils serve as excellent sources of fiber and other complex carbohydrates, protein, and iron (38). The single common identifying factor among all the legumes is that they grow as seeds within a pod (Figure 13-16). Dried beans have served as a dietary staple since the Bronze Age.

Soybeans are unique in that, compared to other plant sources, they have relatively high protein and fat contents, and they can be used to make textured vegetable protein, soy milk (see Chapter 10), meat analogs, tofu, and fermented soybean foods (12).

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FIGURE 13-16 Dried beans.



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Textured Vegetable Protein

Textured vegetable protein (TVP) is derived mainly from soybeans, but other plants such as peanuts and cottonseed may be used in its production. In TVP, the plant material has been altered into fibrous, porous granules that rehydrate rapidly. TVP is often used to extend ground meats in order to lower costs and/or reduce fat content (17). The USDA limits the use of TVP in commercially prepared foods to no more than 30% of any particular product. One cup of TVP is usually rehydrated in a half cup of liquid before being added to hamburgers, hot dogs, chilies, tacos, spaghetti, lasagna, soups, meatloaf, pizza toppings, or other dishes. TVP burns easily, so it should be added only after the meat has been browned. It also retains moisture and contributes to texture by maintaining cohesiveness (17). TVP is available flavored or unflavored, and natural or caramel-colored. A common flavor enhancer in TVP is monosodium glutamate (MSG).

Meat Analogs

Meat analogs (also called meat substitute, mock meat, faux meat, or imitation meat) are imitations of meat products (30). They resemble meat, but are of plant origin, and usually made by blending soy protein with other vegetable proteins, carbohydrates, fats, vitamins, minerals, colorings, and flavors (30). Although its use in the United States started in the 1960s when the USDA allowed soy protein isolates to constitute 2% of cooked sausage, tofu dates back more than 1,000 years in China. Buddhists often consumed tofu as part of their vegetarian lifestyle (17). Today, there are meat analog products that can stand in for breakfast sausages, bacon, ham or turkey slices, pizza toppings, chicken patties or "nuggets," chicken or beef chunks, chili mixes, and taco fillings. Even the classic hamburger and hot dog can be made with nonmeat ingredients. These products contain one-third the fat of the meats they replace, and no cholesterol; however, depending on how they are made, the protein quality is relatively low because soy protein lacks sufficient amounts of the essential amino acid methionine. They are also higher in sodium and more costly than the meats they simulate. However, when used with a mixed diet of grains and seeds, these meat analogs can contribute to a balanced diet.

Tofu

Tofu is the "cheese" made from soy milk. The protein in soy milk is precipitated out through the use of coagulants: salts such as calcium sulfate dihydrate (increases volume), calcium chloride (increases firmness and calcium content), and/or magnesium chloride; acids (glucono delta-lactone); and enzymes (papain and proteases) (34). Choosing the coagulants determines the quality of the produced tofu. After the soy milk coagulates, and the liquid is removed, the curds are pressed into blocks that removes more liquid and determines the desired texture: silky, soft, firm, or extra firm. Fresh tofu blocks are sold in plastic containers filled with water, in aseptic packages with no water, or in bulk by selling several blocks together in buckets of fresh water. When refrigerated, tofu is relatively stable. Once opened, draining off the water prior to and during refrigeration and replacing it with fresh water increases its shelf life.

Tofu has a bland flavor, and its texture varies in consistency and firmness. It is available in smoked, dried, seasoned, and sweetened varieties. The curd is often used in stir-fried dishes, sandwiches, soups, casseroles, and egg or meat dishes.

Fermented Soybean Foods

The fermentation of soybeans results in several different foods, including miso, natto, sufu, tempeh, and tamari.

- ***Miso***. A fermented paste made from soybeans (plus salt, sometimes other grains such as rice, barley, etc., and koji, which is *Aspergillus oryzae* fungus, a mold) that is used as a seasoning to make miso soups, stews, dressings, dips, sauces, and gravies (18). There are as many different types of miso in Japan (white to red in color) as there are cheeses in the United States.
- ***Natto***. Natto is a traditional Japanese condiment often served over rice

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with soy sauce and green onions. The fermented cooked soybeans (*Bacillus subtilis* bacteria) have a strong aroma, and sticky, stringy consistency.

- ***Soy sauce (shoyu or soya sauce)***. A condiment produced from a fermented and aged (6 months) paste of boiled soybeans, wheat, salt, and *Aspergillus oryzae* or *A. sojae* fungus. A synthetic or nonbrewed soy sauce usually contains caramel color, hydrolyzed soy or vegetable protein, and corn syrup (32). Traditional soy sauce can still be found and is produced from soybeans (no wheat).
- ***Sufu***. Also known as bean cake, this is a fermented tofu (*Actinomucor elegans* fungus) with a cream cheese type consistency.
- ***Tempeh***. A fermented soybean cake originating in Indonesia that is made from fermented (*Rhizopus oligoporus* fungus) whole soybeans and grains such as rice and millet, and then molded into a cake.
- ***Tamari***. Tamari is a naturally aged and fermented soy sauce that is less salty and milder than regular soy sauce. Its ingredients include soybeans, water, and salt, but not wheat.

PREPARATION OF VEGETABLES

General Guidelines

Vegetables can be prepared by dry-heat methods (baking, roasting, sautéing, or deep-frying) or moist-heat methods (simmering, steaming, braising, or microwaving). Serving styles also vary and include plain, buttered, creamed, **au gratin**, glazed, **scalloped**, and stuffed, or they are used in soufflés, omelets, and cream soups. Regardless of the cooking method or serving style selected, some general principles governing the handling and preparation of vegetables should be followed:

- ***Buying***. Purchase only the freshest possible vegetables in amounts that will be used within a few days.
- ***Storing***. Store vegetables immediately at the appropriate temperature, and do not leave them out of storage for any length of time unless they are being prepared. Leftovers should be refrigerated immediately and used within 3 days.
- ***Washing***. All vegetables must be thoroughly washed (with a vegetable brush when appropriate) to remove soil, microorganisms, pesticides, and herbicides. Washing should be quick because most vegetables absorb excess water when soaked. Many root vegetables, except beets and baked potatoes, are peeled of the outer layer that would normally be washed.
- ***Cooking liquid***. Vegetables should be cooked in as small an amount of liquid as possible; in many cases, leftover liquids may be saved for stock. Using a microwave minimizes the amount of water used.
- ***Cooking time***. The cooking time should be as short as possible; most vegetables will undergo undesirable changes in quality when heated too long. Vegetables should be served promptly after cooking.

How & Why?

How are potatoes, sweet potatoes, and yams different from each other?

Potatoes are actually **tubers** of the *Solanum tuberosum* family. Sweet potatoes are *roots* and part of the morning glory family (*Convolvulacea*) (44). Contrary to popular belief, sweet potatoes and yams are not the same vegetable. True yams are also roots, but they are of the *Dioscorea* genus, larger in size, yellow to white in color because they contain very little β-carotene, and sold mostly in Caribbean or Latino markets. The "yam" sold in North American markets is, in fact, a variety of sweet potato developed in the 1930s by a horticulturist who wanted to distinguish it from other sweet potatoes (53). For many years, the produce and grocery industries have used the term *yam* to describe sweet potatoes with a bright orange color and sweet, moist flesh. Sweet potatoes are often misidentified as yams, so the USDA requires that sweet potatoes described as *yams* must also carry a *sweet potato* label (43).

Changes During Heating

When heated, vegetables undergo several changes in texture, flavor, odor, color, and nutrient retention. Understanding these phenomena can help to retain as much of their quality as possible during preparation.

Texture

High temperatures gelatinize starch, decrease bulk by softening cellulose, and cause a reduction in turgor due to water loss. Although this is desirable when baking potatoes or cooking legumes, it is not recommended for most other vegetables; they should be heated until barely cooked. Acids or acidic foods, such as vinegar or tomatoes, should be added toward the end of the cooking time because they make vegetables more resistant to softening and, by precipitating vegetable pectins, increase required heating time.

To compensate for turgor lost during processing, calcium salts are often added to pickles, canned vegetables, and fruits to make them firmer (31). The salts combine with pectic substances and become insoluble, firming the food's texture. Other calcium sources include molasses, hard water, and brown sugar. Sometimes the toughness of green beans and other vegetables actually results from preparing them in hard water. Adding alkaline ingredients such as baking soda has the opposite effect—these break down cellulose and produce a very mushy texture.

Flavor

Vegetables obtain their flavors from an assortment of volatile oils, organic acids, sulfur compounds, mineral salts, carbohydrates, and polyphenolic compounds. In general, to retain these flavor compounds, vegetables should

Au gratin Food prepared with a browned or crusted top. A common technique is to cover the food with a bread crumb/sauce mixture and pass it under a broiler.

Scalloped Baked with milk sauce and bread crumbs.

Tuber Enlarged tip of a rhizome (underground stem) that stores food.

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be heated in as little water as possible and for as short a time as will do the job. There are exceptions; cooking for long periods with gentle heat yields milder flavors in onions. Garlic flavor also depends on whether it is raw or cooked. Raw garlic is very pungent, yet becomes mellow or sweet when cooked slowly, and even nutty and rich when cooked at length. Only low to medium-low heat should be used for cooking garlic because it cooks quickly and will become bitter when burned. Most of the substances that cause bitterness in vegetables such as cucumber and eggplant can be eliminated with peeling. Those that lurk under the skin can be drawn out prior to cooking by the technique of **degorging**. Droplets containing the bitter compounds are drawn out by osmotic pressure and can then be soaked up with a paper towel or rinsed off and patted dry.

Odor

Food odors contribute to the perception of flavor, but some odors, such as that from cooked cabbage or onions, may be undesirable. These pungent odors are generated by sulfur compounds present in the *Cruciferae* family (the cruciferous vegetables) and the *Allium* genus (onions, garlic, shallots, leeks, chives) (51).

Garlic, onions, shallots, and leeks are odorless until they are cut or bruised, which allows an enzyme to contact a particular substrate to create a distinctive-smelling sulfur compound (Chemist's Corner 13-5). The strong odors of cooked cabbage and onion can be reduced by shortening the heating time, adding a little vinegar to the cooking water, and/or by removing the lid occasionally during cooking to let volatile organic acids escape.

Color

Both fat- and water-soluble pigments are affected by pH, heating, and the presence of metals (Table 13-4). Undesirable color changes can be prevented in several ways. Red cabbage, rich in anthocyanins, is prevented from turning blue if cooked with something acidic such as apples or a teaspoon of vinegar or lemon juice. Anthoxanthin-containing foods such as potatoes, rice, cauliflower, and onions are normally creamy white in color, but turn yellowish if exposed to hard water. This can be prevented by adding ½ teaspoon of cream of tartar, vinegar, or lemon juice

Degorge To peel and slice vegetables, sprinkle them with salt, and allow them to stand at room temperature until droplets containing bitter substances form on the surface; the moisture is then removed.

CHEMIST'S CORNER 13-5

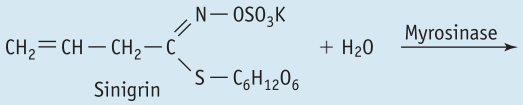
The Chemistry of Pungent Odors

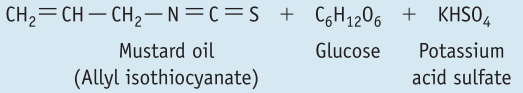
Pungent odors from vegetables in the *Cruciferae* family (e.g., cabbage) and *Allium* genus (e.g., onion) are released by overheating. In cabbages, the heat triggers enzymes such as myrosinase that release an excess of hydrogen sulfide gas (H_2S) and convert sinigrin, a sulfur compound, to mustard oil (Figure 13-17). The flavor of cabbage is further affected by the sulfur compound (+)-S-methyl-L-cysteine sulfoxide as it converts to dimethyl sulfide.

Garlic's sulfur compound, alliin, is odorless until the garlic is cut; cutting allows alliinase enzymes to come in contact with the alliin and convert it to thiosulfinates and volatile, odorous disulfides (Figure 13-17) (60). Exposure to this vapor triggers tears during onion cutting. Two methods to prevent tearing include placing the onions in the refrigerator for an hour to slow down all chemical reactions or wearing a diving mask so the vapor cannot reach the eyes and nose. The thiosulfinates also act as antibiotics, which is probably why warriors rubbed cut onions on their wounds prior to the development of antibiotics. Leeks and scallions contain the same substances, but in lesser concentrations. Pyruvate (pyruvic acid) is also formed and can be measured as a direct equivalent to an onion's pungency (1).

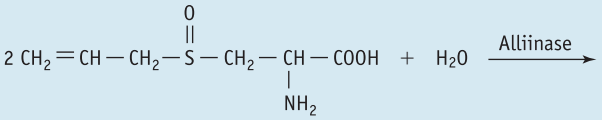
FIGURE 13-17 Heating *Cruicferae* family and *Allium* genus vegetables generates odorous sulfur compounds.

Mustard Oil Formation in Cabbage

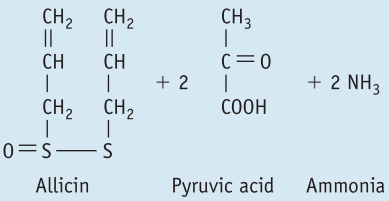




Allicin Formation in Garlic



Alliin (S-allyl-L-cysteine sulfoxide)



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TABLE 13-4 Pigment Colors Change in the Presence of Acid, Alkali, Heat, and Metals

Pigment	Original Color	Acid	Alkali	Heat	Metal
Carotenoids					
	Orange-red Yellow-orange	Lighter color	Brownish	Lighter orange	No effect
Chlorophyll					
Chlorophyll a	Blue-green	Gray-green	Bright green (chlorophyllin)	Initial bright green, then dull olive brown	Copper and zinc help to retain the green color of chlorophyll, but they are not used because of possible toxicity
Chlorophyll b	Green	Olive brown (pheophytin)	Bright green (chlorophyllin)	Initial bright green, then dull olive brown	See above
Flavonoids					
Anthocyanin	Red-purple	Red	Blue, purple, green	Dull reddish-brown	Copper, iron, aluminum, and tin change red-purple colors from green to slate blue
Anthoxanthin	Cream/white	Whiter	Yellowish white	Little change; possible yellowing	Aluminum results in loss of white, yellow hue; whereas iron darkens the cream/white pigments
Betalains	Purple-red/yellow	Red	Yellow	Darkens	Iron darkens, aluminum turns betalains a bright yellow

to each gallon of water used. Adding baking soda to green vegetables makes them appear greener; however, this is not recommended because of the deleterious effect on B vitamin content and texture.

Influences on color other than pigments include the Maillard reaction, the caramelization of sugars, and enzymatic browning (2). Enzymatic browning may be observed in cut-up potatoes that turn pinkish-brown when exposed to oxygen (55). Some potatoes turn dark blue-gray when oxygen reacts with their natural iron content. This discoloration can be prevented by blanching (41) or by soaking cut potatoes in water sprinkled with a little lemon or orange juice, or with cream of tartar added (1 teaspoon per quart) to increase acidity.

Nutrient Retention

Careful preparation of vegetables conserves important nutrients. Because leaching is the greatest cause of mineral loss in vegetables, it is important to cook them using as little water as possible. In many instances, it is better to avoid immersing them in water altogether and instead prepare them by steaming, braising, baking, or microwaving. Other ways to minimize nutrient loss are to leave the skin on whenever possible, to cut vegetables into fewer, larger pieces rather than many smaller pieces, and to cook just to the point of doneness and no further.

Some nutrients may actually increase during food preparation, desirably or not. Frying vegetables increases the fat content of the finished product. Heating also increases the amount of protein available from legumes by destroying the enzymes known as protease inhibitors. Heat softens a food's fiber content and may even increase it as a percentage of weight after some natural water loss due to heating.

Dry-Heat Preparation

Baking

Some vegetables—especially potatoes, winter squash, onions, stuffed green peppers, and tomatoes—can be baked whole at approximately 350°F (177°C).

Potatoes

Potatoes are the most commonly baked vegetable and take approximately 1 hour, depending on their size and the oven temperature. Not all potatoes, however, lend themselves to baking. The starch content, density, and **specific gravity** of a potato determine whether it is a *boiler* or a *baker*. If a potato floats in a saline solution (½ cup salt in 5½ cups water), it is best for simmering. If it sinks to the bottom, it is best for baking. Russet and Idaho varieties, which are mealy potatoes, have a high starch content and are good for baking and mashing because they yield a dry, light, fluffy texture. Cream of tartar is sometimes added to yield a whiter color (Chemist's Corner 13-6). When these potatoes are whipped, they readily incorporate air and soak up added milk and butter. Medium-starch potatoes, such as white potatoes, are all-purpose and are suited for both baking and simmering.

Potatoes may be pierced with a fork before baking or after they have been cooked for 20 minutes (to allow the steam to build up). After they are in the oven, it is best to turn them every 20 minutes for even baking. Wrapping

CHEMIST'S CORNER 13-6

Cream of Tartar and Potatoes

Oxidation of the potato's iron content from ferrous (2^+) to ferric (3^+) results in a dark pigment that makes the potato appear less white. Acid, in the form of cream of tartar, keeps mashed potatoes looking whiter by keeping the iron in the reduced ferrous state, preventing it from being oxidized.

Specific gravity The density of a substance compared to another substance (usually water).

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them in aluminum foil retains their moisture, resulting in a gummier potato, and produces a softer skin, which may or may not be desirable. Foil-wrapped potatoes are steamed, in addition to being baked.

Potatoes can be checked for doneness by squeezing them with an oven glove to see if they give in to pressure and feel soft under their skins. A fluffier potato results if the potato is massaged slightly before being slit open. Once opened, pushing the two ends of the potato together plumps up the insides, making them still more fluffy and easier to empty.

Roasting

Increasingly popular are roasted vegetables such as peppers, onions, and eggplant, which are generally sprinkled with oil and roasted at 375 to 425°F (191 to 218°C) until tender and well browned. Almost all vegetables can be roasted, and this technique creates a very flavorful vegetable as a result of its softer texture and sweeter taste after caramelization. Boiling potatoes briefly in salted water (parboiling) prior to roasting will ensure that they will cook all the way through (52).

Frying

Vegetables can be pan-fried, stir-fried, or deep-fried. The potato is the most commonly pan-fried vegetable.

Stir-Frying

Stir-frying combines a little oil with the vegetable's natural moisture. For best results, tender, quick-cooking pieces such as mushrooms are cut into large, uniform slices, whereas less tender pieces such as carrots and celery are cut to expose the greatest amount of surface area to the heat. Although not necessary, a tight cover over the pan or wok will trap steam and reduce heating time, retaining maximum nutrients, color, and texture, although the vegetables will not brown as readily in the presence of trapped steam.

Deep-Frying

Deep-frying continues to be popular despite the associated increase in fat content. This method is used especially for French fries, onion rings, and breaded zucchini. High-starch russet and Idaho potatoes are preferred for French fries and potato chips (Chemist's Corner 13-7). Potatoes are selected for producing commercial potato chips based on the amount of sugars (specifically, reducing sugars) they contain: the less sugar, the more desirable the potato. These sugars contribute to excessive Maillard browning during frying and are considered a major quality defect (45). Other vegetables well suited for deep-frying are mushrooms, long beans, broccoli florets, okra, and eggplant.

CHEMIST'S CORNER 13-7

French Fry Phenomenon

High-starch potatoes (Russets, Idahoes, and Russet Burbanks) are used to prepare French fries that are crispy, golden on the outside, yet dry and fluffy on the inside. As a freshly cut fry is placed in hot frying oil, the outside starch granules swell and pull moisture from the interior of the potato. The heat seals the outside surface, preventing any more oil from being absorbed by the French fry (40).

Moist-Heat Preparation

Simmering

Vegetables should not be boiled but instead simmered in as little water as possible to avoid nutrient loss and adverse effects on flavor, texture, and color. To simmer, vegetables (with the exception of potatoes) are added to lightly salted boiling water; when the water starts to return to a boil, the heat is immediately lowered to a simmer, and the vegetables are cooked until tender. Mushy textures result from overcooking vegetables or boiling them heavily so they bounce against each other. During simmering, the lid may be left off to allow volatile acids to escape, but leaving it on reduces the heating time. Approximate times for cooking vegetables vary from 5 to 30 minutes, with beets exceeding this general time frame by taking about 30 to 40 minutes for young beets and up to 2 hours for older beets.

Potatoes (peeled or unpeeled) are always started in cold salted water, brought to a boil, and lowered to a simmer. Waxy potatoes such as Round Reds have less starch than others and are more suited for simmering. Their higher moisture content and better ability to hold their shape make them appropriate for such dishes as potato salad, soups, casseroles, and scalloped potatoes.

Simmered vegetables may be served puréed or prepared as baby food. Young, tender vegetables are thoroughly scrubbed, cooked, and puréed. The puréed mixture is then heated to the boiling point, cooled, and served.

Amount of Water

There are two philosophies on the amount of water to use to cook vegetables properly: (1) use a minimal amount of water to reduce leaching, or (2) use a large volume of simmering water to ensure that the vegetables are cooked as quickly as possible. Some people feel that the speed of cooking in larger amounts of water far outweighs any nutrients lost in the cooking liquid; however, many professional chefs choose the first option.

Steaming

Steaming sometimes takes a little longer than simmering (about 5 to 10 minutes more), but it provides better retention of flavor, texture, and color. For steaming, a loose, shallow layer of vegetables is placed in a perforated basket inserted in a pan just above simmering water (Figure 13-18) and cooked, tightly sealed, until just tender (4). Pressure cookers are not recommended because their high temperatures make vegetables mushy; legumes such as pinto beans are the exception.

FIGURE 13-18 Equipment used to steam food.



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Foil-Wrapped Vegetables

Yet another method to prepare vegetables using steaming is to wrap them in aluminum foil and heat them in the oven at 350 to 400°F (177 to 204°C) for about 20 to 30 minutes. Prior to being placed in the aluminum foil wrap, they can be tossed with herbs (rosemary, thyme, sage), seasonings (garlic, salt; pepper upon serving), and a little fat (oil or butter). The vegetables heat in the flavored steam to become softer and tastier.

Braising

Vegetables can be braised by first browning them in a sauté pan and then simmering them in their own juices (37). This method generates a tasty vegetable because of the caramelized flavor that develops during sautéing. A dash of sugar contributes to the browning and flavoring. Adding minced garlic or sliced onions supplies even more flavor. When caramelizing vegetables, know that there is a fine line between browning and burning. Adding a few tablespoons of water just as the vegetable, especially onion, is about to burn will prevent it from burning.

How & Why?

How can you combat the heat when eating hot peppers?

Most people in Mexico use salt and a sliced tomato to neutralize the heat from too much chili pepper.

Microwaving

One of the best ways to retain a vegetable's texture, color, and nutrient content is to cook it in a microwave oven because this method requires very little water and is fast enough to minimize loss of quality. The manufacturer's instructions should be followed for the specific vegetable being prepared, but general guidelines for microwaving vegetables include adding a minimal amount of water, covering with plastic wrap, and microwaving for about 3 to 10 minutes (rotate or rearrange in the middle of the time period) until fork tender.

Frozen vegetables may be cooked in the microwave oven without adding water because water is already present. Canned vegetables are already cooked and need only to be reheated in the canning liquid and then drained. Home-canned vegetables low in acid concentration (above pH 4.6) such as green beans should not be microwaved but rather boiled for 10 minutes to prevent possible foodborne illness (botulism).

Preparing Legumes

Legumes are best prepared by simmering rather than boiling. One cup (½ pound) of dried beans usually yields 2 to 2½ cups of cooked beans; ½ cup of cooked dried beans or peas may be counted as a 1-ounce serving of meat or as one vegetable serving. Cooked legumes can be eaten plain or mixed and matched with other foods, as in red beans and rice, bean burritos, and tostadas. There are three methods for preparing dried beans: overnight soak, short soak, and no soak.

Overnight Soak Method

The beans are sorted, thoroughly rinsed, and then immersed in water; those that rise to the top or are shriveled are discarded. The remaining beans are soaked in a volume of water amounting to three or four times their quantity; that is, 2 cups of dried beans require 6 to 8 cups of cold water. After soaking for approximately 10 hours, they are either drained and combined with fresh water for cooking or simmered directly in their soaking liquid until tender. A lid is used but should be shifted slightly to the side to avoid boiling over. During simmering, water is added as needed to compensate for evaporation loss. Soaked beans require a long, slow cooking time to break down their hard-to-digest starches (Table 13-5).

Short-Soak Method

Sorted and rinsed beans are brought to a full boil for 2 minutes, removed from the heat, and allowed to soak in the same *hot* water for 1 hour. They are then simmered as above in their soaking liquid.

No-Soak Method

Beans can be prepared without soaking, but they take twice the amount of water and double the heating time; they also lose their skins more easily.

TABLE 13-5 Cooking Time for Beans (after a 10-hour soak)

Beans	Approximate Cooking Time
Garbanzo (chickpeas)	4 hours
Mung beans	3 hours
Black beans	1½ hours
Pinto beans	2 hours
Soybeans	2 hours
Black-eyed peas	1 hour
Kidney beans	1½ hours
Lentils, split peas*	20–30 minutes depending on the variety, age, and size (smaller red lentils take only 15 minutes)

*Lentils and split peas are usually not soaked; cooking time is ¾ to 1 hour if they are cooked from the dry state.

The no-soak method is used for lentils and split peas because their smaller size results in shorter cooking times.

How & Why?

Why isn't hard water, salt, or acid added to cooking beans?

When cooking legumes, it is important not to use hard water and not to add salt or acid in the form of tomato products or lemon juice until the beans are well cooked because these substances inhibit the softening of pectic compounds.

Indigestible Carbohydrates

One pitfall of eating legumes is that it often causes flatulence. Gases (hydrogen, methane, and carbon dioxide) are produced by intestinal bacteria when they ferment the bean's indigestible carbohydrates, such as raffinose and stachyose (13). The problem can be minimized by soaking the beans, draining their water, rinsing them well before cooking, and then cooking them properly in fresh water, although this may result in a decrease in nutrients. Enzyme-containing commercial products such as Beano™ may also be taken just before the food is consumed to assist in digestion.

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Preparing Sprouts

Any whole grain or legume can be sprouted (germinated) into fresh greens. The process of sprouting enhances flavor, nutrient content, palatability, and digestibility. Sprouting releases enzymes such as α-amylase that break down the starches into more readily digestible sugars (28).

Growing Sprouts

The procedure requires a jar equipped with a mesh top, which can be purchased at a health food store or made by topping a jar with cheesecloth and securing it with a rubber band. The seeds are rinsed and then placed in the jar with three times as much water as seed. An overnight soak in lukewarm water starts the majority of seeds on their way to sprouting, with small seeds needing only 4 hours and others, particularly seeds with very hard coats, requiring 2 days. Alfalfa and oat seeds do not need a presoak. Table 13-6 provides a list of seeds and preparation guidelines.

After soaking, the water is drained from the seeds, and the jar is placed in a warm, dark place, positioned at an angle to let any water drain, and covered with a towel. Then the seeds must be rinsed at least twice daily, sometimes more often, with lukewarm water. Care must be taken to keep the seeds moist but not wet because dried-out seeds do not sprout, whereas too much water causes spoilage. The rinsing process must be carried out gently and evenly so the seeds are not ripped from their tender sprouts.

After the sprouts reach their full height, they are placed in direct sunlight to develop the chlorophyll, which will turn the leaves green within a day. Most sprouts are ready to eat within 3 to 6 days after presoaking. To make sprouts more pleasant to eat, the seed hulls can be removed by filling the sink with cold water, dropping in the sprouts, allowing the hulls to float to the surface, and skimming them off with a strainer.

Respiration rate The rate of carbon dioxide production from a given amount of produce over a certain unit of time.

Storing Sprouts

Sprouts must be stored in the refrigerator and rinsed thoroughly before use. The Food and Drug Administration (FDA) has warned that sprouts, especially alfalfa sprouts, have been responsible for several foodborne illnesses. As a precaution, some sprout preparers soak seeds in a very weak bleach solution (1 teaspoon per gallon of water) for 30 minutes and then rinse them with clean water prior to sprouting.

STORAGE OF VEGETABLES

After vegetables are harvested, they are still viable and continue to respire by taking up oxygen and releasing carbon dioxide. This natural respiration contributes to the deterioration of their appearance, texture, flavor, and vitamin content. The faster a vegetable's respiration, the more quickly it deteriorates. Post-harvest **respiration rates** differ among vegetables, which explains why potatoes (yielding only about 8 mL of carbon dioxide per hour at 59°F [15°C]) last longer than cabbage and green beans (yielding 32 and 250 mL of carbon dioxide per hour, respectively) (15).

Another factor contributing to produce spoilage is loss of moisture. Vegetables and fruits are highly perishable because they contain about 80 to 90% water (by weight). After being picked, the water is no longer replaced by the source plant's root or leaf system. Water loss, resulting in wilting and accelerated decomposition, can be avoided by maintaining a humid atmosphere, spraying with a fine mist, and/or covering the produce with an edible film or coating (Chemist's Corner 13-8). Optimal humidity for most vegetables and fruits is 85 to 95% (8). Ultimately, the key to properly storing vegetables is

CHEMIST'S CORNER 13-8

Edible Films

Tasteless, odorless films can be made from carbohydrate, protein, or lipids that can then be mixed with plasticizers, antimicrobial agents, vitamins, minerals, colors, or flavors (14). Some of the most common edible films are derived from natural substances such as zein (corn), chitosan (shellfish), casein (milk), and alginate (gum). Other edible coatings include whey protein isolate (WPI), beeswax, or carnauba wax. Edible coatings are applied to foods through dipping, spraying, brushing, or panning followed by drying (14).

TABLE 13-6 Sprout Preparation

Seed	Quantity	Yield	Rinses	Time	Height
Adzuki	½ C	2 C	4	6 days	1 in.
Alfalfa (salads)	2 Tbsp	1 qt	2	4 days	1–2 in.
Beans (kidney, lima, fava, green, pinto)	1 C	4 C	4	6 days	2 in.
Chia	2 Tbsp	3 C	1	4 days	1½ in.
Cress	1 Tbsp	1½ C	2	4 days	1½ in.
Fenugreek (salad)	¼ C	4 C	2	5 days	3 in.
Garbanzo (chickpea)	1 C	3 C	5	4 days	½–1 in.
Guar beans (soak for 36 hours)	1 C	4 C	4	5 days	2–3 in.
Lentils	1 C	6 C	2	4 days	1 in.
Millet	1 C	2 C	3	3 days	¼ in.
Mung beans	1 C	4 C	4	4 days	2–3 in.
Peas	1½ C	4 C	2	4 days	½–1 in.
Radish	1 Tbsp	2 C	2	5 days	½–1 in.
Red clover	3 Tbsp	1 qt	2	5 days	1–2 in.
Soybeans	1 C	5 C	8	5 days	½–¾ in.
Sunflower	1 C	3 C	2	2 days	½ in.
Wheat	1 C	4 C	3	4 days	½ in.

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to slow their respiration and moisture loss, allowing them to stay fresh longer.

Refrigerated

A cooler temperature is the most important factor in reducing respiration rates, and most fresh vegetables will last at least 3 days if refrigerated (19). Storage times for various vegetables are ultimately based on their water content. Vegetables with a high percentage of water, such as lettuce, tomatoes, and spinach, have shorter storage times than do vegetables with less water content, such as potatoes, carrots, and turnips. Because leaves draw moisture from the rest of the plant, removing the green tops of carrots, radishes, or beets increases their storage time. Cooked beans will last up to 4 or 5 days in the refrigerator and up to 6 months in the freezer.

Special Storage Requirements

Some vegetables require special storage treatment. Certain fresh fruits such as avocados (in their skin), bananas, unripe tomatoes, and pears are best not refrigerated. Bean sprouts are best stored in a bowl of cold water in the refrigerator, and the water should be changed daily. Ginger root should be frozen or stored in an airtight container to trap its moisture. It will keep up to a week at room temperature and for a month in the refrigerator (59). Mushrooms will keep up to 5 days if refrigerated in a paper bag or basket but will deteriorate rapidly if exposed to moisture or warm air. Plastic bags are not recommended for mushrooms, which lack the protective skins of vegetables and fruits, contain 90% water, and emit a water vapor that collects inside a plastic bag even if it is vented with small holes. The increased humidity causes brown and black blotches on white mushrooms. Eggplants deteriorate quickly in either warm or cold temperatures, so they should be kept in a cool location (in an aerated plastic bag), where they will normally keep for about a day or two. Asparagus lasts longest if treated like flowers and refrigerated with the stem ends in a jar filled with about 1 inch of water (26).

Maintaining Moisture

An excellent way to retain moisture in vegetables is to store them in the refrigerator's crisper, which is designed for that purpose. If a crisper is not available, plastic bags with tiny holes are a good choice because the holes allow the food to breathe. Airtight plastic bags are not suitable for storing vegetables because they cause them to "stew," thus promoting spoilage. Wrapping paper towels around moist vegetables can help to avoid the spoilage caused by dehydration.

Freezing

Fresh vegetables should not be frozen unless they are first blanched; their high water content causes undesirable texture changes when cell membranes burst upon freezing, and certain enzymes cause undesirable browning and deterioration (62).

Dry Storage

Proper storage does not automatically imply refrigeration. Tomatoes (unripe), eggplant, winter squash, tubers (potatoes), dried legumes, and most bulbs (onions) should never be stored in a refrigerator. Tomatoes are picked green while still firm in order for them to handle the rigors of transportation; however, once at their destination, their ripening can be accelerated by placing them in a paper bag. Keeping them in a bag protects tomatoes from direct sunlight, which softens rather than ripens them. Tomatoes placed in the refrigerator will never reach their optimal flavor and texture. In fact, flavor enzymes will be destroyed, and the tomatoes will lose their texture and become more mealy. They should be stored in the refrigerator only when fully ripe to slow spoilage. Dried beans will keep up to a year stored in airtight containers in a dry place, but if kept too long and/or at high humidity (80%) and temperatures, dried beans will be difficult to cook (Chemist's Corner 13-9).

Storing Potatoes

Potatoes stored in the refrigerator undergo the conversion of their starch to glucose and develop an undesirable waxy consistency when cooked. French fries made from refrigerated potatoes turn an undesirable brown (46). Potatoes should not be exposed to sunlight, which will cause photosynthesis to take place, producing a bitter taste and, eventually, a potentially toxic compound called solanine, which can be seen as a slightly green tint on potato skins and sprouts. Eating large amounts of these green potatoes is not recommended because it may lead to poisoning (23). Potatoes will keep for a couple of weeks at room temperature stored in a basket or bag with holes, or longer in a cool root cellar (45 to 50°F [7 to 10°C]). The exception is new potatoes, which are very perishable and should be used within a few days. Onions and potatoes should not be stored next to each other because they shorten each other's shelf life.

CHEMIST'S CORNER 13-9

Legume Storage

It has been known since the third century that certain changes occur in legume seeds during extended storage, especially at high temperatures and humidity, making them difficult to cook. This *hard-to-cook* phenomenon is a result of several hypothesized changes at the molecular level. The pectin–cation–phytate theory suggests that during storage, an intracellular enzyme (phytase) hydrolyzes phytin, resulting in the release of divalent cations. After cooking begins, monovalent cations from the pectin located in the cell wall exchange with these divalent cations to form insoluble pectin. The walls, lined with this insoluble pectin, become extremely strong and make long-stored legumes difficult to cook. Another factor thought to contribute to this phenomenon is the interaction between the protein and starch. The proteins tend to overcoagulate when heated, preventing starch from absorbing enough water to permit hydration and proper swelling (29).

Controlled-Atmosphere Storage

Beyond simple refrigeration is a high-tech method of preservation called "controlled-atmosphere storage," available to commercial food companies. This special method slows down the natural respiration of fresh vegetables by reducing the amount of oxygen and increasing the amount of carbon dioxide available to them while in storage (35). Such a contrived environment reduces a vegetable's respiration and/or metabolic rate to such a degree that lettuce can last up to 75 days. Other advanced storage methods include modified-atmosphere packaging (MAP), edible coatings, and plastic shrink- or stretch-wraps (39).

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PICTORIAL SUMMARY / 13: Vegetables and Legumes

Vegetables in raw or cooked form add color, flavor, and texture to meals as well as enhance a meal's overall nutritional value.

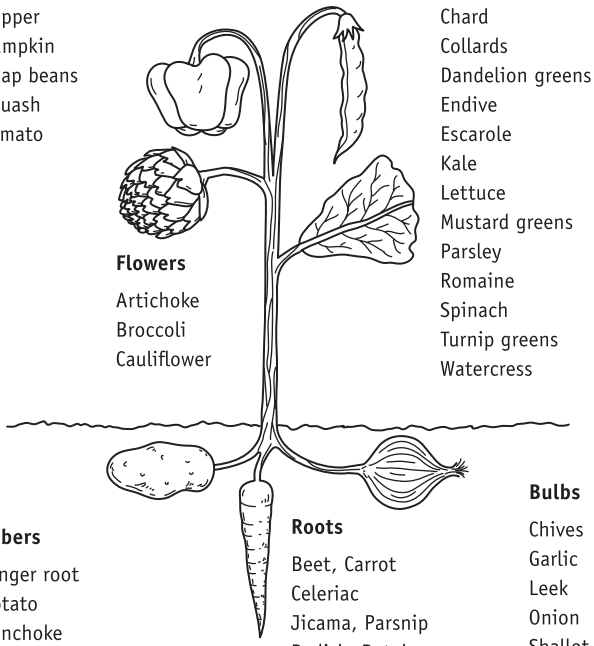
CLASSIFICATION OF VEGETABLES

Vegetables may be derived from almost any part of the plant. Plant parts considered edible include the roots, bulbs, stems, leaves, seeds, and even flowers. A few vegetables are actually fruits; that is, they are the part of the plant that contains its seeds.

Fruits
Avocado
Cucumber
Eggplant
Okra
Pepper
Pumpkin
Snap beans
Squash
Tomato

Seeds
Beans, Corn
Lentils, Peas

Leaves
Beet greens
Bok choy
Brussels sprouts
Cabbage
Chard
Collards
Dandelion greens
Endive
Escarole
Kale
Lettuce
Mustard greens
Parsley
Romaine
Spinach
Turnip greens
Watercress



Flowers
Artichoke
Broccoli
Cauliflower

Tubers
Ginger root
Potato
Sunchoke

Roots
Beet, Carrot
Celeriac
Jicama, Parsnip
Radish, Rutabaga
Sweet potato
Turnip

Bulbs
Chives
Garlic
Leek
Onion
Shallot

COMPOSITION OF VEGETABLES

Most fresh, unprocessed vegetables are cholesterol free and are naturally low in kcalories, sodium, and fat. Vegetables are usually good sources of carbohydrates (especially fiber), certain vitamins/minerals, and nonnutritive compounds called "phytochemicals," which possess health-protective benefits. Vegetables rich in fiber include the following:

- Kidney beans
- Navy beans
- Lima beans
- Lentils
- Peas
- Corn
- Parsnip
- Potato
- Broccoli
- Brussels sprouts
- Carrots
- Green beans
- Mung beans
- Spinach
- Sweet potato

PURCHASING VEGETABLES

Season, ripeness, freshness, yield, and appearance (no bruising or mold) are considered when selecting vegetables. USDA grades for various vegetables can be found at www.ams.usda.gov/grades-standards/vegetables. Grading is voluntary and based on ripeness, color, shape, size, uniformity, and freedom from bruising and decay. Individual selection criteria vary according to the vegetable.

LEGUMES

Beans, peas, and lentils grow as seeds within a pod. Soybeans are relatively high in protein and fat, and they can be used to make textured vegetable protein, soy milk, tofu, meat analogs, and fermented soybean foods, including miso, soy sauce, sufu, tempeh, and tamari.



PREPARATION OF VEGETABLES

Because heat affects the vegetable's texture, flavor, color, and nutrient retention, limiting cooking time helps preserve both flavor and appearance. Acidity toughens vegetables, whereas alkalinity causes excessive softening. Heating vegetables in as little water as possible with the lid on is generally recommended, with a few exceptions, to retain flavor and nutrients. Vegetables may be prepared by either dry-heat (baking, roasting, frying) or moist-heat (simmering, steaming, braising, and microwaving) cooking methods. Regardless of the method selected, vegetables should be thoroughly cleaned before preparation to remove soil, bacteria, and pesticide residues.



STORAGE OF VEGETABLES

Vegetables continue to respire after harvest, which contributes to the deterioration of their appearance, texture, flavor, and vitamin content. Refrigeration slows this process for most vegetables; tubers (potatoes), dried legumes, and most bulbs, however, lend themselves to dry storage. Controlled-atmosphere storage is a commercial process that extends vegetable shelf life by reducing oxygen and increasing the carbon dioxide in the surrounding air. Another commercial process that slows down respiration is coating vegetables with a thin, edible coating such as wax.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Which of the following would be classified as a root vegetable?
   a. Asparagus
   b. Broccoli
   c. Carrot
   d. Garlic

2. Carotenoids found in vegetables are susceptible to damage from which of the following factors?
   a. Light
   b. Heat
   c. Oxygen
   d. All of the above

3. What is the name of the pigment responsible for the green color of plants?
   a. Carotene
   b. Chlorophyll
   c. Lycopene
   d. Xanthophyll

4. Broccoli, cabbage, cauliflower, and kale belong to the family of _____ vegetables that may have protective effects against cancer.
   a. carotenoid
   b. phytochemical
   c. fibrous
   d. cruciferous

5. Tempeh is the name of a meat alternative made from whole _____ that have been fermented.
   a. pinto beans
   b. soybeans
   c. lentils
   d. navy beans

6. Legumes are a group of vegetables that include:
   a. tomatoes, eggplant, and zucchini.
   b. potatoes, peppers, and beets.
   c. brussels sprouts, cabbage, and cauliflower.
   d. beans, peas, and lentils.

7. Which vegetable should not be stored in the refrigerator?
   a. Potato
   b. Carrots
   c. Bean sprouts
   d. Squash

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

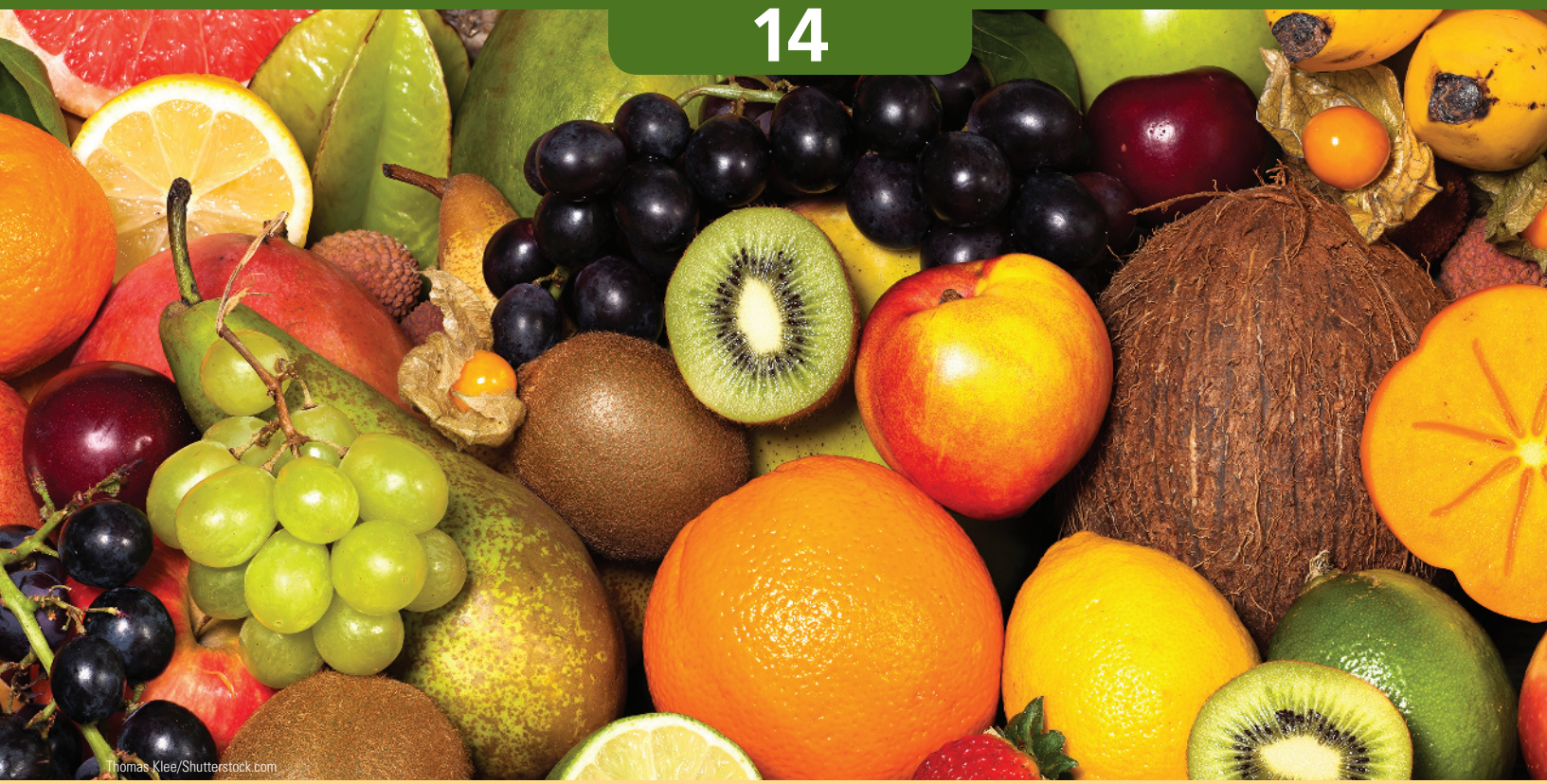
1. List the different classifications for vegetables, and provide examples for each group.
2. Explain how each of the following structural components of the plant cell relates to food preparation: cell wall, plastids, vacuoles, and intercellular air spaces.
3. What are the three major groups of plant pigments? Provide vegetable examples from each group.
4. Discuss how the plant pigments change color in the presence of heat and acid.
5. Describe the specific signs of ripeness for the following vegetables: asparagus, beans, broccoli, celery, garlic, mushrooms, and potatoes.
6. Define *au gratin, scalloped,* and *degorging*.
7. Explain why cabbage and onions have strong odors when cooked.
8. Discuss the various techniques for preventing undesirable color changes in certain vegetables.
9. Describe the three methods for preparing dried beans: overnight soak, short soak, and no soak.
10. Describe controlled-atmosphere storage, and explain why it extends the shelf life of fresh vegetables.

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14



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Fruits

Classification of Fruits . . . 284
Composition of Fruits . . . 285
Purchasing Fruits 289
Preparation of Fruits . . . 302
Storage of Fruits 307

Imagine bountiful cornucopias overflowing with **fruits**—nature's desserts available in almost every shape and color of the rainbow. Even in the times of the pharaohs, fruits were transported, sometimes with great difficulty, across continents and seas to eager consumers. Early explorers and migrating peoples carried fruits and their seeds to all parts of the world, so now many are grown in areas far from their original home. For centuries, dates were cultivated in North Africa, but now they are also grown in California. Pineapples were once indigenous to South America. Lemons and limes originated in India; oranges, now a daily component in many North American breakfasts, came from southeastern Asia; and the kumquat was brought to North America from China and Japan. The kiwifruit from New Zealand is one of the fruits most recently spread from its original home to North American markets. The Fruits and Veggies—More Matters™ campaign, sponsored by the Produce for Better Health Foundation and the Centers for Disease Control and Prevention, recommends that people fill half their plates with vegetables and fruits at each meal (19). This chapter looks at fruits—their classification, composition, purchase, preparation, and storage.

Fruit The edible part of a plant that develops from a flower.

Drupes Fruits with seeds encased in a pit. Examples are apricots, cherries, peaches, and plums.

Pomes Fruits with seeds contained in a central core. Examples are apples and pears.

CLASSIFICATION OF FRUITS

Fruits are the ripened ovaries and adjacent parts of a plant's flowers. They are classified according to the type of flower from which they develop: simple, aggregate, or multiple.

- ***Simple fruits.*** Develop from one flower and include **drupes, pomes,** and citrus fruits (oranges, grapefruits, lemons, limes, kumquats, and mandarins—tangerines and tangelos).
- ***Aggregate fruits.*** Develop from several ovaries in one flower. They include blackberries, raspberries, and strawberries.
- ***Multiple fruits.*** Develop from a cluster of several flowers. Pineapples and figs are two examples.

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Classification Exceptions

Sometimes it is difficult to tell the difference between a fruit and a vegetable. For example, is a tomato a fruit or a vegetable? The confusion over the tomato's classification even attracted the attention of the U.S. Supreme Court, which ruled it was a vegetable in 1893 (14). At the time, there was an import tax on vegetables but not fruits, so U.S. tomato growers changed the tomato from a fruit to a vegetable to protect themselves from foreign tomato growers trying to export to the United States. Despite the Supreme Court ruling, botanists beg to differ; botanically, the tomato grows from a plant's flower, so it is technically a fruit, even though it is not sweet. Squash, okra, green beans, and cucumbers, too, are botanically fruits. Nuts are actually fruits, also, but they are seeds rather than fleshy fruits, so they are grouped separately.

Confusion of the opposite sort is stirred up by rhubarb, which is really a vegetable but is usually treated as a fruit.

COMPOSITION OF FRUITS

The cellular structure and pigments of fruits are similar to those of vegetables, described in Chapter 13. Organic acids, pectic substances, and phenolic compounds are also found in some vegetables but have more relevance to fruits and are discussed here.

Organic Acids

Natural sugars such as fructose, glucose, and sucrose are the major contributors to the sweetness of fruits, whereas the tart flavor component is partially due to organic acids located in the cell sap. Acidity varies with the maturity of the plant, usually decreasing as the fruit ripens. The organic acids found in fruits are either volatile or nonvolatile. Volatile acids vaporize during heating, whereas nonvolatile acids do not, but they can leach out when fruit is cooked in water.

The common organic acids in fruit include citric acid in citrus fruits and tomatoes; malic acid in apples, apricots, cherries, peaches, pears, and strawberries; tartaric acid in grapes; oxalic acid in rhubarb; and benzoic acid in cranberries. Cranberry juice also contains a unique blend of quinic and malic acids in a ratio so consistent that it is used by juice processors to determine cranberry juice authenticity and to calculate the percentage of cranberry juice content in juice drinks (45). The oxalic acid in rhubarb can combine with calcium in the intestine to form calcium oxalate, an insoluble complex that cannot be absorbed. It may also combine with other minerals to form similar compounds.

Acidity of Fruits

Acids cause most fruits to have a pH value below 5.0 (Table 14-1). The tartness of fruits is related in part to their acidic content. For instance, limes, lemons, and cranberries are very tart fruits, with the lowest pH values (around 2.0).

TABLE 14-1 Average pH Values for Selected Fruits

pH	Foods
2.2	Lime juice
2.3	Lemon juice
3.1	Apples, boysenberries, grapefruit, prunes
3.2	Rhubarb
3.3	Apricots, blackberries
3.4	Strawberries
3.5	Orange juice, peaches
3.6	Raspberries, red sour cherries
3.7	Blueberries
3.8	Sweet cherries
3.9	Pears
4.0	Grapes
4.2	Tomatoes
4.6	Bananas, figs
5.1	Cucumbers
5.2	Squash

The least acidic fruits are more bland and sweet in flavor, and those with a pH above 4.5 most often serve as vegetables.

Pectic Substances

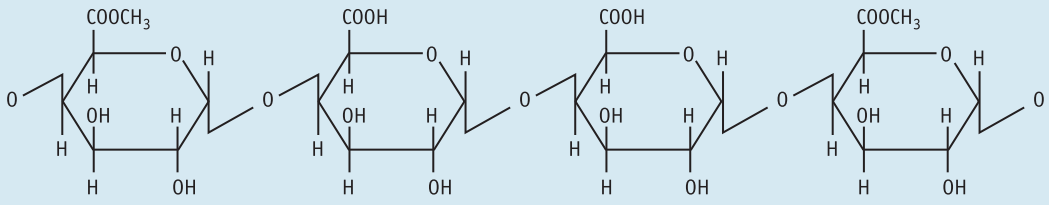
Another group of compounds frequently found in fruit are pectic substances, of which there are three types: protopectin, pectin (pectinic acids), and pectic acid. *Pectin* is a general term describing peptic polysaccharides, which act as a cementing substance between cell walls and are partially responsible for the plant's firmness and structure (Chemist's Corner 14-1). Pectin is used commercially to contribute to the gelling of fruit preserves. The string-like pectin molecules bond

CHEMIST'S CORNER 14-1

The Chemical Structure of Pectin

Depending on its source, pectin contains several different polysaccharides, but they all consist of methyl pectate, the compound responsible for gelling. The methyl pectate molecule, which has a high water-holding capacity, consists of a long, thread-like chain of repeating galacturonic acid units obtained from the sugar galactose (Figure 14-1).

FIGURE 14-1 Methyl pectate.



Portion of a methyl pectate molecule

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to each other under the right conditions to form a net-like solid structure that is able to trap water and form a gel. Pectin is found between the plant cells and within the cell walls but not in the juice, so commercial sources of pectin include the pulp (pomace) remaining after apples are pressed for juice and the spongy **albedo** of citrus fruits.

Use of Pectin by the Food Industry

In addition to its use in jams and jellies, pectin is used in several other foods as an emulsifier, stabilizer, thickener, and texturizer. Frozen foods benefit from pectin's ability to improve texture by controlling ice crystal size, preventing loss of syrup during thawing, and improving overall shape. Fruit pieces in yogurt are evenly distributed with the aid of pectin, and pectin imparts more body to diet soft drinks (46).

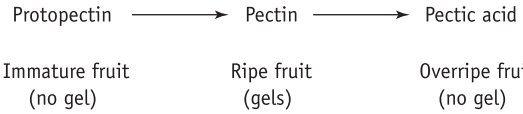
Pectin Formation in Ripening Fruit

Prior to the formation of pectin, the pectic substance in immature fruit is protopectin, a large, insoluble molecule. As the fruit ripens, enzymes convert protopectin to the more water-soluble pectin (18). Enzymes play a key role in the softening of fruits, with the largest influence derived from enzymes that break down pectin. Ripening mechanisms trigger the pectinase enzymes, which break down the pectic substances as the fruit ripens, and the degree of fruit softening is related to how many pectic substances were degraded. The stage of ripeness affects pectin concentration, and it is the pectin extracted from ripe fruits that is used to gel jams and jellies.

As fruit continues to ripen and becomes overripe, all the pectin gradually turns to pectic acid (Figure 14-2). Because neither protopectin nor pectic acid can contribute to gelling, only fruit at the height of ripeness should be used for making fruit spreads without added pectin. Heating also converts pectin to pectic acids by hydrolyzing the chemical bonds holding the molecules together, causing the texture of the fruit to become soft and eventually mushy.

Albedo The white, inner rind of citrus fruits, which is rich in pectin and aromatic oils.

FIGURE 14-2 Chemical breakdown of protopectin. Only fruits at the height of ripeness should be used for making fruit spreads without adding pectin.



Pectic Substances and Juice Cloudiness

When juice is extracted from fruits, pectic substances can sometimes cause it to cloud. Although this is desirable in orange juice, where it contributes to body, other juices, such as apple juice, are often more appealing to consumers if they are clear (56). One way to remove the cloudiness is through a clarification process in which enzymes such as pectinases are added to the juice to break down the pectin compounds. Juice processors can also add enzymes to certain juices to increase juice extraction. Enzymes such as cellulase and hemicellulase break down the cellulose and hemicellulose in cell walls, releasing more juice (24).

Phenolic Compounds

Phenolic compounds, another group of compounds found in fruits, are responsible for the browning and bruising that often occur in ripening fruit (49). These compounds, also known as tannins, are found predominantly in unripe fruits, giving them a bitter taste and leaving an astringent feeling in the mouth. Fruits containing phenolic compounds include apples, apricots, avocados, bananas, cherries, dates, grapes, nectarines, papayas, peaches, persimmons, pears, and strawberries (49).

Phenolic Compounds and Enzymatic Browning

All of the foods just listed turn brown from enzymatic browning, which, as you learned in Chapter 3, occurs in the presence of three substances: phenolic compounds, found within the cells; polyphenol oxidase enzymes (enzymes that oxidize phenolic compounds), also known as phenolase, catecholase, and tyrosinase; and oxygen, which enters the cells when the food is cut or bruised (Figure 14-3) (49). The polyphenol oxidase enzymes turn the color of the phenolic compounds from clear to brown. These brown compounds, called melanins, although they look unappetizing, are safe to consume.

FIGURE 14-3 Enzymatic browning in fruit is catalyzed (caused) by an enzyme (polyphenol oxidase).



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NUTRIENT CONTENT

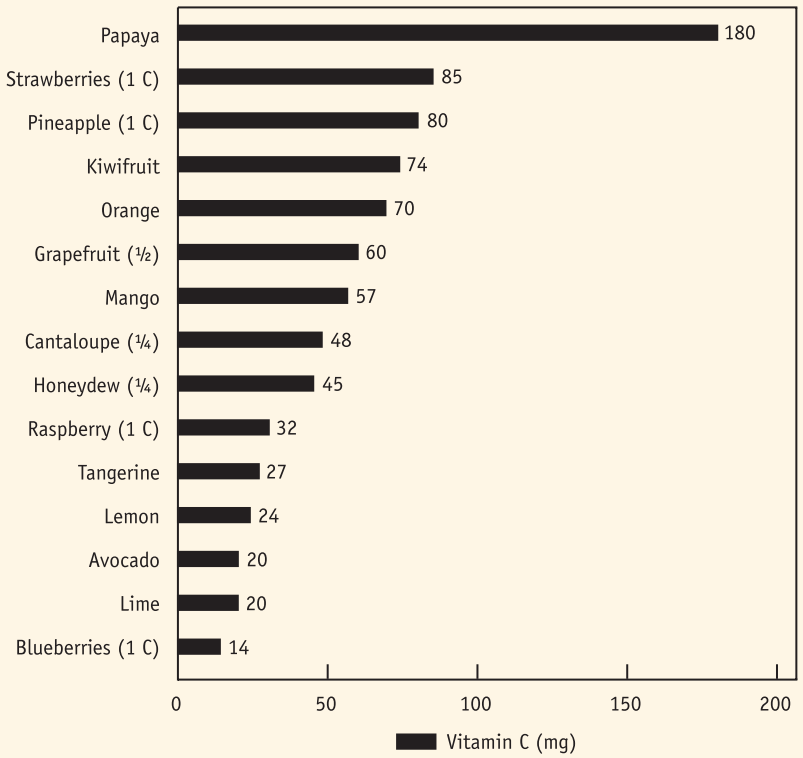
Nutritionally, fruits are **high in carbohydrates, phytochemicals, and water**, which composes 70 to 95% of fresh fruits. They tend to be low in kcalories, fat, and protein, as described in the Calorie Control feature.

Carbohydrates. **Carbohydrates are the main source of kcalories** in fruit (see the Calorie Control box). The carbohydrate in fruit starts out in the form of starch, but as ripening takes place, it is converted to sugars such as glucose, fructose, and sucrose. These sugars sweeten the fruit and increase its palatability. If the ripening process is inhibited, which occurs, for example, when bananas are refrigerated, the starch cannot be hydrolyzed to sugar; but when fruits are allowed to ripen normally, their sugar content increases as they mature. **Different types of fruits contain different amounts of carbohydrate**: avocados contain only 1% carbohydrate, whereas dates can run as high as 61% carbohydrate. Canned or frozen fruits with added sugar have higher carbohydrate concentrations and thus greater caloric content.

Fat. The **exceptions to the "fruits are low in fat" generalization are coconuts, avocados, and olives**, as shown in Table 14-4. The fat in coconut is predominantly saturated, whereas that in avocado and olives is mostly monounsaturated. Fruits are cholesterol-free because they are of plant origin, and a liver is necessary to produce cholesterol.

Vitamins. The U.S. Department of Agriculture (USDA) recommends that people eat a variety of vegetables and fruits as part of an overall healthy diet, which may reduce the risk of heart disease (heart attack and stroke), certain types of cancers, obesity, and type 2 diabetes (70). Such a diet helps to **ensure an adequate intake of vitamin C, β-carotene, and fiber**. Oranges are an excellent source of vitamin C, but as Figure 14-4 shows, papaya, strawberries, pineapple, and kiwifruit contain even more. The vitamin C content is reduced if the fruit is exposed to air by bruising or cutting,

FIGURE 14-4 Fruits high in vitamin C (quantity = 1 medium-size fruit, unless otherwise noted).



(continued)

Fruits as Functional Foods

Fruits and components of fruits are important contributors to the growth of the functional foods industry. Some, but not all, fruits are rich in certain types of phytochemicals, fiber, vitamins, and/or minerals (75). *Phytochemicals* refers to a wide variety of substances found in plants. They include, but are not limited to antioxidants, polyphenols, flavonoids, flavones, isoflavones, catechins, anthocyanidins, isothiocyanates, and allyl sulfides. Epidemiologic studies suggest diets rich in fruits and vegetables are associated with decreased rates of certain diseases. Furthermore, individual substances in fruits have been isolated and studied to determine their potential beneficial effects (79).

- ***Antioxidants.*** These protect against oxidative damage by being oxidized themselves, thereby protecting the structural and functional integrity of living material. Lycopene is a red compound found in watermelon and tomatoes that has antioxidant activity. Diets rich in lycopene are linked to a reduced risk of certain cancers, including prostate and colon cancer (79). Anthocyanins are another type of antioxidant that give berries their dark color. In laboratory tests, anthocyanins from berries reduce the growth of tumor cells and protect normal cells from damage (31). Vitamins A (carotenoids, including carotene, lycopene, xanthophylls, lutein, zeaxanthin), E, and C are powerful antioxidants; they also have anti-inflammatory effects.
- ***Polyphenols (phenolics).*** High intakes of foods rich in compounds called "polyphenols" are associated with decreased risks of high blood pressure, heart disease, stroke, and dementia (20) (Chemist's Corner 14-2). Some of these beneficial effects are thought to be due in part to the effect of polyphenols on blood vessels: the vessels relax

Phytochemical A nonnutritive component ("chemical") in plants ("phyto") considered to have positive health benefits.

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or to alkali or copper through cooking or processing. Fruits high in β-carotene (vitamin A) include mangoes, cantaloupe, apricots, persimmons, plantains, papaya, and guava.

Minerals. Fruits are generally **low in minerals, but there are some exceptions**. Raisins and dried apricots are high in iron, and potassium can be obtained from avocados, apricots, bananas, dates, figs, oranges, plums, prunes, melons, and raisins.

Fiber. Certain fruits are a rich source of **dietary fiber**, which has been linked to a **decreased risk of colon cancer and to reduced blood cholesterol** (39). Pectin and other soluble fibers may help lower high blood glucose and cholesterol levels in some people (8). **Not all fruits are high in fiber**, but some good sources are raisins, pears, apples, raspberries, strawberries, prunes, and oranges. **Removing the skin diminishes the fiber** content; paring an apple, for example, removes 0.8 grams of fiber. Fruit juice has less fiber than the whole fruit, with most fruit juices averaging only about half a gram of fiber for each cup (30). In addition to being consumed for fiber, prunes and prune juice are often used as a laxative because they contain diphenylisatin, a compound that stimulates intestinal movement.

and increase the delivery of blood to the brain and heart. High levels of polyphenols are found in pomegranates, grape seeds, and berries—specifically, highly colored berries such as blueberries, blackberries, grapes, black currants, and elderberries, among others (51). Blueberries were consumed by World War I pilots who claimed the fruit improved their vision.

Food Additives in Fruits

Common food additives used to prevent dried fruits from browning include sulfites, sorbates, and benzoates (15). Some people are sensitive to sulfites, so the most frequent alternative used is ascorbic acid (vitamin C) (54). The FDA prohibits the use of sulfiting agents on raw produce in food establishments,

CHEMIST'S CORNER 14-2

Berry Power

Polyphenols (phenolics) are chemical structures in berries that include flavonoids (anthocyanins, flavonols, and flavanols), tannins (proanthocyanidins, ellagitannins, and gallotannins), stilbenoids, and phenolic acids (58). Among berry phenolics, the anthocyanins (colorful pigments) have a wide range of bioactivities, including antioxidant, anticancer, and anti-inflammatory properties.

Berries differ in their phenolic concentrations. For example, blueberries and cranberries contain predominantly proanthocyanidins, whereas blackberries, black raspberries, red raspberries, and strawberries contain predominantly ellagitannins. These differences also influence the berry's biological properties (58).

- **Cranberries.** Their bacterial antiadhesive properties are due to its oligomeric proanthocyanidins.
- **Blueberries.** The positive impact on neuronal function and behavior in aging animals may be due to their specific tannins.

CALORIE CONTROL
Fruits

Portion Control

- About 1½ to 2 cups of fruit a day are recommended (see www.ChooseMyPlate.gov).
- Approximately ½ a cup fits into a person's palm (Figure 14-5).
- Replace high-kcalorie/fat snacks with fresh fruit.
- Enjoy fruits daily but do not overdo it, especially fruit juices (see Chapter 27).

FIGURE 14-5 Approximately 1/2 a cup.



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How Many Kilocalories in Fruits?

- Based on the Food Lists for Diabetes, each fruit choice—defined as 1 small (¾ to 1 cup) fresh fruit; ½ cup of frozen/canned fruit or unsweetened fruit juice; or 2 tablespoons dried fruit—provides about 60 kcalories, derived primarily from 15 grams of carbohydrate, with very little protein or fat (with the exceptions noted below).
- Rounding that number to 50 creates another method to control kcalories: counting in multiples of 50. This makes it easier to count total kcalories for each meal (Chapter 6).
- Tables 14-2 (whole fruit) and 14-3 (cups of fruit) show how much fresh fruit measured whole or by the cup delivers approximately 50 kcalories.
- Kilocalorie values for fruits vary depending on how they are processed. These tables are for *fresh* fruit. Frozen fruits come close to these values if sugar has not been added. Canned fruit is much higher in kcalories because of the added syrup (which is "sugar"), unless it's a lower-sugar version (Figure 14-6).

(*Continued*)

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TABLE 14-2 Whole Fresh Fruit Portions Equal to about 50 Kilocalories[1]

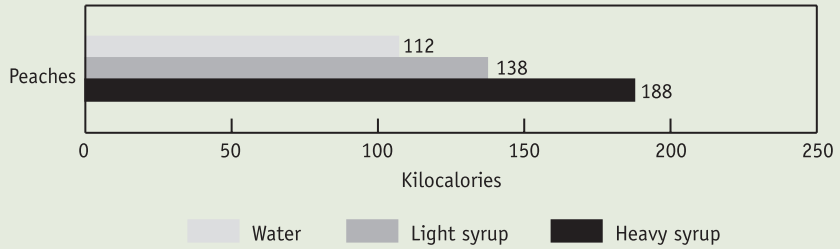
½ Fruit	1 Fruit	2 Fruits	Multiple Fruits
Apple (40 kcal)	Kiwi	Figs (dried)	Apricots (3 pieces)
Banana	Nectarine (70 kcal)	Guava	Cherries (10)
Grapefruit	Orange (70 kcal)		Dates (2)
Mango	Peach		Grapes (15)
Papaya	Persimmon		Lychees (10)
Pear	Plum		Raisins (2 Tbsp)
Persimmon (Japanese)	Tangerine		
Pomegranate			

[1]Same for frozen fruit with no added sugar. Canned fruit is higher in sugar, so read Nutrition Facts label for kcalories.

TABLE 14-3 Cups of Fresh Fruit Equal to about 50 Kilocalories

Under 1 Cup Fruit	1 Cup Fruit	Over 1 Cup Fruit
½ Cup	Blackberries	1¼ Cups
Applesauce (unsweetened)	Cantaloupe	Strawberries
Figs (dried)	Honeydew melon	Watermelon
Lychees	Raspberries	
Peaches (canned)		
¾ Cup		1½ Cup
Blackberries		Ohelo berries
Blueberries		Starfruit
Pineapple		

FIGURE 14-6 Kilocalorie content of canned fruit in water, light syrup, and heavy syrup.



- Read the Nutrition Facts label to determine the caloric content of processed foods.
- **Exceptions to the rule:** A few fruits deliver more than the usual number of kcalories (Table 14-4). Both avocado and coconut derive some of these kcalories from their high fat content, while dried fruits that are very low in fat are a good source of kcalories for healthy adults (with no carbohydrate restrictions) who want to gain weight.

TABLE 14-4 Selected Fruits High in Kilocalories

Fruit	Serving Size	Kilocalories	Fat (grams)
Avocado	1 medium	300	30
Coconut (dried, shredded)	½ C	250	21
Dried fruit	½ C	200	0

© 2010 Amy Brown

with the exception of grapes (72). Food products from a processing plant that have sulfites added must declare them on their labels. Sulfites can appear on labels under several names:

Sulfur dioxide	Potassium bisulfite
Sodium sulfite	Sodium metabisulfite
Sodium bisulfite	Potassium metabisulfite

Sorbic acid (sorbate) is an antifungal agent that aids in the preservation of various foods. Benzoic acid (benzoate) is a preservative often used in dried fruits or jams. Both substances are found naturally in cranberries, prunes, cinnamon, and cloves.

PURCHASING FRUITS

Fruit consumption is on an upward trend. Not only does fruit look and taste good, but it is also perceived by people as good for them (40). According to the USDA, the most frequently consumed fruits are bananas, apples, and oranges, along with watermelons, strawberries, grapes, and peaches/nectarines (69).

Grading Fruit

Grading fresh produce is difficult because the quality can change between the time it is graded and the time of purchase. Nevertheless, some fruit producers have fresh fruits graded by the USDA on a voluntary basis. USDA grades for various fruits can be found at www.ams.usda.gov/grades-standards/fruits. USDA grading is based on size, shape, color, texture, appearance, ripeness, uniformity, and freedom from defects (see Table 13-2 in Chapter 13). Nutrient content between the grades does not differ to any great extent. The four grades for fresh fruit are U.S. Fancy, U.S. No. 1, U.S. No. 2, and U.S. No. 3 (65). U.S. Fancy grade fruit is the best and most expensive. Processed fruits (canned, frozen) are graded in a different manner, but the grading is still voluntary. USDA grades for canned or frozen fruits and vegetables are U.S. Grade A or Fancy, U.S. Grade B or Choice, and U.S. Grade C or Standard.

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Selecting Fruits

Fruits are selected for purchase based on the individual evaluation factors for each fruit, whether or not the fruit is graded, and the fruit's peak season (Figure 14-7). Many varieties are available, and the following sections provide selection tips for each fruit and explain how different varieties that exist for the same fruit differ (63).



Apples

Apples are the second-most commonly eaten fruit in the United States. Selection is based on whether the apple will be used for cooking or eaten raw (Figure 14-8). Apples for cooking should be firm, be able to hold their shape, and remain flavorful after heating. The exception is applesauce, for which softer, fleshier apples such as a McIntosh are desired. The Red Delicious and Jonathan varieties are ideal for eating raw but not for cooking because they tend to collapse and lose much of their flavor when heated. The Rome Beauty and Newton Pippin are considered best for pies and sauces but are less acceptable for eating fresh. The remaining varieties can be used for either fresh eating or preparation. Choose apples with clean, smooth, and unbruised skins that have good color. Avoid apples that lack color; this indicates an immature fruit with less flavor. Avoid overmature apples, which will be mealy and soft under the skin.

Although there are more than 1,000 varieties of apples, approximately 18–25 varieties constitute almost 90% of commercial apple production in the United States. The most common varieties sold are Gala, Red Delicious, Fuji, Granny Smith, Honeycrisp, Golden Delicious, McIntosh, Cripp's Pink/Pink Lady, Braeburn, and Jazz (64).



Apricots

Apricots originated in China thousands of years ago, but California is now the main supplier of apricots marketed in the United States. Apricot varieties available include Royal Blenheim, Castlebrite, Improved Flaming Gold, and Katy. The new varieties are easier to ship and maintain their freshness longer than older varieties. For best flavor, select soft, ripe apricots with as much golden orange color as possible. Although fresh apricots are available only during the summer, dried and canned apricots are sold year-round.



Avocados

This Central American pear-shaped fruit with greenish-purplish skin was once considered exotic but is now available throughout the year. The selection of avocados is based primarily on touch. If the skin gives slightly to gentle pressure, the fruit is ready for immediate use. Thick-skinned avocados can be tested for ripeness by inserting a toothpick in the stem end; if it moves in and out easily,

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FIGURE 14-7 Peak seasons for various fruits.

Seasons for Fruits

Fruit	January	February	March	April	May	June	July	August	September	October	November	December
Apples	■								■	■	■	■
Apricots					■	■	■	■				
Avocados	■	■	■	■	■	■	■	■				■
Berries						■	■	■	■	■		
Blood oranges	■	■	■									
Boysenberries						■	■	■				
Cantaloupes						■	■	■	■	■		
Cherries						■	■					
Figs							■	■	■	■		
Gooseberries								■				
Grapes						■	■	■	■	■	■	■
Kiwi	■	■	■			■	■	■	■	■	■	■
Kumquats	■	■	■									
Mangoes	■	■	■	■	■	■	■	■				
Nectarines						■	■	■	■			
Papayas	■	■	■	■	■	■	■	■	■	■	■	■
Peaches							■	■	■			
Pears	■							■	■	■	■	■
Pineapples	■	■	■	■	■	■	■	■			■	■
Plums						■	■	■				
Raspberries						■	■	■	■	■		
Strawberries					■	■	■	■	■			
Tangerines	■	■	■									
Watermelons					■	■	■	■	■			

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FIGURE 14-8 Apples.

More than 7,500 varieties of apples are grown worldwide, but only about 18–25 comprise the majority of the North American commercial crop. While many apples can be used for both eating and cooking, tart varieties with a high acid content and firm texture are best for baking.

Some Apple Favorites



Red Delicious
- Bright to dark red, sometimes striped
- Favorite eating apple
- Mildly sweet, juicy
- Available year-round



Winesap
- Dark red
- Appropriate for cider, snacking, and cooking
- Spicy, slightly tart
- Available October to August



Rome Beauty
- Brilliant red, round
- Great for baked apples; holds shape well when cooked
- Available October to June



Golden Delicious
- Yellow-green
- All-purpose apple for baking, salads, and fresh eating; flesh stays white longer than other apples
- Mellow, sweet
- Available year-round



Criterion
- Sweet, yellow, often with red blush
- Wonderful eaten fresh, in salads, or baked; flesh
- Spicy, slightly tart stays white longer than other apples
- Available October to Spring



Gala
- Yellow to red
- Appropriate for cider, snacking, and cooking
- Available October to August



Granny Smith
- Green
- Excellent for cooking, salads, fresh eating
- Tart, crisp, juicy
- Available year-round



Fuji
- Ranges from yellow-green with red highlights to very red
- Excellent for eating or applesauce
- Sweet, spicy, crisp
- Available year-round

Washington State Apple Commission

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the avocado is ripe. Most avocados are still hard when they arrive at the produce stand and will continue to ripen. Avoid avocados that are badly bruised or have soft, sunken spots.

California varieties, such as the Hass, Fuerte, Bacon, and Zutano, supply 85% of the U.S. market, with Florida providing the remaining 15%. The Hass, with its bumpy, dark skin and nutty flavor, is the most commonly sold variety. The others are larger and smoother skinned, but their lower fat content tends to make them less rich tasting.



Bananas

Bananas are the world's chief tropical fruit. The United States is the world's leading banana importer, and Central America is the major exporter. Bananas ripen best if the bunches are cut while still green. This practice also results in less bruising during handling, shipping, and marketing.

The top two banana varieties are the bruise-resistant Gros Michel from Martinique, a long banana with a tapered tip, and the more bruise-prone Cavendish, which has a curved shape. Newcomer varieties include the Red Spanish or Red Cuban, Saba, and Manzano. Bananas contain less than 5% starch and at least 80% sugars (25). When choosing bananas for immediate consumption, pick those that are firm and greenish yellow to clear yellow in color.

Plantains belong to the banana family, but they are so starchy that they are usually baked, boiled, or fried like potatoes, rather than eaten raw. They average 66% starch and only 17% sugar when ripe. When plantain skins are black, the fruit is usually ripe and ready to be consumed, but the amount of black on the plantain is a matter of personal preference. Saba and Manzano varieties are ripe when their skins are completely black.

Berries

The numerous varieties of succulent, delicate berries come into season in a succession that starts with the sweetest and ends with the least sweet berries; first come strawberries, then raspberries, blackberries, blueberries, gooseberries, red currants, and finally cranberries.



Strawberries

Strawberries do not continue to ripen after they have been picked. For that reason, they should ideally come to market when they are bright red and fully ripened. Strawberries are highly perishable because of their high respiration rate and susceptibility to fungal spoilage (44). If they are not to be eaten shortly after purchase, strawberries should be stored, unwashed, in the refrigerator. Rinsing them prior to refrigeration is not recommended because it dilutes the flavor and softens the texture. The short-lived strawberry

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FIGURE 14-9 Strawberries can be hulled with a paring knife (left) or a strawberry huller (right).





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season starts in April and lasts until sometime in July, but strawberries from Florida and other parts of the world, such as New Zealand and Mexico, have helped to extend the season. Common varieties include the Chandler, Douglas, Heidi, and Pajaro. Figure 14-9 shows techniques for removing the stem and core of a strawberry (known as *hulling*) prior to eating. Strawberries should be washed before hulling so they do not absorb water.

Raspberries

Select raspberries that are plump, firm, and free from mold. Red raspberry varieties include the Willamette, Meeker, Heritage, and Sweetbriar. Munger raspberries are black.

Blackberries

Select blackberries that are plump and have an almost black color that covers the entire berry, with no traces of green or red by the stem. Avoid berries with the little caps, which indicate immaturity. Native to North America and Europe, blackberry varieties include Boysen, Cherokee, Logan, Marion, and Olallie.

Blueberries

Select blueberries that are plump, smooth, and blue-black in color with a light grayish "bloom." Grown in the United States and Canada, blueberries come in Patriot, Bluetta, and Earliblue varieties.

Gooseberries

Similar in size and appearance to green seedless grapes, gooseberries are selected based on their smoothness and light green color. Most gooseberries, except for the Poorman variety, are so tart that they have to be cooked and sweetened to be eaten; they are primarily used to make pies and preserves.

Red Currants

These are also quite tart and generally cooked and sweetened or used primarily as a garnish. Red currants are best selected by picking those firmly attached to the stems.

Cranberries

North America is home to only three native fruits: the Concord grape, the blueberry, and the cranberry. The cranberry season starts in September and ends in November, which may explain why the cranberry is associated with the holidays that occur toward the end of the year. When selecting fresh cranberries, choose those that are firm, plump, and smooth-skinned. Four varieties—Early Black, Howe, Searles, and McFarlin—supply most of the cranberries consumed.



Cherries

Dark red or deep purple cherries are the tastiest. Choose sweet cherries that are plump, firm, and brightly colored with an almost mahogany-looking skin. For tart cherries, expect the skin to be lighter. The best choices are Bing, Lambert, Black Tartarian, Chapman, Borlat, Schmidt, and Republican. Tart or sour cherries such as the Montmorency tend to be lighter red in color and are more frequently used for pies. Royal Ann cherries are used to make maraschino and candied cherries.



Dates

These long, brown, wrinkle-skinned berries from palm trees have been cultivated for centuries in the Middle East and North Africa, where they provided sustenance for many ancient desert nomads (60). Although dates appear to be dried, they are, in fact, fresh. Most dates at the consumer level are sold packaged, ripe, and ready-to-eat. There are two basic classes of dates: soft and semidry, although a few are considered dry. Soft dates, such as the Medjool, Khadrawy, and Halawy varieties, contain more moisture; have a very soft, almost caramel-like flesh; and are popular with consumers as a snack. The semidry dates are important to food processors. Although there are more than 100 varieties, Deglet Noors constitute 95% of the market (Figure 14-10). The Zahidi date (semidry) has firmer flesh and is smaller than the Deglet Noor. Other varieties of dates include the Barhi, Thoory (the driest date), and Dayri.



Figs

California is the largest producer in the United States of black and green

FIGURE 14-10 Deglet Noor dates.



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figs. Originating in the Mediterranean basin, figs have been cultivated longer than any other fruit in the world (59). The flowers on fig trees are never seen because they develop inside the fruit and produce the crunchy little seeds that give figs their unique texture. Black figs are selected for eating raw, and green figs are used primarily for cooking and canning. Dried, pressed figs have for centuries been served as a confection. When buying, avoid dry, hard figs or those with flat sides, splits, or mold. These sweet, small, pear-shaped fruits come in a number of varieties, Black Mission being the most common. Others include Brown Turkey, Brunswick, Celeste, and Kadota. Popular dried fig varieties include the Smyrna and Calimyrna.



Grapefruit

Both pink and white/golden grapefruit are available. Grapefruit is at its best when the skin is shiny and smooth and both ends are flat. Avoid grapefruit with pointy ends, thick skins, or deep pores. The pink varieties, which are sweeter, include the popular Ruby Red and Star Ruby, followed by Burgundy Red, Foster Pink, and Marsh Pink. A popular white or golden grapefruit variety is the seedless Marsh.



Grapes

Perhaps no other fruit is used quite as extensively and for as many different purposes as the grape. Grapes are consumed fresh, in the form of wine, or as raisins, juice, jams, or jellies. Most grapes in the United States are grown for the wine industry (55). Grapes are actually berries that grow in clusters, and they come in a wide variety of colors and shapes. Grapes do not get any riper or sweeter after being picked. Choose grapes that are firm, plump, and well colored. Avoid those that are soft, wrinkled, moldy, or have bleached areas around the stem. Table grapes should be chilled for the best flavor and texture. Classification is based on color, and the most common commercial table grapes are the red Flame seedless and green Thompson seedless types. Other popular table grapes include Perlette, Lady Finger, Tokay, Cardinal, Catawba, Delaware, and Emperor. The fragile Concord grape is used primarily for making wine, juice, and jelly. Raisins are usually made from Muscat and Thompson seedless grapes.



Guavas

Select guavas whose skins are yellow rather than green and that yield to pressure and emit a fruity guava aroma. Slightly underripe guavas may be lightly cooked and sweetened. There are several varieties of guava, each with its own distinctive flavor, ranging from strawberry-like to pineapple-like to banana-like. The flesh may be white, red, or salmon in color. Seeds may be present or absent, depending on the type of guava.



Kiwifruit

The New Zealanders changed the name of this fruit from *Chinese gooseberry* to *kiwifruit* as a salute to their native kiwi bird when they started marketing it to the United States. When ripe, kiwifruit yield to gentle pressure. The firmer the fruit is, the tarter the flavor will be. One kiwifruit provides more vitamin C than an orange. Kiwifruit can be peeled, sliced, and eaten, or cut in half and scooped out of its skin with a spoon, but it should not be cooked; heat destroys its color and texture. This fruit is commonly added to fruit salads, but kiwifruit cannot be used in the preparation of gelatin-based foods because an enzyme in kiwifruit, actinidin (a potent proteinase), prevents gelling (35). Grown in both New Zealand and California, green kiwifruit are lemon-sized or smaller and oval, with fuzzy, brown exteriors and green interiors sprinkled with a ring of black seeds. In contrast, gold kiwifruit have a smooth exterior and a yellow interior. They are available year-round.



Kumquats

These small, orange-type fruits are native to China and are eaten whole without peeling. The Nagami and Meiwa are the two varieties commonly sold in the United States. They are most often found preserved in syrup in the specialty food section of the supermarket.



Lemons

Size is not related to juiciness. Lemons with thin skins and those that are heavy for their size yield more juice than their thicker-skinned, lighter counterparts. Storing lemons in water will produce twice the juice when squeezed. Eureka and Hishon lemons are the two main commercial varieties. Other varieties include Avon, Bearss, Harney, and Villafranco. The Meyer lemon is a cross between a lemon and a mandarin and is prized for its floral, almost sweet flavor.



Limes

When buying, select limes that are heavy for their size and have a thin, glossy skin. Sweet limes are available, but only the acidic varieties such as the Tahiti (Persian, Bearss, Idemore, and Pond) and Mexican types are grown in the United States. Key limes differ from the regular limes sold in the supermarket in that they are smaller—closer to cherry tomato size—and juicier, have a more potent lime flavor, and are usually more difficult to find and hence costlier.



Mandarins

This category of orange-derived citrus fruit includes several familiar fruits, all of which are easily peeled. The most popular are tangerines, tangelos (a tangerine–grapefruit hybrid), and tangors (a tangerine–orange hybrid). Choose mandarins that are firm, full-colored, and covered with a thin, almost oily-feeling skin. Tangerine varieties include the Dancy and Robinson. A common tangelo variety is the Minneola followed by the Nova, Early K, Orlando, and Sampson. The most popular tangor variety is the Temple.

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FIGURE 14-11 Cubing a mango.



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Mangoes

The flavor of the golden-orange flesh of this tropical fruit has been compared to a cross between that of a peach and an apricot. Select mangoes that have very little green left and show some red, but are predominantly orange to yellow. The fruit should yield slightly to gentle pressure. Another indication of ripeness is a distinctive mango odor coming from the fruit, especially at the stem end. More than 1,000 varieties are available. Small varieties include the Haden, Van Dyke, and Atalufo; medium varieties include the Francisque and Tommy Atkins; and large varieties include the Keitt and Kent. The latter two varieties will stay green even when ripe, but most of the others will pass through a red phase and then turn yellow. Figure 14-11 illustrates how to cube a mango.



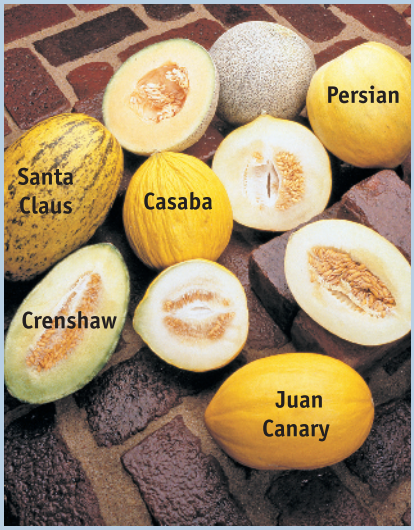
Melons

Melons are one of the most difficult fruits to select because of their hard outer rind and subtle color changes. In the wide assortment of melons available, each has its own selection nuances (Figure 14-12). Melons fall into one of two categories: (1) muskmelons, which include most melons; and (2) gourds, such as the watermelon. Most varieties are sold slightly underripe and will have to ripen a few days at room temperature. When ripe, the stem end becomes slightly indented and yields to pressure. Another indication of ripeness is a distinctive melon odor coming from the fruit, especially at the stem end. Overripe melons will have water-soaked spots, and a rattling sound will occur when the melon is shaken. Selection hints for the different melon varieties follow.

FIGURE 14-12 Melons.

Melons:

These round to oblong fruits grow on vines. The skin on melons is, in fact, a rind that can be smooth, netted, ridged, wrinkled, or warty. The edible pulp inside varies in color and can be white, yellow, pink, green, or red.



Vincent Lee

Cantaloupe

Look for a cantaloupe with a rough, rope-like netting over a golden-colored rind. Other signs of ripeness include cracks near the stem end, a cantaloupe aroma, and a springy response to firm pressure. Cantaloupe varieties include Top-score, Ambrosia, and Saticoy.

Honeydew

Ripe honeydews have a waxy-feeling, creamy-white rind, and honeydew aroma. For best flavor, choose one weighing at least 5 pounds.

Persian

These melons look like big cantaloupes, but the flesh is firmer, smoother in texture, and a deeper orange. Selection tips are similar to those for a cantaloupe except that more of the rind should show through the webbing.

Watermelon

The condition of the stem and the hollow sound when thumped are the two indicators most often used when selecting a watermelon. Do not try to evaluate a watermelon's ripeness by its green color, but rather look for a creamy or yellowish underside. A dull, smooth rind with a symmetrical shape are signs of a good watermelon. Several varieties found in the market include Calsweet, Triplesweet, and Orchid Sweet (yellow flesh).

Figure 14-13 shows how to remove the seeds from a whole watermelon.



Nectarines

Nectarines have been consumed for more than 2,000 years and may soon exceed peaches in popularity. Many children prefer them because they have no fuzz. Select nectarines that yield to soft pressure and that have an orange-yellow background color between the red hues.

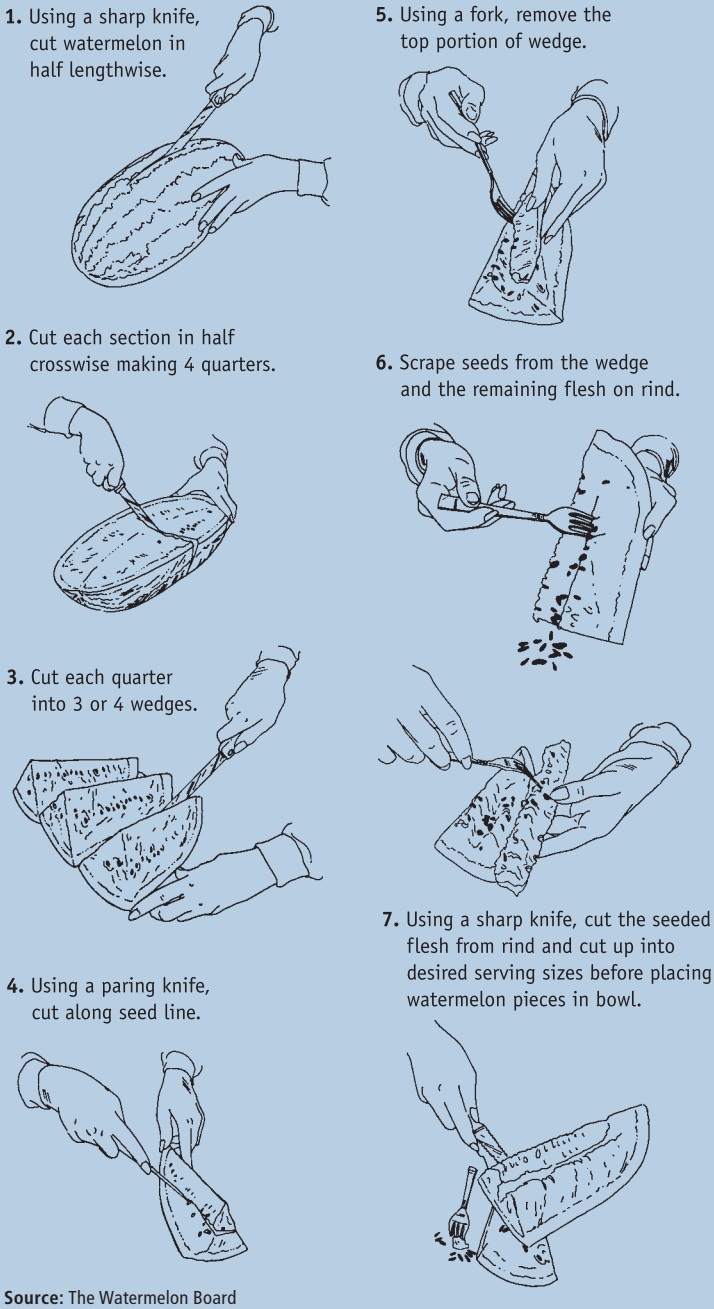
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FIGURE 14-13 Slicing watermelon.



Source: The Watermelon Board

Almost the entire U.S. supply is grown in California, although some are imported from New Zealand and Chile. The favorite varieties include Firebrite, Red Diamond, Flavortop, Summer Grand, Flamekist, and Red Gold.



Olives

Although olives are botanically considered a fruit, they are often treated as vegetables. The trees on which they grow can live 600 years or more and have one of the longest cultivation histories of any tree in the world (9). Unripe olives are green, and they progressively darken the longer they are on the tree. By the time olives turn black naturally, the abundance of olive oil they have produced makes them too ripe for consumption. The exception is the dried Greek olive, or salt-cured olive, which is treated with salt to remove the water and looks shriveled and oily. "Black" olives are actually picked green and processed in a curing solution that turns them black, removes their bitterness (oleuropein), and gives them their characteristic olive flavor. Green olives are fermented rather than subjected to the curing solution used to make black olives. Olives can be cured by using water (months of repeated soakings), brine (1–6 months in a salt solution), oil, or lye, after which they are rinsed and preserved by brine, refrigeration, freezing, drying, or canning (41).

In North America, the three main types of olives are the California-style black ripe olive; the green, Spanish-style olive; and specialty olives such as Niçoise (neh-swahz), Kalamata (also spelled Calamata), Sicilian, and dried Greek. Most olives are sorted according to size and stored in cans or jars of brine. The variety of olive tree determines whether the olive is small, medium, large, extra large, jumbo, colossal, or super colossal (Figure 14-14).



Oranges

Oranges, another popular fruit, are grown primarily in Florida and California. Even though the same varieties are grown in each state, the juiciness, color, and texture of their oranges differ because of variations in soil and climate. Thin-skinned, very juicy Florida oranges provide most commercial orange juice.

The sweetest, juiciest oranges are those picked at the peak of their season, and ideally this is when they come to market. Oranges that feel firm and heavy for their size are the best choice for juiciness. Different varieties are grown throughout the year, and some varieties, inconveniently for the grower, turn orange in the winter before they are ripe. Warmer weather then turns them back to green, so some growers in California expose them to ethylene gas—a gas naturally produced by ripening fruits—to increase the rate of ripening and return their color to orange. In Florida, dye is often used on oranges that do not respond to

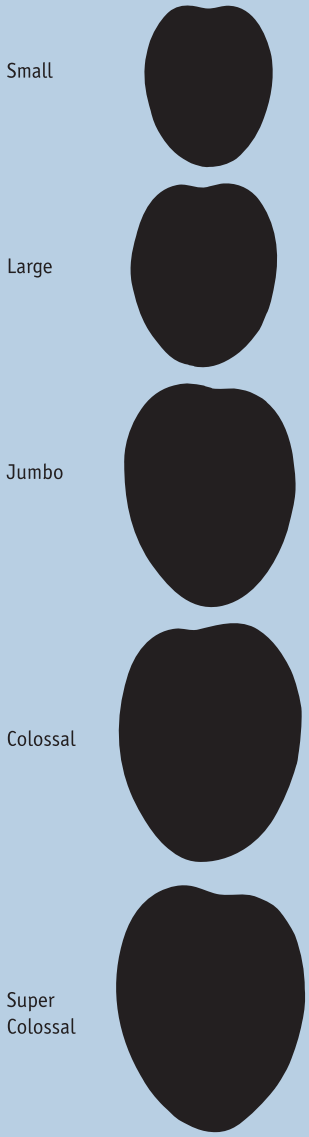
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FIGURE 14-14 Olive sizes vary, depending on the variety of olive tree. Shown here are olive sizes for California Black Ripe olives.



ethylene. Varieties of oranges include the Hamlin, Pineapple, Florida Valencia, and Pope Summer. California oranges are known for their fresh eating qualities and include the Navel and California Valencia varieties. Because California Valencias are thin-skinned, they may also be used for juice. Sour oranges, including Seville and Chinotto, are sometimes sold in specialty markets. Blood oranges with their distinctive deep-red-colored flesh are a wintertime specialty.



Papayas

Ripe papayas are yellow-orange, soft, and prone to damage, so they are shipped to the market in varying degrees of ripeness. The green papayas, which are one-quarter yellow, will ripen in 5 to 7 days; the half-green, half-yellow papayas will be ready in 2 to 4 days; and the papayas that are three quarters yellow-orange are at the ideal stage of ripeness. If they are already yellow-orange, they may be refrigerated and kept up to a week. In addition to being the proper color, the skin of the papaya should be smooth, unblemished, and free of any dark or mushy spots. This tropical fruit comes in two major varieties, Hawaiian Kapoho and Sunrise.



Peaches

Peaches are a very popular fruit. Choose peaches that are already ripe, preferably tree-ripened, and ready to eat. Peaches do not acquire additional sweetness after being picked, although they may become softer and juicier (52). Look for a yellowish or creamy background color. The amount of red is not always a good indication of ripeness because some of the best peaches are pale-colored. Ripe peaches should yield to gentle pressure. Avoid those that are too firm, have any green background, or are bruised.

Hundreds of varieties are available, but the newer varieties of yellow freestones (peaches in which the flesh does not stick to the pit) tend to dominate the market. They are larger, firmer, and more acidic than the older varieties. Clingstone peaches (those in which flesh adheres to the pit) are still available fresh on the market, but most are used in commercial canning.



Pears

Pears are generally of either the European or Asian type. Asian pears differ from European pears in that they vary in color from yellow to yellow-green and brownish-red, and they have a blander flavor and crispier texture that is closer to an apple. There are more than ten varieties of Asian pears, but the top three are Twentieth Century, Shinseiki, and New Kikusui. Skin color is a reliable indicator when selecting Asian pears, which, unlike European pears, are usually sold ripe. One way to test for ripeness is to press the neck near the stem; the fruit is ready if it gives off a sweet aroma. The graininess sometimes experienced when eating an unripe pear results from lignin deposits. European pears are juicy and come in four common varieties. Bartletts, the most common, arrive in late summer and are followed by three winter varieties: d'Anjou, Bosc, and Comice. European pears can be bought underripe and ripened at room temperatures. Pears bought ripe are best kept refrigerated in plastic bags. Pears are soft-skinned, so occasional surface blemishes should be expected.



Persimmons

Although it is originally from Asia, this bright orange-red fruit is now supplied to the United States primarily by California. Commodore Perry introduced the fruit to North America in 1856 when he sent persimmon seeds from Japan to a friend in the United States (27). Fully ripe persimmons have slightly transparent skins revealing the seeds underneath, are a bright orange color, and are very soft. In fact, persimmons are so soft when ripe that they are usually sold unripe and must be allowed to ripen after purchase; otherwise, their high tannin content makes them extremely astringent. They become more sweet and juicy as they ripen, and they are best consumed while still slightly crisp. Pointy Hachiya persimmons account for 90% of the U.S. market. Fuyu is the other main variety and looks more like a small, flat tomato.



Pineapple

Rather than a single fruit, a pineapple is really a cluster of fruits of the Ananas tree. The pineapple is native to South America; it was discovered

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on the island of Guadeloupe by Columbus (34), and it got its name from its similarity to a pinecone (21). It is the second-most popular tropical fruit after the banana. Unlike bananas, pineapples do not ripen after being picked, and even though the outside color will change from green to yellow and the inside will get juicier, the sweetness does not increase. The best pineapples come fresh off the field after having been allowed to ripen to maturity. Most of the pineapples sold on the market, however, were cut while still green.

Color is not always a reliable indicator of a ripe pineapple. The best way to choose a pineapple from the market is by touch and smell. It should be plump; give slightly to pressure; have a fresh, sweet, pineapple scent; and be topped with fresh green leaves. Avoid fruit with soft spots, brown discoloration, a decaying base, or a fermenting odor. Sweetness often depends on variety. Gold is one of the sweeter pineapples available on the market. Figure 14-15 shows several techniques for cutting up a pineapple. Like those in kiwifruit, the enzymes in raw pineapple will prevent gelatin from gelling.

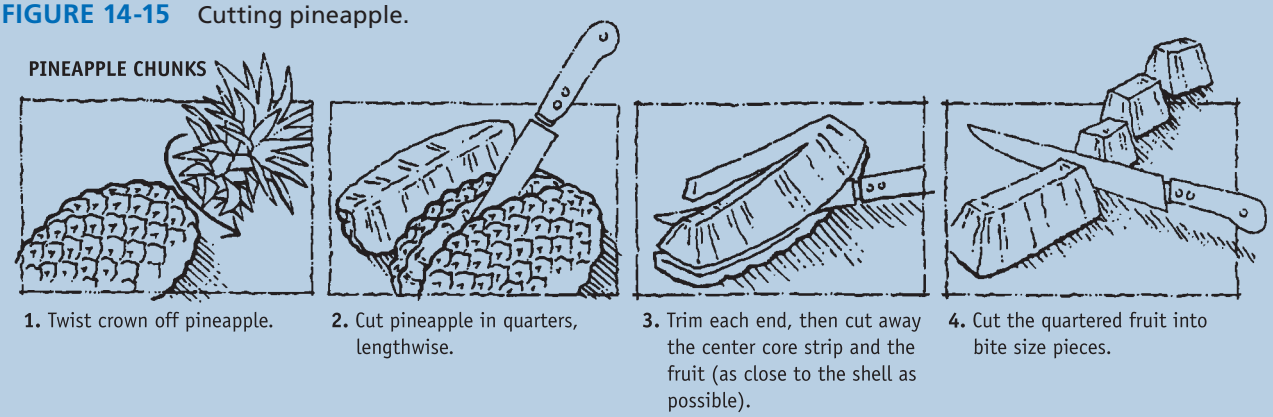


Plums

Plums are available in two types: European plums (blue or purple, yellow, and green) and Japanese plums (yellow or red). Plums, like peaches, come in freestone and clingstone varieties; European plums are usually freestone. Some of the best-tasting varieties of Japanese plums include the Santa Rosa, Laroda,

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FIGURE 14-15 Cutting pineapple.



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and Elephant Heart. European plums are firmer, milder in taste, and are often dried for prunes. Picked when still immature, plums continue to ripen and should be chosen when they give to gentle pressure and have reached full color. Pluots with their reddish, slightly orange color are a cross between a plum and an apricot.



Pomegranates

These ruby-red, leather-skinned fruits are filled with pulp-laden seeds. The name came from the French word for "seeded apple." Choose the largest pomegranates available because the larger the fruit, the more pulp surrounding each seed. Make sure the rind is fresh and not dried out. The bright red seeds may be eaten as is or they may be carefully juiced to extract the tart, bright red juice.



Rhubarb

Rhubarb is, in fact, a vegetable treated as a fruit, being sweet enough for pies after sugar is added. Only the stem of the plant is eaten; the leaves are so high in oxalic acid that they are toxic if eaten in large amounts. Field-grown rhubarb is larger, stringier, and tarter than greenhouse rhubarb. Select rhubarb stalks that are tender, juicy, pink to red in color, and free of fibrous development.

Tangerines—see Mandarins.

Tropical Fruits

As world transportation and marketing outlets have improved, more tropical fruits have found their way into the market (Figure 14-16). Increased consumer awareness of fruits from the tropics—the geographic area between 23.5° north and 23.5° south of the equator—has led to higher demand for coconut, guava, mango, and papaya. Other tropical fruits gaining in popularity include the atemoya, breadfruit, carambola (star fruit), cherimoya, feijoas, granadilla, jaboticaba, jackfruit, loquat, lychee, mamey, mangosteen, passion fruit, papaw, plumcot, quince, sapodilla, sapote, soursop, and tamarind.

FIGURE 14-16 Selected tropical fruits.

Expansion of the global economy and transportation methods have improved the selection of fruits and vegetables from around the world.



Kumquats
- Tart pulp

Cherimoya
- Sweet, custard-like flavor

Plantains
- Served as vegetable
- Starchy, no banana flavor

Passion fruit
- Lemony, tart flavor
- Many small black seeds

Lychee
- Grape-like flesh

Red banana
- Maroon when ripe
- Tangy-sweet flavor

Pummelos
- Largest of citrus fruits

Guavas
- High vitamin C content

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Superfruits

The list of "superfruits" continues to grow and currently includes acai, blueberry, currants, goji, gooseberry, mangosteen, mulberries, papaya, pomegranate, and tart cherries, among others (5). A few of these are discussed next.

Goji and Acai

Goji (Go-Gee) berry (*Lycium barbarum*) and acai (*Euterpe oleracea*) are two fruits that have recently become popular. Both have been consumed for centuries in their native areas. Acai is a purple berry native to the region of South America near the Amazon River, where the river dwellers mix it with manioc flour (cassava) and consume it as a staple. Because it grows wild in the Amazon jungle and is highly perishable, it is exported as dried berries or in juice form for use in beverages, frozen yogurt or ice cream (often mixed with granola and banana), and desserts. Goji has been cultivated for 2,000 years by the Chinese, who often dry this orange-red berry from the nightshade family (12).

Acai and goji berries are now being used outside of their native countries as dietary supplements and food additives for their purported health benefits. Manufacturers claim the antioxidants and other compounds in goji and acai can increase energy levels, protect the heart from chronic disease, and improve overall well-being (58). As a result, these fruits have been categorized as *superfruits*, but that is only a marketing term with no official FDA or USDA definition.

Scientists have evaluated the claims made for goji and acai fruits, but the evidence is not conclusive. Laboratory tests confirm that the berries have high levels of antioxidants (11), and goji berries have a very large ORAC (oxygen radical absorbance capacity) score of 8,430 for each ounce (Chemist's Corner 14-3). In 2010, the USDA Nutrient Data Laboratory removed the USDA ORAC Database for Selected foods from its website because of mounting evidence that antioxidant capacity has no relevance to human health and the fact that

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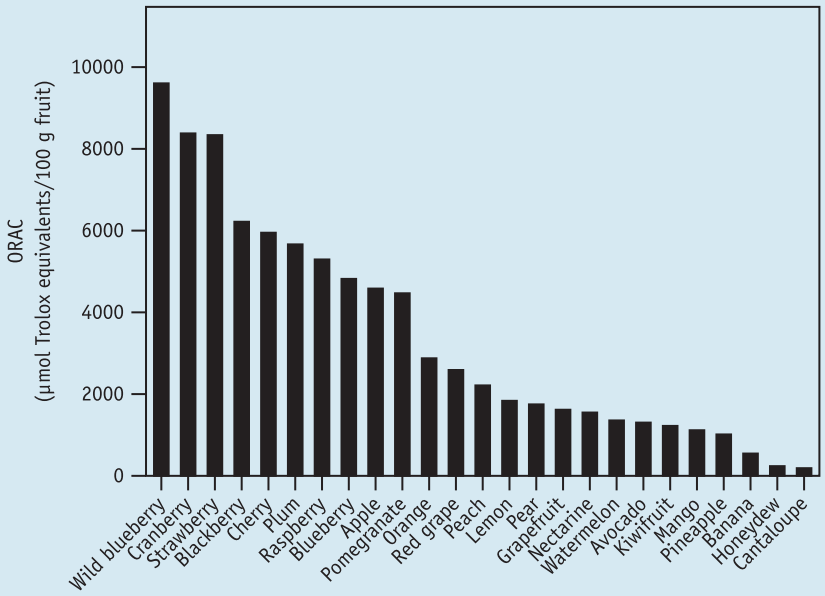
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CHEMIST'S CORNER 14-3

Measuring Antioxidant Power

In 1993, scientists developed an in vitro (in the test tube) method of determining the antioxidant capacity of various foods that they called ORAC (oxygen radical absorbance capacity) (57). Fluorescence intensity is measured with and without the antioxidant to be tested and compared against the activity of a standard antioxidant (vitamin E). The test begins with the addition of a free-radical generator that produces peroxyl free radicals (such as an azide compound) to a fluorescent molecule (such as β-phycoerythrin or fluorescein). The mixture is heated, the free radicals damage the fluorescent molecules, and the loss of fluorescence is measured over time. The amount of reduced fluorescence curve is compared to standardized values created with a known antioxidant. Although some fruits have high ORAC values (Figure 14-17), clinical research still needs to be conducted to determine whether they are relevant to what happens in the human body (57).

FIGURE 14-17 Oxygen radical absorbance capacity (ORAC) values of selected fruits.



Source: Reprinted with permission from Wolfe, KL, et al. Cellular antioxidant activity of common fruits. *Journal of Agricultural and Food Chemistry* 56:8418–8426, 2008. Copyright 2008 American Chemical Society.

ORAC values were routinely misused by companies to promote their products. However, clinical studies in humans have found high antioxidant levels in the blood of individuals consuming the juice or pulp, and a small clinical study reported subjective improvements in energy level and feelings of overall health with goji juice (3).

In experimental studies, extracts of the acai berries can inhibit the growth of cancer cells in vitro (within the test tube) (16), have anti-inflammatory properties, and cause blood vessels to dilate in experimental animals (76). Currently, however, there is no clinical evidence to confirm the effect of goji or acai on long-term medical conditions such as heart disease, cancer, or immune function.

Although there is no real evidence yet (due to insufficient studies being conducted) to suggest they can drastically improve health, these fruits do appear to be safe when consumed in moderation. Consumers should be aware that acai products may also include guarana, which is high in caffeine and can cause its related side effects.

Blueberry

A few studies with rats suggest that a blueberry-enriched diet may protect against oxidative stress, reduce learning impairment, boost memory, and possibly partially protect the rodent brain against Alzheimer's disease (74).

Cranberry

Cranberry juice and cranberry extract have long been touted as useful in the prevention and treatment of urinary tract infections (bladder infections). Clinical studies suggest that the use of supplements or 100% juice may be beneficial in reducing the risk of infections but not effective in treating infections after they start (23).

Pomegranate

Richer in antioxidants than blueberries or cranberries, pomegranate extract used in mice may reduce the risk for inflammatory arthritis symptoms and has antiproliferation effects (reduces cell division) on several cancer cell lines in the test tube (in vitro) (78).

When considering these findings about "superfruits," remember that one or even a few studies does not create a scientific consensus. Many of these studies were conducted on animals, so further research in humans must be conducted before benefits to human health are established.

Processed Fruits

Not so long ago, fresh fruit was available only in the summer, but refrigerated transportation now makes it possible to import fruits from other countries where growing seasons differ from those of North America. Canning, freezing, and drying are other ways of making fruit available all year. Home-freezing and home-drying are on the upswing. Conversely, home-canning knowledge is not as widespread as it used to be. Commercial canning remains responsible for providing the largest portion of processed fruits now reaching the market.

Canned

Commercially, more fruits are canned than are frozen or dried. The most commonly canned fruits are apples and applesauce, peaches, pineapple, pears, cherries, and apricots (66). The advantages of canned fruits are their

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convenience, availability, and variety of forms: whole, half, sliced, chunks, crushed, sauce, or juice. Canned fruits have been cooked, which alters their taste and texture and depletes the water-soluble vitamin content if the cooking juices are not used.

Canning Liquids

According to the *Code of Federal Regulations*, fruits are canned in their own juice (no sugar added); light syrup (some sugar added, 10 to 14% density in fruit cocktail); or heavy syrup (heavier sugar concentration, 18 to 22% density in fruit cocktail) (71). The different packing liquids vary in their influence on the flavor and kcalorie content of the fruit (refer to Figure 14-6).

Grading of Canned Fruit

Not all canned fruits are of the same quality. Voluntary USDA grading places the best fruit under U.S. Grade A or Fancy, with less perfect fruit placed under U.S. Grade B or Choice. Choice canned fruit is usually less expensive, and the fruit may be in smaller pieces than it would be as Grade A or Fancy, which makes it ideal for gelatin salads and fruit mixtures. U.S. Grade C or Standard covers fruits that have uneven pieces and some blemishes, making them best for jams, sauces, and other processed fruit products (71).

Frozen

Some of the most commonly frozen fruits are cherries, strawberries, blueberries, sliced peaches, red and black raspberries, boysenberries, and loganberries. Fruits are simply frozen fresh with or without the addition of sugar or other sweeteners. Freezing a fruit retains its color and taste, but its texture decreases in quality because the cell membranes have a tendency to rupture as the ice crystals expand during freezing (61). Fruits are softer and mushier than their fresh counterparts but still can usually be used the same way as fresh fruit. Frozen fruit makes a quick phytochemical-rich dessert if microwaved for 20 to 30 seconds. When used for pies or other desserts, the fruit is usually partially defrosted in the refrigerator or in the microwave and all or some of the juice is drained away. The sugar content of the recipe can be altered if the fruit has been sweetened.

Signs of Refrozen Fruit

Packages or bags that show signs of juice stains or have a heavy frost clinging to the outside should not be purchased because these are signs that the fruit has been thawed and refrozen. Refrozen fruit is flaccid and less flavorful. A temperature of 0°F (−18°C) should be maintained at all times during storage and transport.

Dried

Drying has been used as a method of preserving fruit for thousands of years. Commonly dried fruits, in descending order of popularity, include raisins, dates, prunes, and apples (1268). Dried apple, banana, and pear slices are also popular.

Drying makes these fruits available year-round. Dried fruits are often packed in small containers for easy transport in lunch bags or boxes, or by backpackers, campers, and seafarers. These dried fruits contain as much as 70% carbohydrate and, with the flavor and nutrients more concentrated, are an alternative to candy or other less nutrient-dense foods. Generally, dried fruit is a good buy if the cost does not exceed five times the price per pound for fresh fruit.

Most fruits are 85% water, but drying lowers that amount to below 30%. It takes about 5 pounds of grapes to produce 1 pound of raisins. The removal of water during drying increases resistance to microbial spoilage. Drying is also responsible for the loss of volatile substances in fruit and softening of the cellulose, resulting in a sweeter-tasting fruit.

Fruit Leather

The jerky-like strips of fruit called *fruit leather* are made from a mixture of fruit juice concentrate. The fruit puree (a blenderized mix of fruit, water, and other ingredients) is often cooked (but not always); dried on a flat surface in an oven; a desiccator, or direct sunlight; and sometimes rolled (22).

Rehydrating Dried Fruit

Dried fruits can be rehydrated to some degree by adding ½ cup of water or other liquid, such as juice or liquor as called for in some recipes, for every cup of dried fruit and microwaving on medium high (70%) for 2 minutes.

Fruit Juices

Most fruits and vegetables contain very high proportions of water, which makes them easy to squeeze or pulverize into a juice. Two exceptions to this rule are bananas and avocados, which hold very little water. Orange juice sales lead the fruit juice market, followed by apple, grape, cranberry, grapefruit, and pineapple juices (68). In addition to the traditional juices, tropical fruits and their juices such as acai, guava, mango, papaya, and passion fruit are growing in popularity (62).

Fruit juices come to market in cans, bottles, and cartons. They arrive fresh, as frozen concentrates, or in powdered forms that often contain added sugar. Concentrated fruit juice has had about three-fourths of its water removed. This may alter flavor somewhat, but the concentration in volume reduces shipping and handling costs.

The labels on juice mixes can be misleading because the product can contain anywhere from 10 to 100% actual juice. The ratio of fruit juice to water determines how fruit beverages may be labeled under federal guidelines (Table 14-5). Other ingredients such as vitamins (vitamin C is most prevalent), preservatives, natural or synthetic flavorings, sweeteners, and colorings are frequently added to the juice. The vitamin A and/or C content will vary depending on what fruit or vegetable the juice was made from, as shown in Table 14-6.

The high antioxidant content of pomegranate juice has led manufacturers to describe it as a "superfruit," but as mentioned earlier, this is a marketing term not defined by the FDA (28).

Fruit/Vegetable Juice Processing

Extraction of juice is the first step in manufacturing fruit and vegetable juices. Other steps of juice production

TABLE 14-5 Fruit Juice Beverage Names Depend on the Percentage of Actual Juice

Beverage Name	Fruit Juice (%)
Juice	Not less than 100
Juice drink	Not less than 50
Nectar	Not less than 30–40
Ade	Not less than 25
Drink	Not less than 10

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TABLE 14-6 Nutrient Comparison: Fruit and Vegetable Beverages vs. Soda

Beverage (8 oz [240 mL])	kcalories	Vitamin A (RE)*	Vitamin C (mg)
Soda	***150***	***0***	***0***
Juice			
Apple, canned/bottled	117	0	2
Apricot nectar, canned	141	332	2
Carrot, canned	95	6327	21
Cranberry cocktail, bottled	144	1	90
Grape, canned/bottled	155	2	0
Grapefruit, fresh	96	3	94
Lemon, fresh	60	5	112
Lime, fresh	66	3	72
Orange, fresh	111	50	124
Papaya nectar, canned	142	28	8
Passion fruit (yellow)	149	595	45
Peach nectar, canned	134	64	13
Pineapple, canned	157	0	26
Prune, canned	182	1	10
Raspberry, bottled	98	24	36
Tangerine, canned	124	104	55
Tomato, canned	42	136	45
Vegetable (V8), canned	46	283	67
Reference Daily Intake (RDI)		5000	60

*RE = Retinol equivalents—a measure of vitamin A activity based on an older estimation of how much vitamin A the body derives from carotenoids.

include clarification, deaeration (removing the air), pasteurization, determining concentration/additions, and packaging (bottle, can, or freezing) (47).

Juice Extraction

Prior to juicing fruits or vegetables, most of them must be thoroughly washed; freed of any bruises, seeds, and mold; and often peeled and pitted. Citrus fruits are generally cut in half and squeezed, either mechanically or by hand. Although the pithy white parts of oranges and grapefruits containing bioflavonoids, and vitamin C may remain, it is important to remove the skins to remove bitter tasting and possibly toxic compounds. The skins of tropical fruits are also usually peeled because they may have been grown in a country that allows the use of questionable pesticides. The skins of waxed produce and the leaves of carrots and rhubarb also must be removed. Cutting the fruits and vegetables into slices or chunks allows them to be placed in a juicer, where they can be processed into a beverage.

Different types of juice extractors result in varying amounts of pulp; some strain out most of the pulp, whereas others produce a thick, pulp-rich beverage. The most traditional commercial method of extracting juices is through the use of presses. Fresh fruit and vegetable juices taste best and are most nutritious when they are consumed immediately after preparation rather than stored for future use.

Clarification

The natural pressing of plant material leaves a semifluid mass of cell-wall material (cellulose and pectin). The small particles of suspended pulp remaining in pressed juice are called "haze" or "cloud" (6). Many consumers prefer crystal-clear fruit juice, so these particles are usually removed.

In tomato juice, the suspended pulp, which contributes to viscosity, is desired. If fresh tomato juice is left to stand, however, the natural enzyme pectin methyl esterase breaks down the pectin, resulting in a progressively thinner tomato juice over time. Tomato juice manufacturers can use the "hot-break process" to inactivate the enzymes by quickly heating the product to 180°F (82°C). Allowing the enzyme activity to proceed and produce a tomato juice with a thinner consistency is called the "cold-break process" (47).



How & Why?

How is the pulp removed from juice?

If a nonpulp texture is desired, fine filters or high-speed centrifuges are used to remove the pulp and associated haze. The centrifuges separate contents based on density differences, with the lighter substances migrating to the top and the heavier ones settling to the bottom. Any minute pulp and colloidal particles still remaining can be removed by adding enzymes (Chemist's Corner 14-4). These enzymes break down pectic substances that settle to the bottom of the juice, followed by further filtering or centrifugation (56). Liquification enzymes are often added to clarify apple, cranberry, and grape juices (6).

Deaeration

Entrapped air in juices is removed by deaeration, a process that reduces undesirable changes resulting from the presence of oxygen. Juices are deaerated by spraying them into a vacuum deaerator. Deaeration improves shelf life, maintains flavor, and reduces the breakdown (oxidation) of vitamin C (47).

Pasteurization

The high heats of pasteurization inactivate enzymes and destroy microorganisms that can cause foodborne illness.



CHEMIST'S CORNER 14-4

Enzymes Reduce Haze

Cellulase and pectinase are added to juices to hydrolyze the cellulose and pectin, respectively. Amylase enzymes are added to eliminate starch haze caused by the presence of glucose polymers (32).

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Some juices, especially fresh juices, are not pasteurized, which raises concerns when *Escherichia coli* outbreaks from nonpasteurized juices are reported (see Chapter 4). Pasteurizing juices diminishes their fresh-squeezed flavor, which can be partially replaced by adding back essence oils and folded peels from the original juice; however, the extraction and finishing processes may ultimately influence juice flavor quality (7). Alternatives to pasteurizing juices currently being studied include irradiation, hydrostatic pressure, ultrasound, high-intensity pulsed electrical fields, and oscillating magnetic fields (38, 73) (see Chapter 28).

Concentration/Additions

Blends of fruit flavors and juices are common and range from pure fruit juices to highly diluted, artificially flavored and colored drinks, which may contain little of the actual juice or its nutrients. The latter types of drinks may also be carbonated, and although they may be less thick and sweet than fruit juice, some are higher in sugar. Some juices are fortified with calcium and vitamin D to appeal to consumers interested in lowering their risk of osteoporosis (42).

Other beverages to which fruit juice has been added include sparkling water, noncarbonated drinks, teas, and wine coolers (48). There are also "texturally modified" beverages that use real fruit pulp or pieces and other components to enhance mouthfeel (77).

PREPARATION OF FRUITS

Limiting Enzymatic Browning

Certain kinds of fruit, when peeled or sliced, are susceptible to enzymatic browning (17). Enzyme activity—and thus enzymatic browning—can be inhibited by denaturing enzymes, adding acid, lowering the storage temperature, and/or blocking exposure to oxygen through the use of coatings or antioxidants.

Denaturing Enzymes

Blanching foods by dipping them briefly in boiling water destroys the enzymes through denaturation. Fruits are not generally blanched, however, because heating already-ripe fruits makes them lose texture and flavor.

Reducing pH

Polyphenol oxidase enzyme activity is inhibited in the presence of acid (2). The optimal pH for this enzyme is 7.0, so the high acid content of fruits such as oranges, lemons, and limes prevents enzymatic browning. Less acidic fruits such as peaches, apples, and bananas can be protected from enzymatic browning by coating them with lemon, lime, or orange juices, or with solutions of cream of tartar or the citric and acetic acids found in vinegar.

Lowering Temperature

Cold temperatures reduce the rate of enzyme activity and thereby slow, but never completely inhibit, enzymatic browning (53).

Coating Fruits with Sugar or Water

Cut fruits can be protected from exposure to oxygen by covering them with a light layer of sugar or syrup (54). Submerging fruits in water also blocks oxygen from contacting their surfaces.

Adding Antioxidants

Antioxidants such as ascorbic acid (vitamin C) and sulfur compounds prevent enzymatic browning by using up available oxygen (29). Ascorbic acid and sulfiting agents are available commercially for this purpose. Many dried fruits are treated in a similar manner (see "Food Additives in Fruits," pp. 288–289). Pineapple juice, which is naturally high in sulfur compounds, can be helpful in inhibiting enzymatic browning when added to fruit salads or compotes.

? How & Why?

Why are some raisins brown and some "golden"?

The difference between light- and dark-colored raisins is that the former are often treated with sulfur dioxide, which prevents enzymatic browning (10).

Changes during Ripening and Heating

Color

The pigments coloring fruit are the same as those in vegetables and are discussed in Chapter 13: carotenoids, chlorophylls, and flavonoids (anthocyanins, anthoxanthins, and betalains). Fruit becomes more brilliant in color during ripening as chlorophyll breaks down, which exposes the underlying pigments. Subsequent color changes in fruits are usually the result of a change in pH or a reaction with a metal salt and/or ethylene gas.

pH

Heating fruit may change the pH, which affects the color of some pigments. Sometimes a harmless blue discoloration is seen in baked products surrounding added ingredients such as cherries, cranberries, and walnuts; this is caused by the interaction of anthocyanins in these foods with the alkaline baking powder or soda in the flour mixture. To prevent this blue color, acid in the form of buttermilk or sour cream can be used to substitute for milk in these products, and walnuts can be roasted (about 10 minutes at 350°F/177°C), which removes the anthocyanin-containing skins (13).

Metal Salts

Canned fruits or vegetables contain acids, which often react with the tin lining to produce metal salts that change the color of pigments, particularly the red-blue anthocyanins. As a result, canned foods and juices containing anthocyanins are often stored in specially treated cans or in glass to prevent food discoloration. Red, purple, or blue juices can also turn bluer when pineapple juice is added if iron has been introduced into the canning process from the pineapple-processing equipment.

Ethylene Gas

One way to facilitate the ripening of oranges and tomatoes to their optimal color is by exposing them to ethylene gas. This stimulates respiration, thereby accelerating the ripening process, but it may cause the fruit to deteriorate more quickly (26).

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CAREER CORNER

A food science class captured Janet Adams's interest because it connected the field of nutrition with the many employment opportunities found in the food industry. She found out that Pizza Hut offered a 3-month internship, which she applied for and received.

Janet says, "Students from other universities can find out about internships by joining their local national food association branch [Institute of Food Technologists; www.IFT.org; IFT also lists universities offering food science degrees]; contacting IFT members; finding someone in the corporation to talk to [www.hoovers.com locates company information]; or summer work via internships." Students should attend food events and national seminars and apply for food scholarships.

"Just getting experience, even if it's a part-time job, is key to entering the field," says Janet. "Another good source is the Grocery Manufacturers Association that provides scholarships, holds annual meetings, offers student memberships, and posts jobs, similar to IFT, on its website [www.gmaonline.org]."



Courtesy of Janet Adams, PhD

Janet Adams—Scientist for Frito-Lay, Incorporated

She started interviewing for jobs the summer before her December graduation, but her search revealed that she would need a master's degree to work where she wanted—in product development. While obtaining her education, she was active in the local IFT association as a student member and met two wonderful mentors. They told her that she needed to set herself apart from other students by participating in internships. She also applied for various food corporation scholarships.

Scientist is Janet's official title in the Product Development division of Frito-Lay. Some of her work entails defining market trends, managing projects, suggesting what new products should be launched, writing specifications for new products, helping to develop new seasonings on potato chips and corn chips, and assisting recruiting teams that travel to various universities to discuss food science careers.

Texture

Fruit is often served raw because the texture is usually more desirable than that of cooked fruit. Heat drastically softens fruit, sometimes to the point of mushiness (e.g., strawberries). During heating, several changes occur that contribute to this softness:

- Conversion of the fruit's protopectin to pectin
- Degradation of cellulose and hemicellulose
- Denaturation of the cell-membrane proteins

This last change influences membrane function and the ability of the fruit to maintain its turgor.

Osmosis

During heating, the fruit's osmotic system of selective permeability is replaced with simple diffusion, contributing to the loss of shape in heated fruits. Normally, the cell walls of raw fruits have semipermeable membranes, which allow water, but not solutes such as sugars or minerals, to pass through. The water moves from a low solute concentration to a higher one, until the solute concentration is equal on the two sides of the membrane. This is the principle behind the practice of spraying water on fruits displayed in supermarket stands to keep them crisp and turgid. The higher solute concentration in the cells draws the water into the fruit, causing cell enlargement and swelling, and keeping the fruits looking full and fresh. This is also the reason why lemons stored in water will produce about twice the juice as those that are not. Sprinkling sugar on fruit produces the opposite effect, causing fruit to become syrupy as water passes out from the cells to the surface where the solute concentration is higher (because of the sugar). This can backfire, however, if sugar is left on fruit too long, producing a soft, mushy texture.

Heating destroys the membrane's ability to prevent the loss or uptake of solutes through the cell wall. Solutes can then freely pass across the membrane until solute concentrations are equal on the two sides.

Sugar may be added to fruit before it is cooked in water to replace the lost sweetness. This also helps the fruit retain its shape and firmness. For the same reason, fruits are often heated in a syrupy solution of greater than 15% sugar. The sugar enters the cells as the water leaves. Sugar further inhibits loss of texture by interfering with the conversion of protopectin to pectin. Calcium salts and acids also help to firm fruit, which is why calcium is added to many canned fruits and vegetables, especially pears and tomatoes (50) (Chemist's Corner 14-5).

How & Why?

Why are canned fruits softer and shinier than fresh fruits?

Heating fruit in water causes the fruit's natural sugars to move out into the water and water to move into the fruit, resulting in the loss of shape. Fruits become more translucent and shiny when heated as water leaves the cells, and the air between cells is expelled.

CHEMIST'S CORNER 14-5

Calcium in Canned Fruits

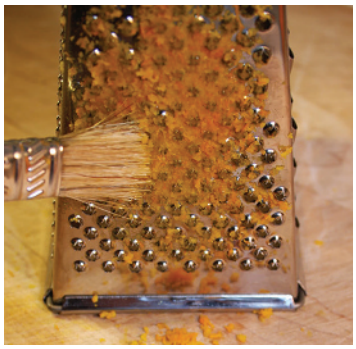
Pectin often exists in nature as salts of calcium or magnesium. It is able to do so because of its abundance of carboxyl groups (–COOH). The bridges formed between the free carboxyl groups and the intracellular ions of calcium and magnesium strengthen the tissue of the plant and resist degradation during the heating of canning (43). Canned fruit also stays firm with the addition of calcium salts: calcium chloride, calcium citrate, calcium lactate, and monocalcium phosphate.

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FIGURE 14-18 Scraping the zest off citrus fruits.



Grater: The smallest holes on a grater can be used to collect zest, which is freed with the use of a pastry brush. Avoid scraping so hard that white pith ends up in the small pieces of zest.



Amy C. Brown

Five-hole zester: The shallow blade of a zester does not go any deeper than the zest, making it easy to collect the flavorful and fragrant long strips of zest peelings.

Flavor

Sugars and acids contribute to the sweet and sour taste of fruits. The flavors are derived from the chemical configuration of compounds such as sugars, acids, phenolic and **aromatic compounds**, and **essential oils**. The flavor substances and volatile compounds that contribute to aroma can be lost during preparation, which is why fruits are either served raw or heated only for a minimal amount of time.

Zest

The peels of oranges, lemons, and limes serve as reservoirs for potent aromatic oils. The colorful outer layer of these citrus fruits, known as the *zest*, often contains more flavor than the fruit's juice. The zest is not the entire peel, but the outermost, bright-colored layer above the white pith (33). The zest can be removed one of three ways: grating with the smallest holes of a grater, using a zester tool, or cutting with a sharp paring knife (Figure 14-18). Various forms of zest—flat strips, julienned slivers, or a fine grate—can be added to many dishes. The amounts of grated zest and unstrained juice obtained from selected citrus fruits are shown in Table 14-7. Large zest pieces can be strained out of a dish after they have contributed their flavors during cooking, or they can be left in the dish if blanched for 2 minutes to make them soft and palatable. Finely grated zest is often added to the batter of dessert dishes, where its small particle size allows it to be evenly distributed.

TABLE 14-7 Amount of Zest and Juice Obtained from Citrus

Citrus Type	Grated Zest, Lightly Packed	Juice, Unstrained
1 lime	1–1½ tsp	about 3 Tbsp
1 lemon	½–1 Tbsp	¼–1/3 C
1 orange	about 1 Tbsp	about ½ C
1 grapefruit	about 1½ Tbsp	about 1 C

Source: ©1998 Molly Stevens, from Fine Cooking Magazine 25:76, 1998. Reprinted by permission.

Aromatic compound A compound that has a chemical configuration of a hexagon.

Essential oil An oily substance that is volatile (easily vaporized), with 100 times the flavoring power of the material from which it originated.

Dry-Heat Preparation

Fruits add variety to meals, and preparation techniques can make overripe fruits or otherwise unpalatable ones such as rhubarb and green apples appetizing. Before preparation, all fruits must be washed to remove pesticide residues, soil, and microorganisms. Because most fruit spoils faster if it is washed before refrigeration, it is best to rinse it just before use. Cooked fruit, with the exception of applesauce and fruit spreads (jams, jellies, etc.), should be served immediately after it has been prepared.

Baking

Whole apples and some varieties of pears are good for baking. The apples may be left whole, or they can be cored, peeled, and placed in a baking dish. A sauce can be made from brown sugar, water, butter, cinnamon, and nutmeg boiled together and poured over the apples, which are then baked uncovered for approximately 1 hour at 350°F (177°C), during which they may be basted occasionally. Bananas, plums, peaches, and rhubarb can also be baked successfully. Fruit can be added to many baked goods to enhance their flavor, color, and texture. Cakes, pies, cookies, muffins, scones, and cobblers, as well as pancakes and waffles, all profit from partnerships with fruit.

Broiling

A few fruits, such as grapefruit halves, pineapple halves, and bananas, can be broiled by placing them on a heavy-duty pan, which is then broiled until the fruit is golden brown. Often, a bit of melted butter mixed with sugar is drizzled on the fruit before broiling to ensure browning.

Frying/Sautéing

A small amount of fat in a frying pan can be used to sauté slices of apple, banana, cherry, and pineapple. Sometimes the fruit is sprinkled with white or brown sugar. Sautéing contributes to a slight increase in the fruit's caloric and fat content. Sautéed fruit may be served alongside roasted meats or as a dessert course.

Moist-Heat Preparation

Stewing/Poaching

Fresh fruits can be stewed or, better yet, poached. For stewing, fruits are heated either without water (for fruit with a high water content), with very little water or juice, or with added sugar or syrup. Stewing fruits in a sugar syrup helps to maintain their shape.

For poaching, fresh fruits such as pears are gently lowered into boiling water or syrup, the heat is reduced to poaching temperatures (160 to 180°F/71 to 82°C), and the fruit is

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cooked until barely tender. This process does not take long, and the fruit should be removed from the heat as soon as cooking is complete. Very soft fruits are best drained immediately to prevent overcooking, whereas firmer fruits such as apples and pears are best left to cool in the poaching syrup to soak up more flavor and prevent wrinkling.

Applesauce Preparation

Applesauce is relatively simple to prepare from cored and chopped cooking apples. The peels may be removed for a smooth sauce or left on to add a touch of color and increase the fiber content. A pound of apples, about 1 to 1½ cups of water or cider, and a cinnamon stick (optional) is added to a saucepan. The pan is covered, and the mixture is brought to a boil, then reduced to a simmer, and cooked for about 10 minutes, until tender. The pan is removed from the heat, and the cinnamon stick is discarded. The apples are then pulverized with a potato masher or fork until smooth. Sugar may be added (½ cup per pound of apples). The applesauce should be served immediately or covered and refrigerated. Chunky applesauce is made by adding the sugar before heating and smashing the fruit only slightly.

Preparing Dried Fruit

Dried fruit is usually soaked in water and then simmered in a covered pan, but some dried fruits, such as prunes, have a higher water content and do not need to be soaked before cooking. They may simply be covered with cold water and brought to a simmer. The natural sweetness of dried fruits usually makes it unnecessary to add sugar, but some fluid may be necessary to rehydrate the dried fruits. To add more flavor, some recipes call for juice or liquors instead of water.

Fruit Spreads

Jam is a common type of fruit spread, but it is not the only one. The many different types of fruit spreads share a common basic preparation method.

Types of Fruit Spreads

The most commonly consumed fruit spreads are fruit preserves, jams, conserves, jellies, marmalades, and butters. Except for bananas and melons, most fruits lend themselves well to these methods of preservation. The type of fruit spread is determined by the amount of added sugar and the form of the fruit—as juice, or mashed, sieved, whole, halved, or in chunks:

- ***Preserves.*** Made from whole fruit, halves, or chunks.
- ***Jams.*** Made from ground or mashed whole cooked fruit.
- ***Conserves.*** Made from a mixture of fruits (usually citrus or at least with some citrus) to which nuts and raisins, but no sugar, are generally added.
- ***Jellies.*** Made from the juice of cooked fruit, with added sugar and pectin. For a clear jelly, the juice is first strained.
- ***Marmalades.*** Contain juice with thin slices of fruit and rind, especially citrus fruits.
- ***Butters.*** These thick and smooth fruit preserves are made from sieved, long-cooked fruit; are usually less sweet than jams and jellies; and do not keep as well as other fruit spread forms.

Ingredients

Fruit spreads gel (or set) when pectin molecules bond to each other and form a mesh-like network. Pectin (1%), sugar (about 60%), and acid (pH 2.8 to 3.4) make the formation of the network possible.

Pectin

Pectin makes fruit spreads gel (see the section "Pectic Substances" under "Composition of Fruits," p. 285). Although pectin is naturally found in fruits, concentrations vary according to the fruit, so more may need to be added when manufacturing certain fruit spreads. At least a 0.5 to 1% concentration of pectin is required for fruit to gel, and if the fruit does not contain sufficient pectin, commercial pectin can be added in either powder or liquid form (Chemist's Corner 14-6). Special pectins are available for making fruit spreads lower in sugar.

Sugar

Sugar is a natural preservative, and most fruit preserves are at least 50% granulated white sugar. For example, one recipe for strawberry jam calls for 5½ cups of strawberries (about 3 quarts), 8 cups of sugar, and one package of powdered pectin. Most microorganisms need water to survive, and when sugar osmotically pulls the water from their cell interiors, they die. In addition to acting as a natural preservative, sugar helps to maintain the firmness of fruits, contributes to their flavor, makes gelling possible—and adds kcalories. Most jams and jellies average 50 kcalories per tablespoon, but this can be reduced by almost half (30 kcalories/tablespoon) by using alternative sweeteners and a unique type of pectin that relies on calcium ions to create a net-like structure (36). Calcium ions contribute to the creation of cross-linking bridges, which help to gel fruit spreads, salad dressings, and diet jellies made without sugar.

Sugar-free, kcalorie-free imitation fruit spreads are available. Another option for lower-sugar spreads is to purchase puréed baby fruits or to blend frozen fruits. Although all fruit spreads should be refrigerated after opening, it is doubly necessary to keep low- or no-sugar spreads refrigerated because there is little or no sugar to prevent microbial growth.

CHEMIST'S CORNER 14-6

Pectins and Methoxylation

Commercial pectins are classified according to their degree of methoxylation (DM); the higher the percentage, the quicker the gel sets. High-methoxyl pectins have a DM value of 50 to 80%, form gels in the presence of acid and sugar, and are most commonly used for the manufacture of fruit spreads. High-methoxyl pectin makes it possible for fruit spreads to gel through coordinate bonding with Ca^{2+} ions or hydrogen bonding and hydrophobic interactions. Low-methoxyl pectins (25 to 50% DM value) gel in the presence of divalent cations such as calcium but are not dependent on acid or high solids content (37). Gelation occurs because of ionic linkage via calcium bridges between two carboxyl groups belonging to two different chains in close proximity to one another.

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Acid

Acid provides both flavor and gel formation. Hydrogen ions (H^+) from acid are needed to neutralize the negative charges that cause pectin molecules in water to repel each other. The pH range that allows pectin molecules to bind is between 2.8 and 3.4, with an optimal pH of 3.2. All fruit spreads should taste somewhat acidic. In fact, without acid, fruit spreads would lack both flavor and gel strength. Some commercial pectins contain added acid. If the fruit mix is too sweet, 1 tablespoon of lemon juice, 1 tablespoon of vinegar, or ⅛ tablespoon of citric acid can be added for every 8-ounce cup of juice (1).

Fruit

Because of their varying amounts of pectin and acid, some fruits are more suited for making fruit spreads than others (4). Table 14-8 shows which fruits contain sufficient pectin and acid for gelling. Adjustments for either low pectin or low acid can be made by combining one fruit with another, using commercial pectin, and/or adding lemon juice.

Preparing Fruit Spreads

To prepare a good fruit spread, the correct balance of pectin, sugar, and acid must be attained. The fruit selected determines the amount of pectin and acid and the overall quality of the spread. Following are the steps for preparing fruit spreads (see Figure 14-19):

1. Heat the fruit.
2. Add sugar and possibly pectin and acid.
3. Pour the mixture into sterile containers.
4. Seal the containers properly.

Ripe fruit, whole or cut up, is simmered in a small amount of water to liberate the pectin and juice. Approximately ¼ cup of water is used for every pound of fruit. Too much water will dilute the pectin and prevent gelation. If the fruit is extremely watery, simply crushing it may provide sufficient liquid. Boiling times vary from 10 to 15 minutes for soft fruit to about 20 minutes for hard, sliced fruit. Uncooked or undercooked fruit will not gel because heat is necessary for the conversion of protopectin to pectin. Sugar and pectin and/or acid

TABLE 14-8 Fruit Pectin and Acid Content

Adequate Pectin and Acid*	Low in Either Pectin or Acid	Low in Both Pectin and Acid
• Apples (sour) • Blackberries (sour) • Crabapples • Cranberries • Currants • Gooseberries • Grapes (Eastern Concord) • Lemons • Loganberries • Plums (not Italian) • Quinces • Red currents	• Apples (ripe) • Blackberries (ripe) • Cherries (sour) • Chokecherries • Elderberries • Grapefruit • Grapes (California) • Loquats • Oranges	• Apricots • Blueberries • Figs • Grapes (Western Concord) • Guavas • Peaches • Pears • Plums (Italian) • Raspberries • Strawberries

*Enough natural pectin and acid to gel with added sugar.

Source: Andress EL, and JA Harrison. Making jams and jellies. Jellied product ingredients. www.uga.edu/nchfp/how/can_07/jellied_product_ingredients.html.

FIGURE 14-19 Preparing fruit spreads. Heat fruit, sugar, and possibly added pectin and/or acid sufficiently long enough (or it will not gel) before pouring into sterilized jars to set.



Tatiana Vorona/Shutterstock.com

TABLE 14-9 Gelling Problems and Their Causes

Problem	Possible Causes
Sugar crystallization (mainly found in grape jelly)	Too much sugar Not enough acid Overcooking Delay in sealing (may be prevented by permitting juice to stand overnight in cold place before making it into jelly)
Weeping	Cause not really known; may occur in jellies made from currants or cranberries high in acid
Cloudiness	Squeezing juice out of bag Starch from apples used to make jelly (avoid pressure on jelly bag when straining)
Failure to gel	Improper balance among pectin, sugar, and acid Lack of pectin or acid in fruit Overcooking
Fermented jelly or mold formation	Jelly glasses not well sterilized Jelly stored in warm, damp place Jelly not completely sealed

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are added, after which the mixture is boiled to concentrate the ingredients. Too much sugar creates a gummy product, whereas too little prevents gelation. Some commercial pectins may be added to the fruit before the sugar, but there will be directions to that effect on the package.

One test to determine whether the mixture is done is to dip a cool metal spoon in the boiling fruit, lift it up, and see if the mixture drops from the spoon in flat-sheet fashion. Heating the mixture beyond this stage will cause the pectin molecules to break down and so prevent the mixture from gelling; also, the color may get darker because of the caramelization of sugars. When done, the mixture is poured into sterile glass containers to within ¼ inch of the rim and sealed with two-part canning lids according to the manufacturer's directions. Fading of the finished spread's color is prevented by storing the jars in a dark, cool place. Table 14-9 lists possible reasons for gelling problems.

STORAGE OF FRUITS

Many types of fruits are picked and shipped to market in an unripe state because the hardships of transportation would damage delicate ripe fruits (77). Unripe fruit can be left at room temperature in a paper bag until ripe. Most European pears, for example, are marketed unripe, so it is best to store them outside the refrigerator in a loosely closed paper bag until they give to firm pressure. Commercially, fruit can be stored under controlled-atmosphere storage or with the aid of coatings or films as described in Chapters 13 and 28.

Fruits differ in their respiration rates, and thus in their rates of ripening. A few fruits, known as "climacteric," will experience an increased phase of respiratory rate right before becoming fully ripe. These fruits continue to ripen after being harvested. Other fruits and most vegetables are nonclimacteric, and although they continue to respire at the same or even a lower rate after being harvested, it is best that they are ripened fully before being harvested (Table 14-10).

TABLE 14-10 Selected Climacteric and Non-climacteric Fruits

Climacteric Fruits (Continue to Ripen after Harvest)	Non-climacteric Fruits (Best Ripened before Harvest)
Apple	Blueberry
Apricot	Cherry
Avocado	Citrus fruits (grapefruit, lemon, orange)
Banana	Grapes
Breadfruit	Mandarin
Cantaloupe	Melons
Guava	Olives
Kiwifruit	Pineapple
Peach	Pomegranate
Pear	Raspberry
Persimmon	Strawberry
Plum	
Sapodilla	
Tomato	
Tropical fruits (papaya, mango, passion fruit)	

Storing Fresh Fruit

Ripe fruit with a high water content is best if consumed within 3 days of purchase. Grapes spoil quickly, so regardless of whether or not they are ripe, they are stored, unwashed, in plastic bags in the refrigerator and washed just prior to consumption. Conversely, cooled apples will keep for weeks.

After fruit is ripe, storage time may be increased by placing it in plastic bags punctured with air holes, and then in the refrigerator (see the back inside cover of this book). An exception is bananas, which are best stored at room temperature because refrigeration interferes with their ripening process and causes their skin to blacken.

The following are storage requirements for specific fruits:

- ***Cherries.*** Cherries should be arranged in a single layer between paper towels, placed in a plastic bag, and refrigerated.
- ***Dates.*** Dates will keep for weeks at room temperature, up to 1 year in the refrigerator, and up to 5 years in the freezer.
- ***Citrus fruit.*** Citrus fruit can be stored at a cool room temperature (60 to 70°F/16 to 21°C) or in light refrigeration temperatures (45 to 48°F/7 to 9°C) for 2 to 3 weeks.
- ***Pineapples.*** Uncut ripe pineapples can be kept at room temperature for up 3 days.
- ***Pomegranates.*** Ripened pomegranates are kept at room temperature for short periods but should be refrigerated if storage exceeds several days.
- ***Guavas.*** After guavas ripen, they can be stored in the refrigerator for 1 to 2 days.

How & Why?

Why does one rotten apple spoil the barrel?

An overripe apple stored with good apples will ruin the others by releasing ethylene gas, an agent that speeds up ripening. All bruised, dented, or otherwise damaged apples should therefore be removed before storing the intact apples.

Storing Canned Fruit

Canned fruits keep their quality longer if the cans are stored in a dry place at temperatures under 70°F (21°C). Bulging, dented, leaking, or rusted cans should always be discarded. Bulging may indicate the presence of the anaerobic bacteria that causes deadly botulism (see Chapter 4).

Olives

The storage requirements for olives depend on whether they are packed in a can or jar. The unused portion from an open can of olives should be stored in the original brine, covered with breathable plastic wrap, and kept in the refrigerator for no more than 10 days; possibly harmful toxins develop when such olives are stored in sealed or airtight containers. The brine of olives in a jar has three times the salt concentration and a much lower pH than that found in canned olives, so it does not matter if the storage container is airtight or not.

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PICTORIAL SUMMARY / 14: Fruits

Throughout human history, fruits have been prized and their seeds transported wherever humans have settled, resulting in the great variety of fruits available today.

CLASSIFICATION OF FRUITS

Fruits are classified according to the type of flowers from which they develop.

Simple fruits develop from one flower:

- **Drupes:** Fruit with seeds encased in a pit, such as apricots, cherries, peaches, and plums.
- **Pomes:** Fruit with seeds contained in a central core, such as apples and pears.
- **Citrus fruits:** Oranges, grapefruits, lemons, limes, kumquats, and mandarins.

Aggregate fruits develop from several ovaries in one flower. They include blackberries, raspberries, and strawberries.

Multiple fruits develop from a cluster of several flowers. They include pineapples and figs.



COMPOSITION OF FRUITS

The cellular structure and the pigments of fruits are similar to those in vegetables. The flavors of fruits are the result of combinations of sugars, acids, phenolic and aromatic compounds, and essential oils. Fruits typically have a pH below 5.0. Pectin plays an important role in fruit ripening and the gelling of fruit spreads.

Nutritionally, fruits are generally low in kcalories, fat, and protein. The few fruits that are high in fat are coconut, avocado, and olives. Fruits are high in water and carbohydrates, the latter providing the majority of their kcalories. Some, but not all, fruits can be excellent sources of vitamin C, β-carotene, iron, or potassium.

PURCHASING FRUITS

Fruits are selected based on appearance, size, color, shape, uniformity, and freedom from defects. The four grades for fresh fruits are U.S. Fancy, U.S. No. 1, U.S. No. 2, and U.S. No. 3. Fruit selection is based on grading factors as well as seasonal availability and criteria particular to each individual fruit variety.

Many fruits are available fresh in summer, but they can be obtained throughout the year in various processed forms: canned, frozen, dried, and juice. Refrigerated transport also makes fruits available year-round from countries with different growing seasons. Grades for canned or frozen fruits are U.S. Grade A or Fancy, followed by U.S. Grade B or Choice, and U.S. Grade C or Standard.



PREPARATION OF FRUITS

Cooking alters the taste, texture, color, and shape of fruit, so fruit is often consumed in its raw state. Cooking fruit adds variety to meals, makes fruit like rhubarb and green apples palatable, and uses overripe fruits. Fruits should be prepared using a minimum of water, time, and heat.

Most fruit can be kept beyond the growing season by combining it with sugar in the following forms of fruit spreads:

Preserves: Made from whole fruit, halves, or chunks.

Jams: Ground or mashed whole cooked fruit.

Conserves: Made from a mixture of fruits (usually including citrus) to which nuts and raisins, but no sugar, are added.

Jellies: Made from the juice of cooked fruit, with added sugar and pectin.

Marmalades: Juice combined with thin slices of fruit and rind, especially citrus fruits.



Butters: Thick and smooth, made from sieved, long-cooked fruit; usually less sweet than jams and jellies, and more perishable than other fruit spreads.

STORAGE OF FRUITS

Most ripe fruit should be stored in the refrigerator in plastic bags punctured with air holes; bananas, which will turn brown if refrigerated, are the exception. Unripe fruit is usually left at room temperature in a paper bag until ripe.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Apples and pears, with their seeds contained in a central core, are called _____.
   a. drupes
   b. aggregate
   c. seed cores
   d. pomes

2. As a fruit changes from immature to overripe, protopectin chemically breaks down to:
   a. pectin and then to pectic acid.
   b. pectic acid and then to pectin.
   c. oxalic acid and then to pectin.
   d. pectin and then to oxalic acid.

3. These fruits commonly have their peels scraped for zest to add flavor.
   a. Kiwifruit, watermelon
   b. Lemon, orange, lime
   c. Grapes, watermelon
   d. Banana, dates, mangoes

4. Jams are best described as fruit preserves made from _____
   a. ground or mashed whole cooked fruit.
   b. whole fruit, halves, or chunks.
   c. the juice of cooked fruit with added sugar and pectin.
   d. the juice of fruits with thin slices of fruit and rind.

5. A fruit juice beverage that contains not less than 30 to 40% fruit juice would be classified as a(n) _____
   a. juice drink.
   b. nectar.
   c. ade.
   d. juice.

6. Most fruits are low in fat, but the exceptions are _____
   a. avocados, coconut, and olives.
   b. figs, dates, and guava.
   c. olives, coconut, and pomegranates.
   d. dates, avocados, and dried fruit.

7. Which of the fruits below contain more vitamin C than a medium-sized orange?
   a. Papaya (1 medium)
   b. Kiwifruit (1 medium)
   c. Strawberries (1 cup)
   d. All of the above

*See Appendix F for answers to multiple choice questions.

Short Answer/Essay

1. Define the three classifications of fruits, how do they differ, and provide examples of each.
2. Discuss the three groups of pectic substances, how they contribute to the ripening of fruits, and how they are used by the food industry.
3. Certain fruits turn brown when cut open and exposed to air. Describe the process by which this occurs. What steps can be taken to inhibit browning?
4. Discuss the grading of fresh fruit and how it differs from the grading of canned or frozen fruit. What are the signs that frozen bags of fruit have been thawed and refrozen?
5. Describe the specific signs of ripeness for the following fruits: avocados, grapefruit, guavas, lemons, honeydew melon, and juice oranges.
6. Rank the types of fruit juice beverages in descending order of their fruit juice concentration.
7. Describe the changes that occur when fruits are heated.
8. What is fruit zest, and how is it used in food preparation?
9. Describe the differences (fruit type and sugar amount) between the following types of fruit spreads: preserves, jams, conserves, jellies, marmalades, and butters.
10. Explain the role that each of the following ingredients plays in the preparation of fruit spreads: pectin, sugar, acid, and fruit.

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15



Soups, Salads, and Gelatins

Soups 310
Salads 315
Gelatins 321

Starting the meal with an excellent soup or salad is equivalent to putting your best foot forward. It is important to begin a meal with flavor and distinction as a prelude to the main course.

The versatility of soups and salads allows them to be served not only before a meal but also during or after—or even as a meal. Countless combinations are possible, which probably explains why soups were some of the first meals ever prepared in a pot over an open fire.

SOUPS

Soups are a liquid food that may or may not contain solid ingredients such as meat, poultry, vegetables, and/or grain-based foods (bread, pasta, noodles, rice, barley, etc.). Stews differ from soups in that their ingredients are more solid than liquid and that they are a complete meal in themselves. Nevertheless, the difference between soups and stews is not always clear.

Soups were commonly served as meals in sixteenth-century France, where specialized shops were set up among the ordinary trade shops to serve soup to the workers. A Parisian soup vendor had a Latin inscription above his door that read, "Come to me all of you whose stomachs cry out and I will restore you" (17). The restorative services of these soup shops eventually led to them being called restaurants, and our English word used for the evening meal, *supper,* is derived from *soup* (14). Pots were often used to prepare soups, which is why the word *pottage* is often associated with soups.

Types of Soups

The enormous assortment of soups now available ranges from light soups that serve as appetizers to very heavy soups that can be offered as a main dish. Most soups are served hot, but there are exceptions, the most famous one being vichyssoise (vee-shee-swahz). Among the many accounts of its origin is the story of Louis Diat, chef of the Ritz-Carlton in New York, inventing this soup in 1917 and naming it after his native town in France (21). Another tale of its origins starts with King Louis XIV of France, who, suspicious that people were trying to poison him, ordered that all his food be sampled by an official taster. The king's taster felt the need for his own taster, who, in turn, also had a taster, and by the time this hot creamed leek and potato soup got to the king, it was cold, and so, legend suggests, it has been eaten that way ever since (12).

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FIGURE 15-1 Types of soups* (with selected examples).

CLEAR AND THIN SOUPS	
Bouillon	Unstrained (unclear) (from simmered meat, poultry, vegetables, or grains)
Court bouillon	A special bouillon containing wine, vinegar, or lemon juice in which another ingredient has been poached
Broth	Strained liquid (from simmered meat, poultry, vegetables, or grains)
Consommé	Cleared with egg white

THICKENED SOUPS	
Cream	Added milk, cream, or sour cream Cream of asparagus, cauliflower, celery, chicken, corn, mushroom, tomato and New England clam chowder
Purée	Blenderized and strained ingredients
Bisque	Combination cream and purée (usually crustaceans) Lobster bisque
Sauce	Thickened with a velouté sauce (egg, butter, and cream)
Other Thickeners	Thickened with the starch from potato, pasta, grain (rice), flour, cornstarch Egg drop soup (cornstarch) Vichyssoise (potato)

TRADITIONAL SOUPS	COLD SOUPS	NOODLE SOUPS	FRUIT SOUPS	DESSERT SOUPS
Avgolemono (Greek)	Borscht (Slavic)	Chicken noodle (American)	**(served hot or cold)**	Ginataan (Filipino)
Legume soups—lentils, beans, peas	Fanesca (Ecuador)	Pho (Vietnamese)	"Frukt suppe" (Norwegian)	Oshiruko (Japanese)
Minestrone (Italian)	Gazpacho (Spanish)	Ramen (Japanese)	Sour soup (Vietnamese)	
Mulligatawny (India)	Vichyssoise (French)	Saimin (Hawaiian)	Winter melon (Chinese)	
Pozole (Mexican)		Thukpa (Tibetan)		
		Udon (Japanese)		

*Many, but not all, soups are made from a liquid foundation of stock (white or brown from meat, poultry, fish, or vegetable) or broth (stock that has not been reduced).

Stocks

Whatever the temperature, all soups are based on **stock** or **broth.** To this foundation are added other ingredients, lending each kind of soup its own name and unique characteristics. Stocks are very simple—primarily water with little or no flavor—and serve as foundations for other added ingredients. Building on this base, a clear, thin, or thickened soup can be made and then developed into any of the almost unlimited variations, including traditional, cold, noodle, fruit, and dessert soups (Figure 15-1). In this section, the different types of stocks are discussed, and then the two basic categories of soups—(1) clear or thin and (2) thickened—are examined, using cream as an example of a thickened soup.

White and Brown Stocks

Cracked bones and water are often the main ingredients of two types of meat stock—white and brown. For **white stock,** neck and knucklebones are preferred because they contain more collagen (which converts to gelatin) and more flavorful extracts than any other bone in the animal (12). Although all bones are porous, splitting them open helps to release the gelatin, which imparts a rich thickness and body to the stock. When stock is made from meats, beef and chicken are the two most commonly used. Veal bones contribute the greatest amount of collagen, making the thickest, most gelatinous stocks, while beef bones contribute the richest, meatiest flavor. Many chefs use both. **Brown stock** has a deeper, caramelized flavor. Browning the bones and meat before adding water has the advantage of discouraging the stock from becoming cloudy. Heating the meat coagulates many of the proteins and traps minute particles that could otherwise cloud the stock.

Water: The Main Ingredient

Pure, clean, cold water is the first ingredient of any stock. Although there is no standard formula for stocks, a general rule is that one pint of water is required for every pound of bones. Spring or distilled water is preferred (although not always used because of cost) because tap water may carry the flavors of chlorine or other substances (13). Simmering the water and ingredients for half an hour up to several hours then generates flavor. It is important to simmer, rather than boil, the stock. Boiling causes the particles floating to the top to churn back into the broth, turning it cloudy and less clean tasting (20). It also toughens the meat and disintegrates any ingredients except bones. If additional water is required during simmering, hot water can be added to avoid cooling the entire stock.

Stock The foundational thin liquid of many soups, produced when meat, poultry, seafood (and/or their bones), or vegetables are reduced (simmered) and strained.

Broth Stock made from meat or meat/bone combinations and some water with little or no flavoring. Broths are seldom reduced (simmered until much of the water evaporates) and therefore are not as strong-flavored as stocks.

White stock The flavored liquid obtained by simmering the bones of beef, veal, chicken, or pork.

Brown stock The stock resulting from browning bones and/or meat prior to simmering them.

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How & Why?

Why is cold water used to start soups?

The water should be cold to start with because ingredients placed in cold water will transfer their flavor more efficiently to the liquid (11). If hot water is used, the stock will be less flavorful and less clear.

Flavoring Ingredients

Flavor can be added by starting with a mirepoix (meer-pwah) made up of 50% onions, 25% celery, and 25% carrots, which is often added to stocks, soups, sauces, and other foods. This standard mirepoix can be modified to produce a white mirepoix, in which leeks replace the carrots in order to create a near-colorless stock (6). Salt or other potent seasonings are not usually added until the last half hour, if at all, in order to prevent their becoming too concentrated as liquids evaporate during cooking. The exception is a **bouquet garni,** which can be added to dishes with a lot of liquid undergoing a long simmer. Standard ingredients of a bouquet garni include parsley, thyme, and a bay leaf, although other aromatics such as cloves, rosemary, sage, and garlic cloves can also be added (26). Cracked or ground pepper should never be added at the start of a long heating process because it will turn harsh and acrid in taste (17). Whole peppercorns may be used instead.

Meat Stocks

Meat stock, based on cracked bones and sometimes raw meat, serves as the major ingredient for all meat soups and major meat sauces. Cooked meat will not yield the same flavor, although it is sometimes used. The more mature the meat, the better, because meat becomes more flavorful with age. In general, red meats contain more flavor than white (veal, pork). Some of the cuts most frequently used for meat stock include the following:

- **Beef.** Oxtail, chuck, shank, bottom round, and short ribs
- **Pork.** Hocks, ham bones, and Boston butt
- **Lamb.** Shank, leg, and shoulder

Adding Meat and Bones

The first step in preparing soup stock made with meat and/or bones is to cube or grind the meat, and/or cut the bones into 3-inch sections. This increases the surface area and improves extraction.

To draw out even more flavor, some chefs first soak the meat or bones in a pot filled with cold water, using 2 cups of water to every cup of meat or pound of bones, or adding water until the packed ingredients are covered with 1½ inches water above them. After half an hour to an hour of soaking, heat to the boiling point, and then reduce it to a bare simmer for up to 3 to 4 hours. The bones and meat heated in the water will release gelatinous particles as the stock simmers that will cloud and form a scum on top of the liquid. Many chefs skim this scum layer before adding any vegetables.

Adding Vegetables

Vegetables are often not added until the last hour or half hour of preparation, both to prevent their becoming mushy with overcooking and to preserve the desired flavor, which would become too concentrated and bitter with the water evaporation that takes place during longer cooking. Sometimes, however, vegetables are placed in the stock at the beginning intentionally so they will get mushy and can be pureed to act as a thickener. The size to which vegetables are cut also makes a difference—large chunks are best for long-simmering stocks, whereas small pieces are added near the end of heating time.

Poultry Stocks

The more mature the poultry used to make stock, the more flavorful will be the liquid. Birds that have been free to roam and scavenge, called free-range birds, yield the most flavor of all (12). An entire cleaned chicken carcass or an assortment of meaty bones (ideally backs and necks) is placed in enough cold water to cover it by 1½ to 2 inches and brought to a simmer with the lid off. It is cooked at a simmer for about an hour (whole bird) to 4 hours (just bones) until the meat is tender and ready to be cut off in bite-size pieces. During this process, the frothy fat is repeatedly skimmed from the top as necessary. After the meat is tender, the liquid is strained and returned to the pot before adding the chicken pieces, chopped vegetables, grain (such as rice or barley), and seasoning.

It is then covered and simmered for another hour. The vegetables often include, but are not limited to, onions, celery, parsley, leeks, carrots, parsnips, and turnips. Common seasonings are bay leaf, onion, garlic, pepper, sage, thyme, rosemary, or any other complementary herb. Chicken bouillon is sometimes added if the stock lacks flavor. Another method to add more flavor is to roast the chicken bones and vegetables before adding water.

Fish Stocks

Most fish stocks use the backbones (called frames or racks), heads, and/or tails of lean white fish. Fatty fish are rarely used because of their strong oily flavors. The high gelatin concentration in the heads contributes to the flavor and body of the stock. Fish frames should be thoroughly washed and eviscerated because remnants and organs, as well as gills and any attached skin, will give the stock an off-flavor (2). The eyes may also be removed. The bones are then combined with all the other ingredients in the liquid. Fish contain less gelatin than do meat and poultry, so the plain water usually used to start a soup stock is sometimes replaced by or fortified with chicken or vegetable stock, or bottled, but not canned (which may have a metallic taste), clam juice (13). The floating fish frames are occasionally pushed down into the liquid to release the flavorful compounds from the bones. Heating time should not exceed about half an hour because more than that makes the stock too bitter or fishy tasting. For more flavor, chopped fennel leaves and the white portions of leeks are classic additions to fish stock, along with the standard combination of onions, carrots, and celery. The celery may be omitted for a milder flavor, and the carrots may be left out if a golden

Bouquet garni A bundle of parsley, thyme, bay leaf, and whole black pepper rolled in a leek and tied together with twine.

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color is not desired in the stock. Sometimes the fish frames and vegetables are first heated in butter to extract more flavor and create a richer-tasting stock. Any added vegetables must be cut small because of the short cooking time.

Shellfish Stocks

Shellfish stocks are usually made from shrimp, lobster, mussels, or clams, or from the shells of the first two. Leftover shellfish shells can be frozen until they are needed to make stock.

Vegetable Stocks

Vegetable stocks have advantages over other kinds of stocks in that they are less expensive, less messy, and less time-consuming than their meat, poultry, and fish counterparts. Vegetables that lend themselves well to making stock include carrots, onions, leeks, shallots, garlic, celery, celeriac, parsnips, fennel, and tomatoes. Just as for poultry and beef, the more mature the vegetable, the more flavor in the extract. Vegetable stock takes only about half an hour to cook; any more time will turn the texture of the vegetables into mush and turn the flavor extract bitter. The standard vegetables and seasonings described under poultry stock are used when making vegetable stocks.

Storage of Soup Stocks

Stock should never be placed in the refrigerator while it is still hot. The large volume of hot liquid can raise the internal temperature of the refrigerator to the point that the stock will not cool sufficiently within 2 hours, and may warm everything else in the refrigerator as well. A good way to cool the stock is to place the hot stockpot in a sink full of cold water and ice cubes until it becomes lukewarm, although the time spent in this procedure should not exceed 1 hour. After the stock is left uncovered for the first half hour and stirred occasionally to cool it, it should then be covered with a lid or an upside-down plate to prevent evaporation, which would cause the stock to become too concentrated. Refrigerated stock cools better in shallow pans. If covered, stock lasts up to 5 days, but it is best if used within 2 days. Stock prepared for future use can be stored frozen for a couple of months (20). Any animal stock should be considered a potentially hazardous food when it comes to food safety and treated accordingly (see Chapter 4). Simmering stored stock for at least 10 minutes before use is a basic safety precaution.

Clear and Thin Soups

Clear soups include bouillons and consommés. Thin soups are somewhat thicker than clear soups.

Bouillon

Bouillon is the French word for broth. Bouillons are less gelatinous than stocks, and they may be added to poultry and vegetable stocks to add flavor. Traditionally, this type of soup is called bouillon if it is based on beef, and court bouillon or fumet if it is prepared using fish. *Court* is the French word for "short," and it describes the preparation time of bouillon, which is much shorter than that for stocks.

Consommé

A **consommé** is a perfectly clear beef bouillon. One raw egg white is added for every quart of broth, and the whole mixture is heated to boiling. The egg white will coagulate on the surface of the broth, forming what is referred to as a *raft*. As the broth simmers, the raft entraps loose particles. The resulting masses of unwanted material can be removed by straining. Because egg whites strip flavor from broth as well as particles, some ground meat and finely chopped vegetables are generally mixed with the egg whites to add flavor back to the broth. Because *bouillon* is the French word for *broth,* and because it is so similar to consommé, the three terms are often used interchangeably (17).

How & Why?

How does a stock differ from a broth?

The terms are often used interchangeably, but stocks are more viscous and have a more full-bodied mouthfeel due to gelatin released from the bones. Broths might utilize the meat rather than the bones so a richer flavor develops. Both can be used to make soups, sauces, and gravies, but broths are more flavorful and can be consumed on their own, whereas stocks cannot.

Thin Soups

Thin soups have a consistency between that of a clear liquid soup and a thickened soup. These soups are broth based but typically contain a garnish of cooked meats, vegetables, and/or starch such as pasta, rice, or barley. Examples include tomato, onion, and noodle soups. Miso soup, originating in Japan, is an increasingly popular thin soup that often contains tofu blocks, seaweed, and green onions. There are many variations of soups with miso as the primary seasoning agent. Miso itself is made by mixing cooked beans (usually soybeans) with cultured rice or barley (*koji is the name of the Aspergillus oryzae* fungus or mold used to ferment the grain) and salt (Figure 15-2). This mixture is then fermented for several weeks or as long as 3 years, depending on the variety of miso. Unpasteurized miso contains potentially beneficial microorganisms. Miso soup will vary in taste depending on the color of the miso soybean paste, which ranges from dark (reddish) to light (pale blond) (Figure 15-3). The darker misos are more bitter, earthy, and salty, whereas the lighter ones are more bland and less salty. In Japan, the larger grocery stores may offer up to 50 varieties of miso soybean paste.

Thickened Soups

Any stock or broth can be thickened with cream, pureed vegetables, a sauce (velouté), or other thickeners such as added bread, noodles, grains (rice, barley, etc.), or plain starch (cornstarch). Adding starches to soups also reduces the perception of saltiness if the components of starch or any added gums bind to sodium (18).

There are many varieties of thick soups. Chowders are usually fish-based soups thickened with vegetable pieces, such as potatoes, that have been cooked in milk. Gazpacho is an uncooked,

Bouillon A broth made from meat and vegetables and then strained to remove any solid ingredients.

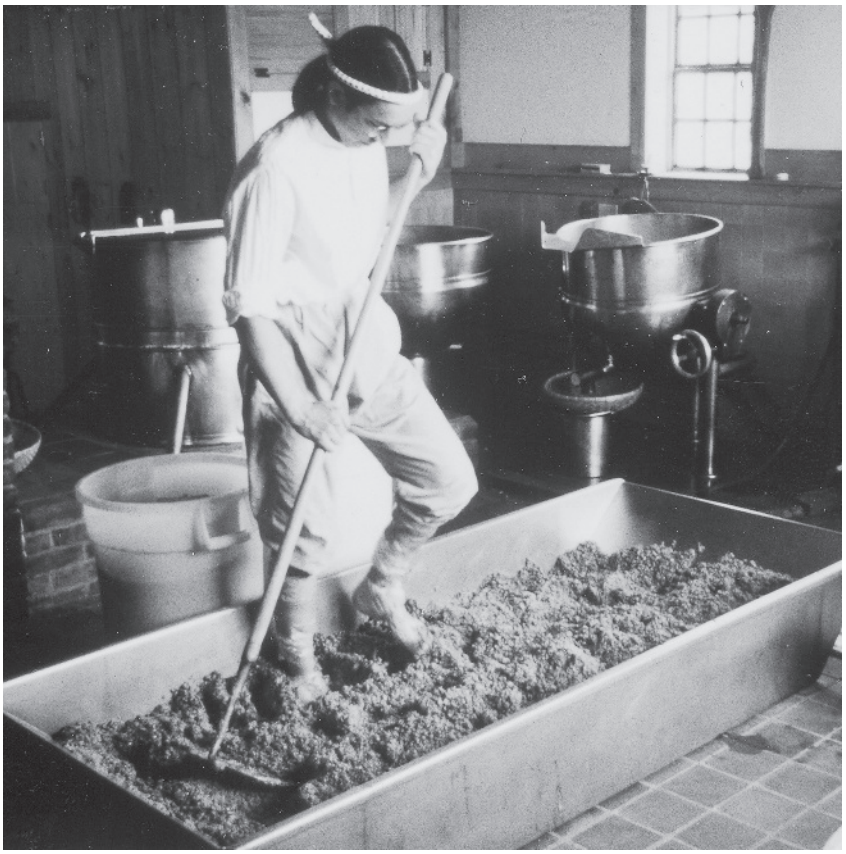
Consommé A richly flavored soup stock that has been clarified and made transparent by the use of egg whites.

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FIGURE 15-2 Miso for miso soup is traditionally made by mashing boiled beans (usually soybeans) underfoot like wine grapes and mixing the mashed beans with cultured grain (*koji is the name of the Aspergillus oryzae* fungus or mold used to ferment the grain) and sea salt. This mixture is then fermented in wooden vats for several weeks or as long as 3 years, depending on the variety of miso. As shown in this photo, the miso maker wears special plastic foot coverings.



Sarah Chester, South River Miso Co

thick, tomato-based soup with added vegetables and Latin American seasonings that is served chilled. Minestrone is an Italian soup that contains macaroni, vegetables, and beans. Egg drop soup is a popular Chinese soup made by dropping a slightly beaten egg into simmering clear stock. In India, mulligatawny soup is popular; it consists of chicken, carrots, green pepper, and apple seasoned with curry, cloves, and mace. Borscht is a Russian/Polish soup that is based on beets and may or may not have vegetables and/or meats added to it (14).

Bisque Traditionally, a cream soup made from shellfish. Marketers sometimes label creamed vegetable soups as bisques.

Thick soups also include any that are pureed or made from starchy vegetables that have been pulverized and sieved. Potatoes are a common thickener for a range of thickened soups.

Cream Soups

Cream soups are a type of thickened soup. Cream soups, including **bisques,** are made by adding cream and/or milk to a thickened, flavorful puree made from meats, poultry, fish, and/or vegetables. Common thickeners are white sauce (equal parts of flour plus fat combined with liquid), potato starch, or pureed potatoes. Cream is usually the thickening agent in bisques. Cream of chicken is the most popular cream soup made from an animal source. The most common vegetable creamed soups include asparagus, broccoli, potato, spinach, tomato, celery, cauliflower, and corn.

Preparation of Cream Soups

In preparing creamed soups, flavorings are added to a thin white sauce, which is then combined with a liquid base that is either milk or white stock. Béchamel is a white sauce often used as a base for traditional cream soups because of its velvety, smooth, creamy consistency. Heavy cream and/or egg yolks may be added after the soup has been heated and seasoned, but these additions increase caloric and fat content. If only one vegetable is featured in the cream

FIGURE 15-3 The flavor of miso soup depends on the type of miso soybean paste.



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FIGURE 15-4 Making low-fat cream soup.



(1) Sauté aromatic vegetables (onions, garlic, shallots, or leeks) over medium heat. Adding herbs such as thyme, sage, or rosemary improves flavor.



(2) Pour in the liquid (water, broth, milk, or a combination), and heat to a simmer. Use 5 to 6 cups of liquid for every 2 pounds of main vegetable to be added.



(3) Add a thickener in the form of rice (½ cup) or raw potato (sliced). Starchy ingredients thicken when they gelatinize, making the soup feel creamy.



(4) The time to add the main vegetable (in even, bite-size pieces) is when the time remaining to cook the thickener is equal to how long it will take to cook the vegetable.



(5) When the thickener reaches its maximum viscosity, puree the soup in batches using a blender or food processor. Another option is to strain the soup to obtain a finer texture.



(6) Finishing touches include adding a little liquid to thin the puree if it is too thick, and/or adding a small amount of cream to give it a "cream" flavor. Serve hot or cold.

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soup, it helps to add a few aromatic ones such as onion, garlic, leeks, and shallots to enhance the flavor. A garnish of parsley or a sprinkle of chives, paprika, or nutmeg makes a colorful addition to a bowl of cream soup.

Lower-Fat Cream Soups

Cream soups by definition contain fat, but substitutions can be made to create a lower-fat soup that will still retain most of the characteristics of a traditional recipe (Figure 15-4). The cream can be replaced by starch in the form of raw rice ($^1/_2$ cup) or potato (thinly sliced) added at the beginning of cooking (20). The starch gelatinizes, creating a thick, smooth consistency. Adding just a touch of cream rounds out the flavor of a starch-based cream soup.

How to Avoid Curdling

One potential problem in making creamed soups is that the acid from ingredients such as tomatoes can cause milk proteins to curdle as the mixture heats. Curdling can be reduced by the following measures:

- Prepare a fat/flour mixture (see Chapter 17) with either the milk or the stock (but cold milk or cream should never be added to hot soup).
- Stir some of the hot soup into the cold dairy product to temper it before adding it to the warm ingredients.
- Do not allow the soup to come to a boil after adding any dairy product, particularly cheese.
- Add acid to milk rather than milk to acid.

Keeping Cream Soups Safe

Because cream soups should not be boiled after the cream or milk has been incorporated, bacteria have a chance to grow. Therefore, these soups should be handled with the safety precautions for high-risk foods discussed in Chapter 4 to avoid foodborne illness.

SALADS

The Romans are credited with inventing salads because they brought garden delectables to the table, sprinkled them with salt and seasonings, and added vinegar and oil. Salt is such an important ingredient that the word *salad* is based on the Latin word for "salt." The practice of serving "salted" greens continued in the Middle Ages, when salads were a side dish that added greens to the massive amounts of meat served in castles.

Over the years, the concept of salads has evolved and branched out so much that almost any food imaginable can be made into a salad. The definition of *salad* now extends beyond the common green salad to which vegetables, fruit, cheese, and/or nuts may be added. Salads, which can be served as an appetizer, a main course, a side dish, or even a dessert (Table 15-1), are available even at fast-food restaurants (22). The most common types of salads are grouped by their main ingredient: leafy

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TABLE 15-1 Types of Salads

Salad Type	Examples	
Appetizer	Dinner salad	Shrimp cocktail
Main course	Chef's salad	Fruit plate with yogurt or cottage cheese
	Chinese chicken salad	Taco salad
Side dish	Coleslaw	Potato salad
	Pineapple-carrot salad	Three-bean salad
Dessert	Fruit cocktail	Melon and/or citrus wedges
	Jell-O fruit salad	Waldorf salad

greens, vegetables, fruits, proteins, pastas/grains, gelatin, or some combination of these. Sometimes salads such as tuna, potato, rice, pasta, egg, chicken, and ham are categorized as "cooked," but, in this chapter, they are classified by their main ingredient. This section discusses the basics of creating various types of salads and salad dressings; gelatin-based foods are covered in the next section.

Salad Ingredients

The salad's base, also called an underliner, is the item that serves as the salad's first layer or foundation. It is usually lettuce or some other green, but the base might also be pasta, rice, cottage cheese, or gelatin. The predominant ingredient or main part of the salad on top of the base is called the body. Topping it all off is the dressing, which adds flavor and moistness. Tart dressings go best with greens, vegetables, or protein-based salads, whereas sweetened dressings are usually reserved for fruit salads.

Garnishes

Sometimes garnishes are added for eye appeal. A few of the more common garnishes are fruit wedges (lemon, orange), hard-cooked eggs (slices, halves, or wedges), tomatoes (cherry, slices, or wedges), mushrooms, pimentos, radishes, olives, pickles, watercress, mint, and parsley.

The flavor, texture, and color of salads can be made more interesting by adding toppings such as croutons, cheese, shredded vegetables (carrots, red cabbage), herbs (Figure 15-5), tender greens (Figure 15-6), flowers, seeds, and nuts.

Toasting Nuts

Most nuts can be toasted by spreading them on a cookie sheet, placing them in the oven at 325 to 375°F (162 to 191°C), stirring every few minutes, and removing them after 5 or 10 minutes or when they have turned light brown (7). They should be allowed to cool before being added to the salad. Sometimes adding sugared nuts such as candied walnuts adds new flavor to a salad.

Principles of Salad Preparation

There are several principles to keep in mind when constructing a salad. The ingredients must be of the finest quality because fresh dishes cannot hide inferior quality as cooked dishes sometimes can. The more assertively flavored a food, the smaller its role in the salad should be. Flavor variety is important to maintain a diner's interest; salads can include ingredients that are crunchy (croutons, toasted nuts, dried wonton pieces); sweet/juicy (mandarin slices, apples, pears, grapefruit, and other fruits); bitter (endive, frisée, kale); and salty/tangy (olives, capers, cheese) (23). Color and texture should also be considered when making salads. The ultimate goal is to assemble and arrange ingredients with a good balance of color, texture, and shape within the rim of the chilled salad plate (Table 15-3).

Leafy Green Salads

In general, when people think of salads, leafy green ones are the most likely to come to mind; examples include garden, tossed spinach, mixed green, and Caesar salads. Greens range in flavor from extremely mild to tangy, bitter, and sharp. Iceberg lettuce is the most mild-flavored and the most frequently

FIGURE 15-5 Herbs add interest and flavor to salads and other foods and beverages (see Appendix D for uses).



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FIGURE 15-6 Tender young lettuces and other greens add variety to salads.



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CALORIE CONTROL
Fat and Fiber in Salads

Just because something is called a salad does not automatically mean it is low in fat or kcalories.

- **Limit Fatty Ingredients.** Many salads contain high-kcalorie/high-fat ingredients such as meat, egg yolks, cheese, avocado, coconut, olives, nuts, and oil-based dressings. A chef's salad harbors large amounts of both kcalories and fat even before the dressing is added (Table 15-2).
- **Control Portions—Especially the Dressings.** Many salad dressings contain oil, which averages 120 kcalories and 13 grams of fat per tablespoon, along with a fair amount of sodium.
- **Boost Fiber.** Salads are not necessarily good sources of fiber; iceberg lettuce contains only 1 gram per cup. Because the daily fiber recommendation is 25 grams for women and 38 grams for men, that adds up to 25 to 38 cups of lettuce a day, which is not practicable. So a salad's fiber content may be boosted by topping leafy greens with high-fiber vegetables such as broccoli, cauliflower, carrots, baby corn, cooked dried beans, and potato pieces with skins.
- **Limit Starchy Ingredients.** Starch adds approximately 100 kcalories per slice of bread, or per ½ cup of grains (rice, bulgur, etc.), pasta (noodles, elbows, etc.), or starchy vegetables (see Chapter 13 for individual vegetables).

TABLE 15-2 Kilocalorie Contributors to Chef's Salad

Salad Ingredients	Kilocalories	Fat (g)
1 oz beef	75	6
2 oz turkey	80	1
1 oz ham	70	5
1 oz cheese	114	9
1 hard-cooked egg	74	5
3 ripe olives	15	1
Lettuce (2 C)	18	—
3 tomato wedges	19	—
Total	465	27
Salad Dressings (2 Tbsp)	**Kilocalories**	**Fat (g)**
Blue cheese	154	16
French	134	12
Italian	137	16
Russian	151	16
Thousand Island	140	14

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TABLE 15-3 Adding Color, Flavor, and Texture to Salad Greens

Vegetables		Fruit	Protein Foods
Artichoke	Cucumber	Apples	Anchovies
Asparagus spears	Hearts of palm	Avocado	Cheese
Baby corn	Mushrooms	Grapefruit	Chicken, turkey
Bell peppers	Peas	Olives	Egg slices
Broccoli	Radishes	Oranges	Ham, bacon
Carrots	Red onion	Papaya	Nuts (sunflower, walnut)
Cauliflower	Scallions	Pears	Salmon, sardines, shrimp, tuna
Celeriac (celery root)	Tomatoes (cherry, sun-dried)	Pimento	
Celery		Pineapple	

used to fill out the body of salads. Its bland flavor almost necessitates that other, more distinctive-tasting, ingredients be added. Other salad greens include Romaine, Bibb, Boston leaf, and Ruby lettuces and even spinach. If more assertive flavors are desired, escarole, Chinese (Napa) cabbage, kale, and either green or red cabbage make good choices. Flowers and herbs provide additional flavor and color, but should be added in limited amounts, except when preparing an herb salad made only from leafy herbs (Figure 15-7).

Constructing a green salad starts with a thorough rinsing of the greens to remove any soil (Figure 15-8). Many greens are grown in the ground, and not adequately removing the soil leaves a gritty feel between bites of leaves. Any water left clinging to greens after washing will dilute the flavor, adversely affect the texture, and accelerate deterioration, so it should be removed either by draining greens in a colander, patting them between paper towels, or using a salad spinner. Next, the stems and/or cores must be removed. Greens should be refrigerated for 30 minutes to several hours prior to use in order to promote crispness. After they are ready for the salad bowl, the greens are torn by hand into bite-size pieces. Hand-tearing the leaves is preferred over cutting with a knife because it reduces bruising and allows more salad dressing to be absorbed into the leaves. Commercial food-service units often rely on quicker methods, however, and Figure 15-9 shows several techniques for cutting iceberg lettuce. Cabbage and carrots can also be prepared for salads (Figure 15-10).

FIGURE 15-7 Edible flowers add color and flavor.

Edible Flowers:

A noteworthy trend in gourmet produce is edible flowers. A colorful, peppery tasting addition to salads can be made by adding a sprinkle of nasturtium flowers or calendula petals. Daylily, squash, and pumpkin blossoms are delicious dipped in tempura batter and quickly deep-fried. Lavender and many geranium blossoms add a perfumed, herbal scent to beverages and desserts. Viola, pansy, and violet blossoms can be candied and used as edible decorations for cakes and other desserts.



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FIGURE 15-8 Cleaning salad greens.



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Clean greens. Briefly soaking and swirling the greens in a bowl of cool water dislodges grit. The leaves are lifted out with separated fingers, the water in the bowl is replaced, and this process is repeated until no grit remains.



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Dry greens with a salad spinner. Water is removed by repeatedly spinning the leaves, draining the bowl, and tossing the leaves between spinnings.

Vegetable Salads

Vegetable salads are those whose main ingredients are nonleafy vegetables. These may be composed of a single vegetable, as in a tomato salad, or made up of a combination of vegetables. Examples of combination salads include cucumber and tomato; green bean, mushroom, and carrot; and coleslaw salads. Any vegetable is eligible, and those that are raw, cooked, canned, or marinated are all suitable candidates. Vegetables that are commonly used in salads include tomatoes, cucumbers, broccoli, cauliflower, beets, radishes, olives, green bell peppers, carrots, peas, mushrooms, onions, and celery. Tougher vegetables such as carrots and celery will have an improved texture when shredded with a knife, grater, or food processor. Potato salad is best prepared with red or white boiling potatoes. They are less starchy and hold their shape when boiled better than the Russet or Idaho potatoes usually used for baking.

Fruit Salads

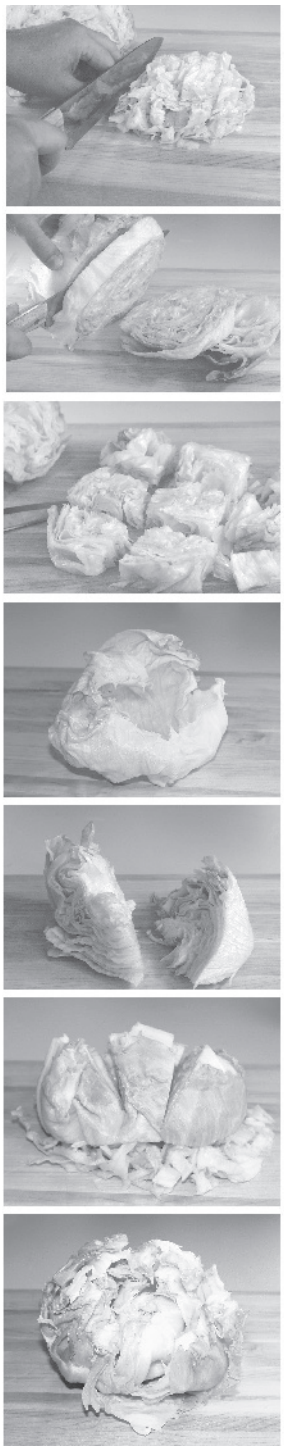
Fruit salads are often served as a dessert or luncheon dish combined with a higher-protein food such as cottage cheese or yogurt. Some of the fruits most frequently used for salads are apples, avocados, oranges, bananas, kiwi, pineapple, melons, grapefruit, pears, peaches, cherries, blueberries, strawberries, grapes, and raisins. Acidic fruits should be balanced with mild greens and a light sauce (17). Canned fruit should be thoroughly drained, and all fruit should be cut into pieces no bigger than bite-size (Figure 15-11). Some fruits undergo enzymatic browning when cut, which may be prevented by coating them lightly with citrus or pineapple juice, sugar, or an ascorbic

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FIGURE 15-9 Methods of preparing iceberg lettuce.



Shredded
Manual—Cut each head in half lengthwise. Then slice crosswise into 1/8–1/2–inch strips.
Automatic slicer—Crisp iceberg lettuce is the only lettuce suitable for shredding using slicers or slicing attachments. Use half heads; set the gauge for 1/8–1/2–inch strips.

Rafts
Cut each head crosswise into slices about 1–inch thick. A head should yield about three to four rafts.

Chunks
Slice head into rafts. Then cut each raft crosswise and lengthwise into 1 1/2–inch square chunks.

Large Leaves or Cups
Begin by holding a full head core side down. Gently separate leaves and lift them away from the head. For smaller portions, cut heads in half, and then lift off leaves.

Wedges
Small iceberg lettuce heads cut into quarters yield an average wedge. Wedges should weigh about 4 ounces each. Larger heads should be cut into six or eight wedges to yield similar-size portions.

Half Heads
Cut a full head in half lengthwise. Then place cut side down on a board, and make two or three parallel cuts partially through the half head. Present over a mound of shredded iceberg lettuce with the cuts spread open and filled.

Full Heads
Select a firm, springy head and core. Remove a slice from the core end, and then pull out about a 3–inch heart from the center of the head and shred. Spread remaining leaves back from the center like a rose. Place shredded lettuce back into the center of the prepared head.

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FIGURE 15-10 Preparing cabbage and carrots for salad.



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Shredding cabbage



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Grating carrots

acid (vitamin C) mixture. Fruit salads are often arranged, rather than tossed, in order to prevent their delicate flesh from bruising or damage.

Protein Salads

Basing a salad on protein foods such as cold meat, poultry, fish, eggs, or dairy products helps to make it a main course. All except the dairy items must be used in their cooked form. Firm cheeses, such as cheddar or Swiss, are often cubed and added to salads. To quickly prepare chicken breasts specifically for salad, poaching works well (see Chapter 8). Four boned, skinned chicken breasts yield 2 cups of cubed chicken meat, which should be chilled by refrigerating at least 2 hours prior to assembly of the salad. Some chefs prefer roasted chicken for chicken salads.

Pasta/Grain Salads

A bland background of pasta or grains serving as the body of a salad is a perfect invitation to more colorful and flavorful ingredients, especially if they are acidic or salty. The large number of pasta shapes (elbows, shells, noodles) and varieties of grains (rice, bulgur, wheat, etc.) allow the creation of an almost unlimited array of salads. Chapter 16 discusses the preparation of the grains and pastas themselves.

Salad Dressings

There are as many different kinds of salad dressings as there are kinds of salads. The original dressing was probably just plain salt. The word *salad* is derived from *herba salata,* Latin for salted greens (17). During Roman times, freshly picked greens were salted to enhance their taste, but now there are many different types of dressings, which can be thought of as "sauces for salads" (Figure 15-12).

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FIGURE 15-11 Preparing fruit for salad.



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Trimming pineapples



Warren Price Photography/Shutterstock.com

Coring apples



Teri Virbickis/Shutterstock.com

Preparing melon balls

Oil and Vinegar Dressings

Vinaigrette is the most basic of all dressings (1). The flavor of the vinaigrette is varied by the types of oil and vinegar used.

Vinaigrette A salad dressing consisting of only oil, vinegar, and seasoning.

Emulsion A liquid dispersed in another liquid with which it is usually immiscible (incapable of being mixed).

FIGURE 15-12 Pouring dressing over salad.



Anna Om/Shutterstock.com

Oils

A vinaigrette may use a flavorful oil/vinegar duo such as extra-virgin olive oil with red wine vinegar, walnut oil with a raspberry vinegar, or sesame oil with an oriental rice vinegar. Other salad dressings based on vegetable oil may rely on a neutral-flavored oils such as corn, cottonseed, soybean, or safflower. Winterized oils, often called salad oils, are those that have been treated so they do not cloud when refrigerated. Olive, peanut, walnut, hazelnut, and almond oils are sometimes chosen for their characteristic flavors. A nutty-flavored salad dressing can be made by adding toasted sesame oil to the dressing.

Vinegars

Balancing the oil in a vinaigrette is some form of vinegar, of which the three most common types are wine, cider, and white/distilled (24). Vinegars differ in their base and ingredients, but they are similar in that they are all fermented from alcohol to acetic acid by the bacterium *Acetobacter* (4). The word *vinaigre* is French for "sour wine," and the higher the percentage of acetic acid (shown on the label in fine print) that the vinegar contains, the more sour and stronger the vinegar will be. Vinegars were originally produced as a by-product of wine-making (19). Better-tasting vinegars are slowly fermented naturally, whereas those fermented with the aid of heat and chemicals often have harsh, metallic tastes (25). Some of the vinegars used in salad dressings include the following:

- ***Wine.*** Made from wines such as red, white, cabernet sauvignon, champagne, and sherry. These vary widely in terms of flavor and quality.
- ***Cider.*** A golden brown vinegar made from fermented apple juice; it has a strong flavor.
- ***White/distilled.*** A colorless, extremely acidic, almost flavor-free vinegar made from grain alcohol.
- ***Herb.*** Cider, white, or wine vinegar with herbs added; tarragon vinegar is a common herb-flavored vinegar.
- ***Fruit.*** Cider, white, or wine vinegar with fruits added; raspberry vinegar is increasingly popular.
- ***Rice.*** Made from rice wine, this vinegar has the lowest acidity, is clear to slightly yellow, and has a mild flavor.
- ***Balsamic.*** A rare, dark brown vinegar made from a very sweet grape concentrate; it has a slightly sweet taste. It is more costly than other vinegars because it is aged in wooden barrels for more than 10 years. Most balsamic vinegar available in grocery stores is, in fact, a red wine vinegar to which concentrated grape juice and perhaps caramelized sugar have been added.

The ratio of oil to vinegar varies among salad dressings. Flavor becomes more bland and less acidic as more oil is added, but it shifts to a sharper, acidic taste when vinegar concentration increases. Sometimes lemon juice is added or replaces vinegar when a more lemony flavor is desired.

Emulsified Dressings

Oil and vinegar normally separate if left to stand, and they need to be mixed together before being applied to a salad. If the oil and vinegar mixture has been treated to create a permanent **emulsion,** however, the ingredients will not separate (see Chapter 22). One such emulsion is mayonnaise, which can be served as is in chicken salad, potato salad, and coleslaw or can be used as a base for many other salad dressings, including Chantilly, creamy Roquefort, Green Goddess, dill, Thousand Island, and Russian.

Other Dressings

There are many other possibilities for salad dressing bases. Little or no oil is found in cooked dressings; these have a viscous consistency because of an added starch thickener. Some dressings are dairy based, with sour cream or yogurt as the main ingredient. A few dressings are made from fruit juice, and their lower kcalorie/fat content makes them a good alternative for health-conscious consumers. Commercial salad dressings are often made with food additives that serve various functions (Chemist's Corner 15-1).

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CHEMIST'S CORNER 15-1

Food Additives Used in Soups, Salads, and Gelatins

Food additives are used in commercial soups, salad dressings, and gelatins for various purposes. Additives used in soups include cornstarch, a drying and anticaking agent; sodium bicarbonate, which is used to neutralize excess acid and clean vegetables; and modified food starch, a drying and processing aid. In salad dressings, carob bean gum is used as a stabilizer and thickener, while propylene glycol serves as an emulsifier and humectant, and EDTA (ethylenediaminetetraacetic acid) serves as an antioxidant and sequestrant. Sodium chloride (salt), which is a common flavor enhancer, and guar gum, which is a stabilizer and thickener derived from the guar plant, are found in both salad dressings and soups. In gelatin desserts, aspartame is occasionally added as a low-kcalorie sweetener, and dioctyl sodium is used as an emulsifier.

Adding Dressings to Salads

The best time to add dressing to a salad is just before serving because the acidity of the dressing will start wilting the leafy green vegetables as soon as the dressing is added. It is best to chill the dressing for at least half an hour to improve its ability to coat the salad ingredients. Add only enough dressing to lightly coat the ingredients; too much overwhelms the salad's flavor, while too little defeats the purpose of adding the dressing, leaving the flavor unenhanced. Salads are best tossed to evenly coat all the ingredients with a taste of dressing. Topping a salad with dressing without mixing is a less desirable way to serve any salad.

GELATINS

Because gelatin salads rely on the formation of a gel, gelatins as a whole are discussed in this chapter; however, many other foods include gelatin as an ingredient. Several foods that benefit from the gelling properties of gelatin are yogurt, ham coatings, ice cream, cream cheese, cottage cheese, pastry fruit toppings, fruit salads, pastry toppings, gravies, sauces, and soups (16). This section discusses the definition of gelatin, its nutritional value, the factors that influence gel formation, and the preparation of gels.

What Is Gelatin?

Gelatin itself is a mixture of proteins extracted from the collagen found in the hides, bones, and connective tissue of animals. The principle commercial sources of gelatin are pork skins and the bones and hides of cattle (15). These sources of gelatin are sometimes avoided or replaced with alternatives by vegetarians or people following kosher guidelines. Gelatin is available in either powder granules or sheets, the latter being used by commercial food manufacturers and institutions (1 teaspoon of gelatin powder is equivalent to 2 sheets). Consumers are typically sold uniform packets containing about 2½ teaspoons (7 grams) of powdered gelatin, which will usually gel about 2 cups of liquid (1 pint or 500 mL). The sheets sold to commercial entities vary in thicknesses and weights but average 1/10 ounce (3 grams) per sheet and are sold in 1-kilogram boxes. Gelatin is available in a colorless, almost transparent, odorless, and virtually tasteless state, or in a flavored state, in combination with sugar, coloring, and flavoring agents.

Is Gelatin Nutritious?

Even though gelatin is an animal-derived protein, it is low in tryptophan, an essential amino acid. Gelatin protein is therefore considered incomplete and of low **biological value.** A few gelatin manufacturers have added tryptophan to some of their products in an effort to remedy this problem, but gelatin's contribution to dietary protein is nevertheless limited by the small amount—only 1 tablespoon (7 grams protein, 23 kcalories)—required to gel 2 cups of liquid. A serving size is about one-fourth that amount, so it would contribute little in the way of nutrients.

Preparation of a Gel

A gel is prepared by hydrating gelatin granules or sheets, dispersing the gelatin particles by heating and stirring the mixture, and then cooling it. Heating protein solutions decreases the protein's solubility and increases the interaction between dissolved proteins (27). Pieces of foods such as meats, vegetables, or fruits can be added during the cooling period when gelation or thickening takes place. The type of food incorporated into the gel determines whether the gel will be a salad, a dessert, or a main dish. A special type of gel that can be made with gelatin is an **aspic**. Sometimes aspics also have fruit or vegetable juices added, as in a tomato aspic.

Phases of Gel Formation

The three phases of gel formation are hydration, dispersion, and gelation.

Phase 1—Hydration

Gelatin can absorb five to ten times its weight when heated in water. Unflavored gelatin will clump unless it is first hydrated in cool or barely warm water before adding it to other ingredients. To separate the granules, the gelatin is sprinkled over the water (1 tablespoon of gelatin per ¼ cup of water) and left to stand without stirring for 5 minutes. The initial hydration can be skipped when preparing flavored gelatin because it has been acidulated, or treated, so that it dissolves instantly when boiling water is added. Commercial gelatin sheets are soaked and separated in ice water for at least 15 minutes until they become very soft. Just prior to being stirred with hot water, they need to be squeezed to remove any excess cold water.

Phase 2—Dispersion

After hydration, hot water or a flavorful liquid such as stock or juice is usually added to disperse the protein granules (Figure 15-13). Gelatin disperses at 100°F (38°C), and faster at higher temperatures. When adding hot liquid, it is important to stir, especially along the sides

Biological value The percentage of protein in food that can be used by an animal for growth and maintenance. High-quality, complete proteins are considered to have a high biological value.

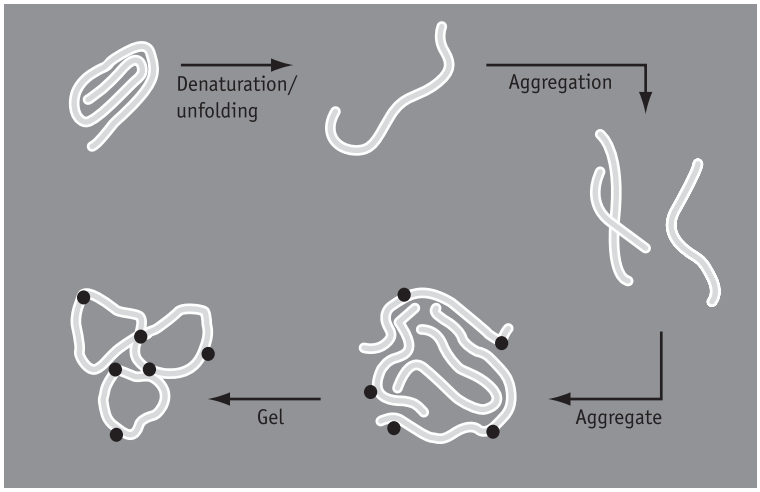
Aspic A clear gel prepared from stock or fruit or vegetable juices.

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FIGURE 15-13 Dispersion and gelation. Increasing the temperature by adding hot water causes the protein molecules to denature and unfold. On cooling, the protein molecules aggregate, forming a gel.



and bottom of the container where the granules may stick, to ensure sufficient dispersion. Boiling is not recommended because it can burn the gelatin. After the granules have been completely dispersed, cool liquid can be added. Cooling the remaining liquid not only speeds up the gelling process but also prevents the loss of volatile substances that evaporate into the air when hot liquid is used.

Phase 3—Gelation

Refrigeration is crucial to the gelling process. As the liquid containing the gelatin protein cools in the refrigerator, it will convert first to a **sol,** which has a liquid consistency. It is either left in the mixing bowl or poured into individual serving containers or a larger mold that may be lightly coated with salad oil for easier unmolding. Molds vary in shape and can include any number of designs—a ring, a fish, a pineapple, or others.

Cooling the sol further (1 to 6 hours) will create a more solid-like gel. The result is a solid structure that can be used in gelatin-based molded salads (as well as desserts and plain-flavored gelatin). These can be topped with a sauce, a whipped topping, or mayonnaise, depending on the ingredients.

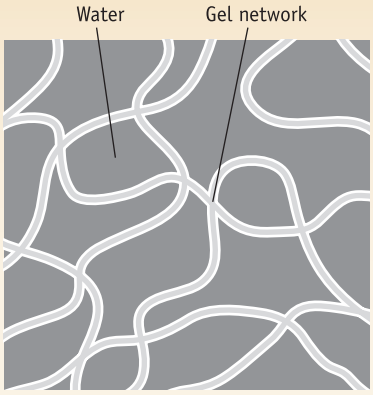
Sol A colloidal dispersion of a solid dispersed in a liquid (see Chapter 3 for colloidal dispersions).

How & Why?

How does gelatin contribute to gel formation?

The long, thin protein strands of the gelatin give it its unique ability to gel. The gelatin protein molecules, each surrounded by water molecules, slowly start to form a network by creating cross-links (bonds or bridges) among themselves. The water remains trapped within the protein strands, creating an elastic solid (Figure 15-14).

FIGURE 15-14 Gelation phase.



A gel forms when the protein molecules form a network, trapping water into a more solid mass.

Unmolding a Mold

After the gel has cooled and set, it is ready to be served in its container(s) or removed from the mold(s) and placed on a serving dish. To unmold a gelatin, first slip the tip of a knife around the top edges of the mold to release some of the vacuum. Dip the mold in lukewarm water up to the upper edge of the container for a few seconds but not long enough for the gel to start melting. Invert the mold over a plate, or, placing a plate over the mold, invert them together. A few shakes should then release the gel from the mold. The process should be repeated if the gel is still sticking to the container. A few drops of water or oil on the plate will allow the gel to slip to the center. Not all gels are firm after being unmolded; in that case, they should be covered and put back in the refrigerator for further chilling before being served.

Factors Influencing Gel Formation

Many things can affect gel formation, including the gelatin concentration, temperature, added ingredients, and whether or not the gelatin is whipped.

Gelatin Concentration

Gelatin concentration should be approximately 1 to 2%, which is equal to a little under 1 tablespoon of gelatin per 2 cups of liquid (Chemist's Corner 15-2). Adding more gelatin allows the gel to set faster and be firmer, but it can also result in a tough, rubbery, and almost bouncy texture. Insufficient gelatin will result in a wobbly gel. The amount of gelatin required varies with each dish and its other ingredients. For example, food-service organizations use about 2 ounces of unflavored gelatin for every gallon of liquid, but that same amount of water requires 24 ounces of gelatin if it is sweetened (11).

Temperature

The faster the sol cools, the quicker it sets. The cooling process may be accelerated by adding ice cubes or crushed

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CHEMIST'S CORNER 15-2

Measuring Gelation Potential

The gelation potential of a particular gel is measured by the bloom test. Bloom is the amount of force required to compress a gel (6.67% concentration) a distance of 4 mm (8)—the higher the bloom, the smaller the amount of gelatin that is required for the gel to set (15).

ice to the dispersed gelatin or by placing the container in a larger bowl filled with ice water. The container may also be placed in the freezer for a short time, but it should not be allowed to freeze because this damages the gelatin layers next to the pan. There are some disadvantages to quick cooling: fast-setting sols result in weak gels that are more likely to lose their structures when brought to serving temperature, and more tough lumps may be formed during gelation.

Added Ingredients

Sugar

Sugar delays gelling and weakens the gel's structure by competing with water for cross-linking sites. To compensate, more gelatin is added to mixtures containing sugar: approximately 2 tablespoons of gelatin for every half cup of sugar.

Acid

A gel is at optimal strength between pH 5 and 10. Acids weaken gels by hydrolyzing the gel's network of protein molecules. Vinegar or acidic fruits and juices such as lemon or tomato juice can decrease pH to below 4, which can prevent gelation or result in a soft gel. This is why it is best to avoid adding these ingredients; for dishes that feature them, the problem is avoided by doubling the concentration of gelatin used.

Enzymes

Proteolytic enzymes found in fresh pineapple (bromelin), papaya (papain), kiwi (actinidin), and figs (ficin) prevent or weaken gel formation by hydrolyzing the protein of the gel network. As a result, these foods are seldom added to gels. Heat denatures the enzymes in these fruits, so cooked or canned versions pose no threat to the gel's structure.

Salts

Salts strengthen the structure of gels. Because hard water and milk contain natural mineral salts, incorporating either of these two liquids into a gel will cause it to be firmer than usual. Adding calcium in the form of a salt has long been known to firm gels (10).

Solid Ingredients

The addition of solids, such as chopped fruits, vegetables, marshmallows, and nuts, also weakens gel formation. If any of these are acidic or contain proteolytic enzymes, the gel's structure is compromised even further, unless gelatin is added to compensate. To avoid lowering the gelatin concentration, either any added solids should be completely free of liquid or the amount of other liquids added should be reduced to compensate for that contributed by the solids. It is best to use only a small amount of solid ingredients and to chop them up as finely as possible to decrease interference with the protein cross-links being formed. Solid ingredients should be added just before the sol has the consistency of beaten egg whites and is about to turn into a gel; otherwise, the solids will float to the top.

Whipping

Gels increase to two to three times their volume when whipped into a **foam** just before they are set. If the gel is whipped before it has had enough time to partially set, the foam will float to the top while the gel will set and sink to the bottom. Overgelling results in broken-up chunks of gel. Properly formed gels and foams can be used together to create a two-tone effect, as seen in parfaits.

Prior to gelling, a number of unique gel-related products are created by whipping the gel and/or adding egg whites or whipped cream (5). A whip is a clear gel that is partially set and then beaten until fluffy. A snow or sponge is created by added unbeaten egg whites to a partially set gel and then beating until it is stiff. Mousses are often formed by chilling the gel until it mounds when dropped from a spoon and then folding in whipped cream. A panna cotta is an Italian gelatin dessert flavored with vanilla and topped with fruit, caramel, chocolate sauce, or spices. It is made by simmering cream, milk, and sugar with gelatin and then letting it cool. Chiffons are custard gels (containing egg yolks, milk, and gelatin that have been cooked) chilled to the point of forming mounds when dropped from a spoon and then folded into stiffly beaten egg whites. Another gel product, a Bavarian, is simply a chiffon with whipped cream added.

Storage of Gelatin

Dried gelatin can be stored in a cool, dry place for many months. When stored too long, however, the gelatin becomes less soluble and loses its ability to hydrate; and without hydration, there is no gelation. Once prepared, gels are best served within 24 hours. Beyond this point, the gel continues to form bonds between the gelatin proteins, resulting in an increasingly firm, more compact gel as the spaces between the lattices in the gel network become smaller and smaller. Eventually some of the water will be squeezed out in a process known as **syneresis.** Most gels will lose their shapes when exposed to temperatures above 80°F (26.5°C) (3).

Foam A colloidal dispersion of a gas in a liquid.

Syneresis (weeping) The expulsion of the liquid component of a gel.

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PICTORIAL SUMMARY / 15: Soups, Salads, and Gelatins

As the first act, a soup or a salad often sets the tone for the meal to come. But their versatility also allows them to take center stage as a complete meal in themselves.



SOUPS

Soups are based on a stock, which is the flavorful liquid remaining from cooking bones, meat, and/or vegetables. Stock should be simmered, never boiled, and cooking time varies from half an hour to 12 hours. Hot stock should never be placed in the refrigerator without proper precooling.

The main types of stock are meat, poultry, fish, and vegetable.

Meat/poultry stocks. Simple stocks made from water and bones, cracked to release flavor, are called *white stocks*. If the bones are browned prior to simmering, it is a *brown stock*. If meat is added, it is usually raw. A bouquet garni or mirepoix of onions, celery, and carrots is often added to enhance flavor.

Fish stocks. Fatty fish are rarely used for stock because of their strong and oily flavor. Fish frames must be thoroughly cleaned, and heating should not exceed about half an hour to preserve the delicate flavor. Another stock (chicken or vegetable) or bottled clam juice may be added to fortify the flavor of the base. Fennel and leek are classic vegetable additions, along with the standard onions, carrots, and celery.



There are three different types of soups:

- **Clear and thin:** Removing the particles found in a stock results in a clear soup such as a bouillon or consommé. Thin soups have a consistency between a clear liquid soup and a thickened soup.
- **Thick:** Any stock can be thickened with starch or pureed vegetables to yield thick soups such as chowder, gazpacho, minestrone, egg drop, mulligatawny, and borscht.
- **Cream:** Adding cream and/or milk plus a thickening ingredient to a puree made from meats, poultry, fish, or vegetables results in a creamed soup, or bisque.

SALADS



A great salad combines the freshest possible ingredients with a good balance of flavor, color, texture, and shape.

Types of salad. The most common types of salad are grouped by their main ingredient: leafy green, vegetable, fruit, protein, pasta/grain, gelatin, or a combination of these. Leafy green salads are the most common, and examples include garden, spinach, mixed green, and Caesar salads.

Salad dressings. There are many types of salad dressings, but the most basic are dressings based on oil and vinegar. Emulsified dressings such as mayonnaise do not separate as regular oil and vinegar dressings do. Dressings may also be made with little or no oil, with dairy products such as sour cream or yogurt, or from fruit juice.

Common garnishes:

- Fruit wedges
- Hard-cooked eggs
- Tomatoes
- Mint
- Mushrooms
- Pimentos
- Radishes
- Parsley
- Olives
- Pickles
- Watercress

Salad Toppings

- Croutons
- Herbs
- Edible flowers
- Cheese
- Seeds, nuts
- Shredded vegetables

GELATINS



Gelatin dishes are made from proteins extracted from the collagen found in animal skins, bones, and hides. Gelatin is prepared by hydrating the granules, dispersing the protein by heating and stirring the mixture, and cooling it until it sets. Factors influencing these three stages of gel formation include gelatin concentration, temperature, acid, salt, sugar, enzymes, and added solid ingredients. Dried gelatin can be stored in a cool, dry area for months, but prepared gelatin salads should be served within 24 hours.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. All soups are based on _____.
   a. milk
   b. bouillon
   c. a bouquet garni
   d. stock

2. What is the term used to describe a cream soup made from shellfish?
   a. Foam
   b. Bisque
   c. Sol
   d. Consommé

3. Thick soups are made from stocks that have usually been thickened with some type of _____.
   a. white stock
   b. brown stock
   c. bisque
   d. starch

4. Besides lettuce, what else may be used as a base for a salad?
   a. Pasta
   b. Rice
   c. Cottage cheese
   d. All of the above

5. Adding acidic fruits to a gelatin salad will decrease the pH and result in a salad that is too _____.
   a. soft
   b. rubbery
   c. firm
   d. sweet

6. Gelatin concentration should approximate _____.
   a. 1 to 2%, or 1 tablespoon of gelatin to 2 cups of water
   b. 4 to 5%, or 4 tablespoons of gelatin to 2 cups of water
   c. 8 to 9%, or 8 tablespoons of gelatin to 2 cups of water
   d. 10 to 11%, or 10 tablespoons of gelatin to 2 cups of water

7. Fruits such as pineapple, papaya, kiwi, and figs are usually not added to gels because of their _____ content.
   a. acid
   b. sugar
   c. proteolytic enzyme
   d. salt

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. All soups are based on stock. Describe the properties of a stock, and list the four major types of stock. What are the basic steps involved in preparing a stock?
2. Explain the difference between white and brown stocks.
3. Define *mirepoix, bouquet garni, bouillon,* and *consommé.*
4. Soups differ in their consistency. Explain the differences among clear, thin, and thick soups.
5. Provide several pointers for the preparation of each of the following types of salads: leafy green, vegetable, and fruit.
6. Discuss the recommended techniques for adding dressings to salads.
7. List and briefly discuss the three phases of gel formation.
8. Explain how the following elements influence gel formation: gelatin concentration, temperature, sugar, acid, enzymes, salts, and added solid ingredients.
9. What are the storage recommendations for dried gelatin and prepared gelatin?
10. Explain why water sometimes escapes out of aging gels. What is the name for this process?

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16



Cereal Grains and Pastas

Composition of Cereal Grains 327
Uses of Cereal Grains 329
General Types of Cereal Grains 329
Cereal Grains Containing Gluten . . . 330
Gluten-Free Cereal Grains 334
Preparation of Cereal Grains 338
Storage of Cereal Grains 339
Pastas 340
Preparation of Pasta 341
Storage of Pasta 342

The term *cereal* is derived from the name of the Roman goddess of agriculture, Ceres (31), which in turn was derived from the verb *creare,* which means "to create" (57). The word *cereal* refers to grains in general, not just those that may be poured out of a box at breakfast. Cereal grains are seeds from the grass family *Gramineae* (13). The edible portion of the plant is the caryopsis, also known as the grain, kernel, or berry (13). These seeds and their products may indeed be regarded now, as in ancient times, as "the staff of life." According to archaeological evidence, wheat and barley were being cultivated in the Fertile Crescent around 8000 BC, and rice was cultivated in Thailand as early as 4500 BC (24). The importance of grains to the well-being of humans is so great that breads are religious symbols throughout the world. Many Christian denominations symbolize the body of Christ with a form of bread, and during Judaism's Passover celebration, unleavened bread is served to symbolize the Jews' hasty exodus from Egypt, when there was no time to wait for bread to rise.

Grains are the world's major food crops, and there are numerous varieties (Figure 16-1). The most common grains are corn, rice, and wheat, which together account for 90% of the world's production of grains. The remaining 10% consists of barley, sorghum, millets, oats, and rye (Figure 16-2) (25). In the U.S. market, sales are highest for the whole grains of wheat, corn, rice, and oats (13).

Although commonly consumed in the form of breakfast cereals, grains also find their way to the table as flour in baked goods and pastas, alone as vegetables (corn, hominy), as alcohol, and indirectly through the meat of animals that had consumed grains.

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FIGURE 16-1 Several of the many varieties of grain.





Corn. Indigenous to Mexico, corn is one of the most important cereals in the form of grain, meal, and flour. It is used to make corn bread and hominy, and is also an important source of starch and of cooking oil.





Basmati rice. Grown in the foothills of the Himalayas, this narrow long-grain rice is one of the finest. It should be soaked before cooking, and is the best rice to eat with Indian food.





Wheat. Thought to have first been cultivated in the Nile region, it is the source of the highest-quality bread and baking flours. There are many different varieties: the durum wheat type is best known for making pasta.





Barley. Indigenous to the East, barley is used for making malt liquor, as a side dish similar to rice, and also in soups.





Millet. The seed of an annual, gluten-free grass that is widely eaten as a cereal in Africa and Asia. It is also used as a source of starch.

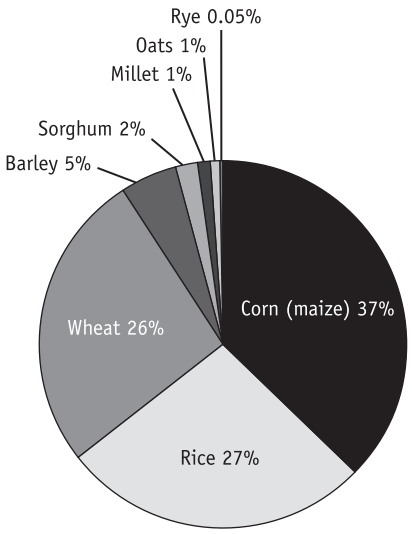




Oats. Native to Central Europe, oats are used to make oatmeal and flour, and are often added to cakes and cookies.

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FIGURE 16-2 The most common cereal crops and their contribution to world grain production.



Source: Food and Agricultural Organization. FAOSTAT, 2013. http://www.fao.org/faostat/en/#data. Accessed 6/2/2017.

COMPOSITION OF CEREAL GRAINS

Structure

All grasses have individual kernels or grains, called caryopses, which are similar in structure. Each caryopsis has a protective outer **husk,** a **bran** covering, a starchy **endosperm,** and a **germ** (Figure 16-3).

Husk

The husk, also called the "chaff," protects the grain from frost, wind, rain, extreme temperatures, insects, and other potentially damaging environmental factors. Husks are not usually consumed but are sometimes processed into fiber supplements.

Bran

Bran is about 14.5% of the grain by weight and is an excellent source of fiber and minerals. Just beneath the bran, there is a less fibrous coating called the aleurone layer, which contains protein, phosphorus, thiamine and other B vitamins, and some fat. Both the bran and the aleurone layer are removed from grains as they are processed into white flour.

Endosperm

The endosperm makes up about 83% of the grain (13). The starch in the

Husk The rough outer covering protecting the grain.

Bran The hard outer covering just under the husk that protects the grain's soft endosperm.

Endosperm The largest portion of the grain, containing all of the grain's starch.

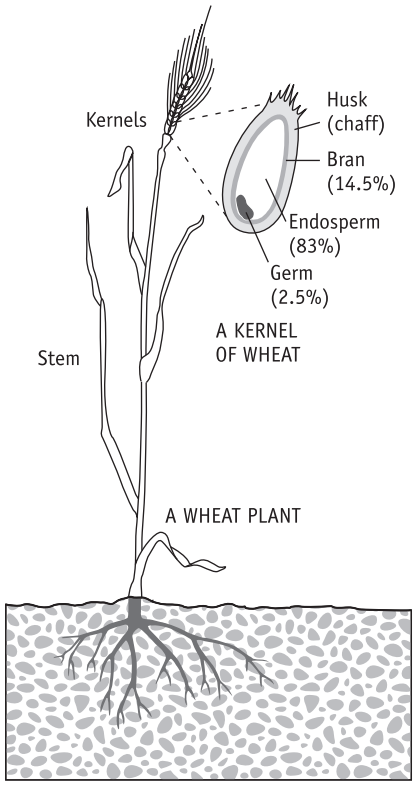
Germ The smallest portion of the grain, and the embryo for a future plant.

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FIGURE 16-3 Structure of grains.



Source: Sizer F, and E Whitney. *Nutrition Concepts and Controversies*. Wadsworth, Belmont, CA, 1997.

endosperm makes grains, especially **whole grains** with their added fiber from the bran, excellent sources of complex carbohydrates (41). The endosperm serves as the basis for all flours. Refined flours are made by separating the endosperm from the husk, bran, and germ, and then milling it into fine powder (17). In whole-grain flours, the bran and germ are also milled into the flour—thus the name *whole grain*.

Germ

The germ (or embryo) is found at the base of the kernel and accounts for only 2.5% of the grain's weight. Rich in fat and with some incomplete protein, vitamins, and minerals, the germs are collected separately and sold as wheat germ, an excellent source of B vitamins and vitamin E. The fat content found in the germ makes it susceptible to spoilage, which is why wheat germ should be refrigerated. In addition, because whole-grain flours contain the germ, they have a much shorter shelf life than pure white flours.

Whole grains As defined by the American Association of Cereal Chemists (AACC), "Foods made from the entire grain seed, usually called the kernel, which consists of the bran, germ, and endosperm."

Fermentation The conversion of carbohydrates to carbon dioxide and alcohol by yeast or bacteria.

NUTRIENT CONTENT

A **cup of cooked cereal, grain, or pasta** contains about **160 kcalories, 30 grams of carbohydrate, 6 grams of protein**, some vitamins and minerals, and a trace of fat. Whole-grain products provide additional fiber.

Carbohydrate. Grains are an excellent source of ***complex carbohydrates*** that come in the form of breads, cereals, rice, pasta, and/or food products primarily made from these ingredients. ChooseMyPlate.gov recommends that at least half of the grain selections come from whole grains and/or their products because of their health benefits (32).

Protein. Although cereals supply 56% of the energy and 50% of the dietary protein worldwide (8), their **protein is incomplete** because grains are low in the essential amino acid lysine. They do, however, have adequate amounts of the amino acid methionine. For this reason, they are often paired with legumes, which lack methionine but have sufficient levels of lysine, to achieve protein complementation.

Fat. Cereals are very **low in fat and contain no cholesterol**. A slice of bread averages only 100 kcalories, but spreading **1 tablespoon of butter, margarine, mayonnaise, or peanut butter** on the bread adds another **100 kcalories and about 10 grams of fat**.

Vitamins and Minerals. Unfortunately, refined grains are also **low in many vitamins and minerals** because the milling process removes the husk, bran, and germ. Certain vitamins are lost during milling: 77% of the thiamine (B_1), 80% of the riboflavin (B_2), 81% of the niacin, 72% of vitamin B_6, 50% of pantothenic acid, 67% of folate, and about 86% of vitamin E (48). The term "enriched baked products" refers to those that have had specific nutrients replaced: thiamine (B_1), riboflavin (B_2), niacin, folate, and iron.

A difficulty in obtaining minerals from unleavened bread is that some of them may bind to phytate (phytic acid), which reduces their absorption in the intestinal tract (37). This does not occur with leavened breads because yeast, commonly used to leaven bread during bread making, breaks down the phytate and prevents it from binding to minerals and hindering their absorption (49).

Fiber. Consuming whole grains may also help meet the recommendation of the Academy of Nutrition and Dietetics that **at least 25 grams of fiber (for women) or 38 grams (for men)** be consumed each day. Whole-grain products are specifically a good source of soluble fiber, which has been shown to reduce high blood cholesterol and to help stabilize high blood glucose (33), and of insoluble fiber, which may help reduce the risk of colon cancer (52). Whole grains also contain phytochemicals, lignans, and phytoestrogens, compounds that are structurally similar to estrogenic substances and may have a protective effect against certain types of cancer. Overall, there is an inverse association between whole-grain consumption and increased risk of death from cardiovascular disease and total cancers (10).

Food Additives in Grain Products

So many grain products exist that categorizing common food additives for this group of foods is impossible. However, the label on any package of processed foods containing grains will list the food additives, and many of these are described in Appendix E. Some common nutrient and preservative additives are addressed here; the individual chapters on breads, cakes, pies, and pastries contain additional information.

The stable fat-soluble vitamins (A, D, E, and K) can be added to the dough before baking. The nutrients not stable to heat (the B vitamins and vitamin C) can be applied by spraying them on the cereal after it has been heated. Butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are often added to cereals to act as preservatives. Cereal

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grains would quickly stale without antioxidants that preserve product freshness. However, there is some concern about BHA and BHT, and so some consumers feel that other, less controversial antioxidants should be used (see Chapter 28).

USES OF CEREAL GRAINS

Cereal grains are grown primarily for flour, pasta, and breakfast cereals. They are also used in the manufacture of alcoholic beverages and animal feeds.

Flour

Flour is the fine powder obtained from crushing the endosperm of the grain. In the case of whole-grain flours, the bran and germ are also milled into the flour (45). Although any grain can be used to make flour, wheat flour is the predominant choice because it provides the protein structure that facilitates the rising of baked goods (see Chapter 17). Flour is used to make breads and an assortment of other baked products, such as biscuits, rolls, crackers, pretzels, chips, cookies, cakes, and pastries. It also plays an important role as a thickener (see Chapter 18).

Pasta

Pasta, meaning "paste" or "dough" in Italian, is an extruded grain product made predominantly from flour starch and water (28). It comes in a variety of shapes, and is sold in both dried and fresh forms (see the "Pastas" section).

Breakfast Cereal

During the mid- to late 1800s, a vegetarian craze hit the United States. Among its advocates was the religious group called the Seventh-Day Adventists, who hired Dr. John Harvey Kellogg to be the director of a health sanitarium. Dr. Kellogg instituted many health-promoting innovations, among them the use of a vegetarian substitute, in the form of dry cereal, for the traditional breakfast of ham or sausage and eggs. Charles William Post, another Seventh-Day Adventist, visited the sanitarium, returned home with the dry breakfast cereal concept, and started a cereal company. At that point, Dr. Kellogg's brother, William Keith Kellogg, seeing the financial success experienced by Post, introduced Kellogg's Corn Flakes to the general public, and the dry cereal industry boom began.

The breakfast cereal market has grown since its early beginnings and is now categorized into ready-to-eat (RTE) cereals (cold cereals) and hot cereals. Over 75% of breakfast cereals are the RTE type made from wheat, corn, or oats, and it is probable that neither of their originators could have foreseen the emergence of cereals with bits of chocolate or tiny colored marshmallows in the box. New cereal products are continually being introduced into the market by food companies.

How & Why?

How do food companies create so many different shapes for their cereals?

The varying shapes of ready-to-eat cereal available to consumers depend on whether they have been extruded (pressed through a die), flaked, granulated, puffed, rolled, or shredded (Figure 16-4). Extrusion cooking is popular for RTE cereals. After extrusion, they are shaped, toasted, flavored, colored, and sometimes enriched or fortified before being packaged and shipped to the consumer (18). Fortified cereals often provide a substantial percentage of a person's Reference Daily Intake (RDI) for vitamins and minerals.

Alcoholic Beverages

Various grains are used to make alcoholic beverages through the process of **fermentation.** For example, rice is used to make sake, a Japanese rice wine, and barley, rye, or corn may be used in brewing beer or distilling liquor.

Animal Feeds

Grains are important in the manufacture of livestock and pet feed. Many dried dog foods list ground yellow corn as the first ingredient on their labels.

GENERAL TYPES OF CEREAL GRAINS

The grains of primary importance in the world, in descending order, are corn, rice, wheat, barley, sorghum, millet, oats, and rye. Any food made from a cereal grain is a grain product, and examples of grains at www.ChooseMyPlate.gov include bread, pasta, oatmeal, breakfast cereals, tortillas, and grits. Grain products may be divided into two basic groups—whole grains and refined grains. The difference, as noted by ChooseMyPlate.gov, is that whole grains contain the entire grain kernel—the bran, germ, and endosperm. Whole grains are composed of the intact, ground, cracked, or flaked kernel (54). Commercially, the food industry,

FIGURE 16-4 Processing grains into cereal.



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CALORIE CONTROL
Grain and Pasta Calories Quickly Add Up

- *Dietary Guidelines*. Grain portions are measured in ounce equivalents as shown below, and approximately 6 ounces per day are recommended for a person consuming 2,000 kcalories.
- 1 ounce of grains is equivalent to the following:
  - 1 slice of bread
  - ½ C cooked rice, pasta, or cereal
  - 1 C ready-to-eat cereal
  - 1 ounce of dry pasta or rice
  - 3 C popped popcorn
- The key to kcalorie control is to practice portion control, or else excess kcalories pile up quickly! It's important to include whole-grain products because of their additional fiber, which over time may contribute to feeling fuller with reasonable portion sizes.
- Watch the rice:
  - ⅓ cup = 80 kcalories
  - 1 cup (1 fist) = 240 kcalories
- Watch the pasta:
  - ½ cup (½ fist) = 110 kcalories
  - 1 cup (1 fist) = 220 kcalories
  - 4 cups (4 fists) = 880 kcalories (excluding bread or sauce)

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previously dominated by refined grain products, is shifting toward whole-grain food products for consumers now interested in adding more fiber to their diets (50). Examples of whole grains include the following:

- Whole-wheat flour (or any other whole-grain flour)
- Bulgur (cracked wheat)
- Oatmeal
- Whole cornmeal
- Brown rice
- Less common whole grains: amaranth, buckwheat, millet, quinoa, sorghum, triticale

Refined grains have been stripped of the bran and germ during milling to give grains a finer texture and improve their shelf life, but it also removes dietary fiber, iron, and many B vitamins. Some examples of refined grain products are as follows:

- White flour
- Degermed cornmeal
- White bread
- White rice

Most refined grains are *enriched,* meaning that certain B vitamins (thiamine, riboflavin, niacin, folic acid) and iron are added back after processing. The removed fiber is not replaced. Some food products are made from mixtures of whole grains and refined grains. Whether a food is a whole- or refined-grain product can be quickly determined by reading the ingredients list.

Grains and their products may additionally be categorized as gluten-containing or gluten-free. **Gluten,** a protein present in wheat and several other grains, is avoided by consumers with celiac disease, gluten sensitivity, or wheat allergy (see Chapter 17). Manufacturers have responded by marketing an increasing number of gluten-free products in recent years.

CEREAL GRAINS CONTAINING GLUTEN

Wheat

Wheat is one of the top three grains produced in the world. The country producing the most wheat is Russia, followed by the United States. About 75% of all of the harvested wheat is made into flour, and the remaining 25% is used for cereals, pasta products, animal feed, wheat germ, and wheat germ oil.

Gluten The protein portion of wheat flour with the elastic characteristics necessary for the structure of most baked products.

Classification of Wheat

Wheat is divided into classes based on growing season, color, species, and/or texture. There are fourteen different species of wheat, and each of them has several different varieties. As a result, there are more than 30,000 varieties throughout the world, but only three species—common, club, and durum—account for almost 90% of all the wheat grown in the world (Figure 16-5). Among the lesser-known wheats are spelt, emmer, and einkorn, referred to as ancient wheats because they were some of the earliest cultivated species (l).

Growing Season

The two major types of wheat defined by their growing season are winter wheat (hard) and spring wheat (soft). Hard and soft wheats also differ in their protein content, which makes wheat flour more suited than any other grain for a variety of different baking purposes. Hard wheats, of which durum is the hardest and highest in protein, are more

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FIGURE 16-5 The three most common types of wheat.



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suitable for bread and pasta production (28). The majority of wheat grown in the United States is soft, or common, wheat. Soft wheat produces a flour that is lower in protein and is ideal for cakes, cookies, crackers, and pastries.

Color

Wheat may also be distinguished as being red or white, with various shades of yellows and ambers in between. After they are milled, however, many flours (excluding whole wheat) appear white and lose many of their distinguishing color characteristics.

Forms of Wheat

Flour is just one of the many possible forms of wheat. Other forms on the market include wheat berries, rolled wheat, cracked wheat, bulgur, farina, wheat germ, and wheat bran.

Wheat Berries

The simplest form of wheat is wheat berries, or groats, which are whole wheat kernels that have not been processed or milled. These take the longest time to cook as compared with other wheat forms.

Rolled Wheat

Flattening wheat berries between rollers produces rolled wheat, a product similar to rolled oats but different from the extruded wheat flakes used in breakfast cereals.

Cracked Wheat

This consists of wheat berries that are ground until they crack. It is available in coarse, medium, and fine grinds. Cracking wheat reduces the cooking time from 1 hour to about 15 minutes, resulting in a form of wheat that is more tender and less chewy than whole wheat berries.

Bulgur

Bulgur is wheat berries that have been ground even finer than cracked wheat. The berries have been partially steamed, dried, and then cracked to produce a more pronounced flavor. Bulgur is a common ingredient in tabouleh, a dish originally from Lebanon that is a salad of bulgur, vegetables, and herbs.

Farina

Farina (which may be familiar as the product known as Cream of Wheat™) is made by granulating the endosperm of the wheat into a fine consistency.

Wheat Germ

The germ of wheat is a good source of vitamin E (unless it has been defatted), some B vitamins, and fiber. Wheat germ contains polyunsaturated fat, and, unless it has been defatted, it will become rancid if not refrigerated.

Wheat Bran

Wheat bran is a source of insoluble fiber—specifically, indigestible cellulose. The various fibers, along with their chemical compositions, are described in Chapter 3.

Ancient Wheat Grains

Since ancient times, wheat has been selectively bred to increase its gluten strength; perhaps this has contributed to the rising number of people with gluten sensitivity. Einkorn, emmer, Kamut®, and spelt are all old or ancient wheat grains. One of the earliest wheats cultivated was einkorn, which contains only fourteen chromosomes compared to the forty-two found in modern wheat. Emmer (also known as farro) was one of the first domesticated crops in the Near East, and Kamut® is the name given to a Khorasan wheat variety. It is an ancient Egyptian grain nutritionally superior to wheat in protein content that has a rich, buttery texture (13). Spelt, another wheat variety, served as an important staple in Central Europe from the Bronze Age to medieval times. Ancient nonwheat grains or pseudo grains discussed under gluten-free cereal grains include amaranth, millet, quinoa, sorghum, and teff (20).

Barley

Barley was one of the first grains cultivated by humans (36). It is a hardy plant that grows in a wide range of climates. The heavy "beards" growing on the grain made it a symbol of male potency for the ancient Chinese. Early Greek athletes believed that their sports ability was enhanced when they ate barley mush during training. Roman gladiators were called *hordearli,* meaning "eaters of barley." Spaniards introduced barley to South America in the mid-1500s, and it spread northward from there. Barley is now used primarily as a malt (see below); in cereals and soups; for livestock feed; in the manufacture of beers and whiskey; and in soups, salads, and stews (34).

Forms of Barley

Used for thousands of years in the production of certain foods and beverages, barley is available in various forms: hulled, pot, pearled, flaked, barley grits, and malt.

Hulled Barley

Barley in its natural form is enclosed by a tough hull that can be removed, leaving the bran intact.

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Pot Barley
Pot barley has had the hull and some of the bran removed from the grain in a process called "pearling" (43).

Pearled Barley
In pearled barley processing, additional pearlings remove more of the bran, germ, and part of the endosperm, resulting in tiny grains with a polished, pearl-like color. Pearled barley is used to make barley flour, grits, and flakes, which can then be incorporated into breakfast cereals, breads, soups, cookies, and crackers. It is also cooked as is and added to soups, salads, and stews.

Flaked Barley
Flaked barley is rolled or pressed and used primarily as a hot cereal.

Barley Grits
Barley grits are barley grains that have been toasted and cracked into particles.

Malt
Malt is germinated (sprouted) barley that has been gently dried to stop the growth of germinating roots, leaving intact the enzymes that contribute to flavor and color. The enzymes are important for converting the starches to sugars such as maltose (Chemist's Corner 16-1). The barley grain is well suited for the production of the malt required in some alcoholic beverages because the aleurone layer contains the enzymes needed to convert some of the endosperm starch to maltose. In addition, the aleurone layer of barley is three to four cells thick, as compared to the single-cell layer in other cereal grains. About 4% of all barley is used in the production of malt, which can be purchased in dry or liquid form for use as food flavorings, as color additives in caramel, and as optional ingredients in baked products. Common foods to which malt is added include milk shakes, cereals, waffles, pancakes, ice cream, baked foods (cookies, crackers, pretzels, pizza, bagels), imitation coffees, and confections (34).

Oats

Oats are usually eaten as a hot or cold cereal or in energy bars, cookies, biscuits, breads, yogurts, and crackers (42). The low protein content of oats limits their use in bread making. Though oats are supposed to be gluten-free, some people with celiac disease or gluten sensitivity still react to them, so they are classed with gluten-containing grains here. The safety of oats for sensitive people depends on the variety and whether or not they have been cross-contaminated with wheat products. Health benefits of oats include their cholesterol-lowering and high blood glucose-lowering functional properties (47).

Forms of Oats
Oats are available in a variety of forms: groats, steel-cut, rolled, and bran (Figure 16-6).

CHEMIST'S CORNER 16-1
Malt Production

Malt is derived from maltose, the disaccharide naturally found in barley grain. The grain's starch must first must be broken down into smaller molecules: dextrins and maltose. Enzymes (α- and β-amylase) found in the barley grain convert its starch to dextrin and maltose, resulting in a liquefied mass known as "wort." The wort is evaporated under a vacuum to convert it into a syrup (80% solids), and the temperatures at which this occurs determine what type of malt extract is produced. These malt syrups can then be dried into "malts" that have the same color, flavor, and sweetness of their liquid counterparts without the enzyme activity (34).

Oat Groats
Oat groats are whole oats without the husks. They can be prepared like rice or used as an ingredient in other foods.

Steel-Cut Oats
Steel-cut oats are groats that have been cut lengthwise and then placed in cans or packages. They have a chewy texture, and are often imported from Scotland and Ireland, where they are more frequently consumed than they are in the United States.

Rolled Oats
Rolled oats have been heated and pressed flat with steel rollers. They come to market as regular old-fashioned, quick-cooking, or instant oatmeal. Instant oats have been steamed to pregelatinize the starch, allowing immediate hydration and making them, like all other pregelatinized cereals, the quickest to prepare. Rolled oats are often incorporated into granola, which is a mixture of toasted oats, nuts, dried fruits, and sweeteners. Muesli, the European version of granola, contains oats that have not been toasted and is usually lower in fat than granola.

Oat Bran
This is the bran isolated from oats; it has been reported to be effective in lowering high blood cholesterol.

Rye

Rye is second only to wheat as a grain used in bread making, but in the United States, rye is used primarily to produce rye crackers and whiskey. Compared to wheat, rye usually contains less protein (but still contains gluten) and starch but more free sugars and dietary fibers (4). As a result, the loaf volumes of rye bread are half of that obtained for wheat products; however, rye breads are richer in flavor and aroma, and they have a longer shelf life (Chemist's Corner 16-2) (56). Rye thrives in cold, wet weather and is widely grown and consumed in Scandinavia, Eastern Europe, and Russia. During the Middle Ages in

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FIGURE 16-6 Varieties of oats.


Steel-cut oats


Groats


Rolled oats


Quick oats


Instant oat flakes


Oat bran


Source: The Quaker Oats Company

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CHEMIST'S CORNER 16-2

Rye Proteins and Starches

The lower volume and sweeter taste of rye breads as compared to wheat breads are due to the unique characteristics of rye's protein and carbohydrate content. Rye proteins are more water soluble than wheat proteins and exhibit the properties of both a viscous liquid and an elastic solid (9). Starches also play a key role in baked crumb structure, firmness during slicing, and chewiness. This contributes to the compact and moist nature of rye bread. The starch granules found in rye bread are more easily disrupted and gelatinize at lower temperatures than wheat starch, which allows them to be degraded by α-amylase enzymes for a longer period of time during baking. Also contributing to the stickiness, moistness, and sweeter taste of rye bread is the ability of the pentosans (water-soluble, five-carbon carbohydrates such as D-xylose and L-arabinose) in rye to retain water (14).

parts of Europe, only the nobility were allowed to consume wheat bread, leaving the peasants to subsist on a type of rye bread. Some historians believe that ergot poisoning (Holy Fire or Saint Anthony's Fire), a foodborne illness caused by a fungus that grows on grains, especially rye, was a contributing factor to the French Revolution: the peasants were consuming ergot-prone rye, whereas the ruling classes were eating wheat bread free of the taint of ergot poisoning. Ergot poisoning can cause delusions, hallucinations, and erratic behavior, and it has been suggested that it may have been a factor in the Salem witch trials as well (24).

Triticale

Triticale is a relatively new hybrid grain that was developed in 1875 by a Scottish botanist who crossed wheat (*Triticum*) with rye (*Secale*) to create a grain with the bread-making quality of wheat and the climate hardiness of rye. Triticale, one of the few fertile hybrids, has a higher protein content and more of the essential amino acid lysine—the most common limiting amino acid in grains—than wheat. The flour from triticale produces excellent loaf volume, but "sticky dough" problems prevent it from being widely used (43).

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GLUTEN-FREE CEREAL GRAINS

Amaranth

Amaranth was eaten by the Aztecs, who considered it a "superfood" because of its purported energy-enhancing and athletic performance–enhancing effects (13). It is one of the earliest known plants used as a food source. This high-protein, gluten-free grain is now becoming more available in the marketplace (Table 16-1). It yields a flour that imparts moistness and a nutty flavor to baked products. Amaranth can also be served like popcorn by popping it in a dry frying pan. The grain is so small that an expression in Africa states, "Some things are not worth an amaranth (seed)" (38). Amaranth is high in protein and fiber, and it has double the amount of iron found in wheat. Because of its excellent nutritional profile, the National Academy of Sciences recommended that amaranth be promoted as an addition to the American diet (13).

TABLE 16-1 Gluten-Free Grains

- Amaranth
- Buckwheat
- Corn
- Millet
- Quinoa
- Rice
- Sorghum
- Teff

Buckwheat

Buckwheat is not related to wheat and is not, strictly speaking, a true grain. It is, in fact, the fruit of a leafy plant that is related to rhubarb and is thus gluten-free. It is, however, generally categorized as a grain because of its use as a flour and cereal. The nut-like flavor of buckwheat flour makes it a popular addition to pancake flour and some breakfast cereals and crepes. A dish made of roasted, cracked, and granulated buckwheat groats, known as kasha, is popular in Eastern European countries.

Chia Seeds

Growing in popularity are tiny chia seeds (1–2 mm) similar to tapioca balls in their ability to absorb water, expand, and become gel-like. The name *chia* is from the South American Aztec people (3). Not only are chia seeds high in omega-3 fatty acid, but a double-blind, randomized, clinical trial revealed that chia seed supplementation may promote weight loss and blood glucose control (55).

Masa A corn product made by cooking corn in water and then grinding it into a pourable slurry. *Masa* means "dough" in Mexico, and it is often used to make tortillas, tamales, and many commercial corn-based snacks.

Corn

Corn is native to the Americas, where fossilized corn pollen grains found near Mexico City have been estimated to be more than 80,000 years old. Corn plays a very important role in the religious life of many Native American peoples, especially the Hopi in Arizona, among whom life from birth to death revolves around corn. Over 50% of the world's corn is grown in the United States. Outside the United States, corn is referred to as *maize* worldwide.

FIGURE 16-7 Corn is classified by its kernel type.



Dent Corn | Flint Corn | Popcorn | Sweet Corn

Nancy Bauer/Shutterstock.com; Gurcharan Singh/Shutterstock.com; Gurcharan Singh/Shutterstock.com; Jacinta Photography/Shutterstock.com

Classification of Corn

Corn is classified according to its kernel type—dent, sweet, flint, popcorn, flour, and pod (Figure 16-7)—and by its color. Yellow and white predominate, but there are also red, pink, blue, and black corn varieties, as well as corn with bands or stripes.

Dent Corn

Dent corn, so named because each corn kernel has a small dent on top after it is dried, accounts for over 95% of all corn grown in the United States. Although almost half is sold as livestock feed, the rest is stored as a buffer against the next year's crop, exported, or used by food manufacturers in the production of corn syrup, alcohol, starch, and canned or other processed corn.

Flint Corn

Colonial settlers were taught to grow flint corn, also known as Indian corn, by the Native Americans. Grinding the extremely hard corn kernels makes a good quality cornmeal. Grown primarily in Central and South America, it is now used for harvest time decorations in North America.

Popcorn

A special variety of corn with thick-walled kernels is used to make popcorn. During popping, the moisture inside the kernels heats into steam that builds up to 135 pounds of pressure per square inch, finally bursting the kernel open and exposing the puffy starch.

How & Why?

Why don't some popcorn kernels pop?

Kernels that do not pop are believed to contain leaks that allow the steam to escape. Making sure the popcorn is stored in an airtight container, preferably refrigerated, reduces the number of UPKs—unpopped popcorn kernels.

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Sweet Corn

Most canned corn is derived from sweet corn, or "corn on the cob," which can be either yellow or white. Sweet corn tastes best before the milky fluid in the fresh corn kernels has had a chance to harden.

Flour Corn

This white or blue corn is common among Native Americans of the Southwest, who have been using its flour as a staple for more than 1,000 years. Blue corn chips are sold commercially on the same shelf as the standard potato, corn, and tortilla chips.

Pod Corn

Pod corn is a noncommercial corn in which each kernel is encapsulated in a separate husk, and the entire ear is wrapped in a large husk.

Forms of Corn

The bulk of corn grown in the United States is used for livestock feed. The remainder is used to make ethanol, for human food, and for its seed (5). Corn is consumed in its natural state on the cob, as kernels, or as processed foods, including hominy, hominy grits, cornmeal, cornstarch, corn syrup, and corn oil.

Corn on the Cob and Kernel Corn

Corn on the cob is eaten directly off the cob. Corn kernels removed from the cob can be used as a vegetable in a wide variety of dishes. Fresh corn varieties include yellow corn, white corn, and a hybrid corn that contains both yellow and white kernels.

Hominy

Hominy is enlarged kernels of hulled corn with the bran and germ removed. The endosperm of this white corn is enlarged because it has been soaked in lye and dried (Figure 16-8). It is available in canned or frozen form and is particularly popular in the southeastern region of the United States.

Hominy Grits

Grits refers to coarsely ground grain, so hominy grits are obtained by grinding dried hominy into small uniform particles that are served boiled as a breakfast dish in the southern United States (Figure 16-8).

Cornmeal

Meal is the coarsely ground version of any grain, so cornmeal is coarsely ground corn. The original corn can be whole or degerminated and either yellow or blue-white in color. Bread made from cornmeal has a shorter shelf life than wheat bread because cornmeal has a higher fat content than wheat flour.

FIGURE 16-8 Hominy and hominy grits.



Lew Robertson/Getty Images

(a) Hominy is corn kernels that enlarge due to processing.



istock.com/burwellphotography

(b) Hominy grits are made by grinding hominy corn kernels.

How & Why?

How does cornmeal become a corn chip?

Many commercial snacks, including corn chips and collets, are made from cornmeal. Fried corn chips are manufactured by cooking corn in water until it becomes soft. This resulting **masa** (50% water) is then extruded, cut into pieces, fried, seasoned, and salted. Collets are often cheese curls or balls of extruded cornmeal treated under high heat and pressure (Figure 16-9). The collets are coated with cheese seasonings. The general composition of a cheese coating consists of partially hydrogenated oil, cheddar cheese powder, acid whey powder, cheese flavor, and salt. The compositional differences in masa, seasonings, and shape result in different types of chips and collets.

Cornstarch

Cornstarch is finely ground corn endosperm used to thicken gravies, puddings, and sauces because of its high starch content (see Chapter 18).

FIGURE 16-9 Collets are used to create cheese curl or ball cornmeal-based snacks.



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Corn Syrup

Corn syrup is a viscous liquid consisting of fructose, glucose, and other sugars (maltose, dextrins) obtained by treating cornstarch with selected enzymes. Corn syrup may be light or dark; the dark is the stronger flavored of the two. High-fructose corn syrup has been chemically altered to increase its sweetness (discussed in Chapter 21).

Corn Oil

Corn oil is extracted from the germ of the corn kernel.

Indian Rice Grass

Native to the western United States, Indian rice grass was grown by Native Americans about 7,000 years ago. Montina® flour is produced by grinding this gluten-free grass.

Millet

Millet grows wild in Africa and is thought to be one of the world's first cultivated grains (13). It is a staple in Asia and Africa and is thought to have existed in China since 5500 BC.

One of the smallest among the cereal grains, millet contains insufficient amounts of gluten, the protein required for bread to rise properly (see Chapter 17), for use in leavened breads, but it is used in many countries throughout the world to make unleavened bread as well as beer. Millet is less common in the United States, where it is used primarily for birdseed, but it is grown widely in Russia, China, Japan, India, Africa, and southern Europe. The varieties of millet include common (also known as Indian, Proso, Hog, and Broomcorn), finger, foxtail, Japanese, little, and pearl or bulrush millet.

Quinoa

Quinoa (KEEN-wah), made from the seeds of the *Chenopodium* plant, is a pseudo cereal because it is not a member of the grass family and is technically a fruit and gluten-free (20). A staple food of the Andean culture since 3000 BC and sometimes referred to as "Inca rice," quinoa is a very good source of plant protein (18%), higher in the amino acid lysine than wheat, and popular among vegetarians (20). The Incas of South America called quinoa the "mother of all grains" (20). The tiny, seed-like kernels must be rinsed before cooking to remove the naturally bitter coating of saponin on the surface, leaving a rather mild, pleasant-flavored grain that cooks very quickly. In some cultures, quinoa was considered a sacred crop and was a dietary staple served with potatoes and herbs.

Rice

Over half the world's population relies on rice as a staple food (15). In Asia, where 94% of the world's rice is produced, rice is so important that it is a symbol of life and fertility. This is why rice is sometimes thrown at the bride and groom at a wedding. Per capita yearly consumption in the Far East, where people may eat rice three times a day, averages 200 to 400 pounds, compared to only about 31 pounds in the United States (7). China and India lead the world in rice production.

FIGURE 16-10 Rice is classified by the length/width ratio of the grain.



Classification of Rice

Rice is classified according to its mode of cultivation, grain length, and texture. More than 90% of all rice is grown with its roots submerged in water and is known as lowland, wet, or irrigated rice. It is not necessary for water to cover the base of the rice plant, but this method protects it from insects and weeds, which results in a better yield. Highland, hill, or dry rice is grown in areas of plentiful rain, where the hilly terrain prevents flooding. The length in relationship to the width of the grain determines whether rice is considered to be long-grain, medium-grain, or short-grain (Figure 16-10). Most long-grain rices, which are about four times longer than they are wide, cook to a drier, fluffier consistency, which allows the grains to separate. Medium- and short-grain rices have less amylose, which makes them stickier when cooked. The difference in stickiness among the rices is due in part to the fact that long-grain rices contain more amylose, whereas short-grain rices are higher in amylopectin, making them more waxy and glutinous. The very starchy short-grain rice known as arborio gives Italian risotto its characteristically creamy texture. It is ideal for rice pudding (22). The sticky short-grain rice with an oval shape is also preferred by the Chinese and Japanese because of its easier handling with chopsticks and when preparing sushi (Figure 16-11). The rice varieties consumed in

FIGURE 16-11 The sticky starch of short-grain rice makes it better suited than other rices for sushi and being picked up by chopsticks.



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North America are typically nonglutinous (less sticky, and lighter, drier, and fluffier when prepared) and include long-, medium-, and short-grain rice.

Forms of Rice

Rice comes in various forms, depending on its type and the way it is processed: white, converted, instant, brown, black, red, glutinous, specialty, bran, and wild. Although there are more than 40,000 different varieties of rice worldwide, white rice is the most common (46).

White Rice

White rice has been milled and polished to remove the husk, bran, and germ. Removing the bran layer and germ eliminates all of the fiber and most of the B vitamins and iron, although some of these are replaced in enriched grains. The exception is riboflavin (B_2), a B vitamin that is not normally added to rice because it turns the grains slightly yellow. The surface of white rice becomes smooth when it is placed in machines equipped with revolving bands of felt or leather, which rub off the grain's bran and some of the endosperm.

Converted Rice

Converted or parboiled rice is long-grain rice that has been soaked, steamed under pressure, and dried before milling. It accounts for about 20% of all the rice sold in North America. Converted rice is commonly used in food-service establishments because the grains stay firm and separate.

Instant Rice

Instant rice is rice that has been cooked and then dehydrated, so it takes only a few minutes to prepare. The texture is inferior, however, and the grains have a tendency to split during cooking and become dry.

Brown Rice

Brown rice has had only the hull removed, leaving the bran and germ intact. The presence of the outer covering of bran results in more fiber, but longer cooking times are required, and the result is a tougher texture as compared to white rice.

Black Rice (Purple or Forbidden Rice)

This specialty rice turns more deep purple than black when cooked because of its high anthocyanin content. Its moistness, nuttiness, and gelatinous consistency are hallmarks of a sticky rice. Normally reserved for feasts and ceremonial purposes, black rice is becoming more and more common, especially in gourmet meals.

Red Rice (Red Rice Koji)

Popular in China for centuries, red rice gets its color from the yeast *Monascus purpureus*, which is cultured on the rice (44). Monacolins, substances that inhibit cholesterol synthesis, can be isolated from red yeast rice (or rather from *Monascus*). Monacolin K is a potent inhibitor of 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase (the enzyme that catalyzes the rate-limiting step in cholesterol synthesis) and also known as lovastatin (Mevacor®), a drug used for lowering high blood cholesterol. The Food and Drug Administration (FDA) has banned the sale of red yeast rice for the purpose of lowering high blood cholesterol because this use would make it a drug.

Glutinous Rice

Also known as sweet rice, glutinous rice is slightly sweeter, stickier, and more translucent than regular white rice when heated. This rice is easily shaped and molded and is thus preferred for preparing rice dumplings, rice cakes, and sushi.

Specialty Rice

A number of long-grain rice varieties known as specialty rices have nuttier tastes, separate easily, and are more expensive. These specialty rices are not enriched. Examples include basmati, jasmine, Texmati, Wehani, and wild pecan/popcorn rice.

Rice Bran

Rice bran is just as effective in lowering high blood cholesterol as oat bran, but the bran from rice has a slightly different taste and a shorter shelf life than that from oats.

Wild Rice

Wild rice is not really rice, or even a grain, but rather a reed-like water plant (*Zizania aquatica*). It is harvested from areas in the Great Lakes region and in Canada where it grows wild, although increasingly it is deliberately cultivated. This food, historically consumed by Native Americans, has a nutty flavor and is often used to stuff game and poultry (23). It is sometimes mixed with dried fruits, mushrooms, or citrus. It may be mixed with brown or white rice for commercial purposes, and it contains twice the amount of protein and more B vitamins than white rice. Wild rice is cooked until the grains pop, revealing a creamy center. Cooking time varies from 40 minutes to more than 1 hour. Wild rice swells up to four times its size during cooking. Unlike traditional rice, wild rice does not absorb all of the water in which it is cooked (23).

Sorghum

Sorghum is a cereal grain of major importance in Africa and certain parts of Asia (11), Central America, Pakistan, and India. It is consumed in the form of food (usually porridge), alcoholic beverages, or livestock feed. Cushiony puffed sorghum grains can also be used as a biodegradable packing material.

Teff

Teff is a gluten-free grain that originated in Ethiopia between 4000 and 1000 BC. Its seed is smaller than that of millet or quinoa. Unlike wheat, teff is high in protein and has an excellent amino acid composition, providing all eight amino acids essential for humans.

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PREPARATION OF CEREAL GRAINS

Cereals in their natural form are nearly indigestible. The hard outer covering of the seeds of these grasses prevents their immediate consumption and can even break a tooth. This barrier is overcome by heating the grain in water, which softens the outer covering and makes the starchy endosperm digestible. Cooking also gelatinizes the starch, which improves the flavor and texture of cereals as the grains soften and expand. Gelatinization occurs when heated starch molecules absorb water and expand—a phenomenon seen when grains expand to two or three times their volume when cooked. The degree of expansion depends on the type of grain and is partially caused by the escape of amylose and amylopectin from the starch granule. The results desired in grain preparation are most commonly achieved by moist-heat methods: boiling, simmering, microwaving, and baking in the presence of liquid.

Moist-Heat Preparation: Boiling/Simmering

The type of grain dictates the amount of water to be added and the intensity or duration of heating. Table 16-2 lists recommended ratios of water to grain, cooking time, and yield for each of the different grain types. The two most important factors in grain preparation are the amount of water used and the exposure to heat.

Prepreparation

Whole grains are first rinsed thoroughly prior to cooking to remove any dirt or insect parts.

Cooking the Grain

The most common preparation method for grains such as rice is the "absorption method." The grain is added to a measured amount of boiling water. Salt is added in the ratio of $^1/_4$ teaspoon per cup of uncooked grain to provide flavor. The pan is then covered, and the water is brought back to a boil. The heat is then immediately reduced, and the contents are allowed to simmer (covered) for the remainder of the preparation time.

TABLE 16-2 Recommended Liquid Quantities and Heating Times for Grain Preparation

Per ½ C Uncooked	Liquid (Cups)	Cooking Time	Yield (Cups)
Wheat			
Whole berries	1½	1 hour, 10 minutes	1¾
Cracked wheat	1	15 minutes	1
Bulgur	1	15 minutes	1½
Wheat flakes	2	53 minutes	1
Rice			
Brown, long-grain	1	25–30 minutes	1½
Brown, short-grain	1	40 minutes	1½
Brown, instant	½	5 minutes	1¾
Brown, quick	¾	10 minutes	1
White, long-grain	1	20 minutes	1¾
White, instant	½	5 minutes (let stand 5 minutes)	1
Converted	1½	31 minutes	2
Arborio	¾	15 minutes	1½
Basmati, white	½	15 minutes	2
Jasmine	1	15–20 minutes	1¾
Texmati long-grain, brown	1 (plus 2 Tbsp)	40 minutes	2
Texmati long-grain, white	¾ (plus 2 Tbsp)	15 minutes	1¾
Wehani	1	40 minutes	1¼
Wild	2	50 minutes	2
Wild pecan	1	20 minutes	1½
Barley			
Hulled	2	1 hour, 40 minutes	1¾
Pearl	1½	55 minutes	2
Quick	1	10–12 minutes (let stand 5 minutes)	1½
Flakes	1½	30 minutes	1
Corn			
Grits	⅓	40 minutes (let stand 2–3 minutes)	⅓
Oats			
Groats	1	6 minutes (let stand 45 minutes)	1¼
Steel-cut	2	20 minutes	1
Old-fashioned rolled	1	5 minutes	1
Rolled, quick	1	1 minute	1
Oat bran	1	(let stand 3–5 minutes) 6 minutes	1
Rye			
Rye berries	1½	1 hour, 55 minutes	1½
Rye flakes	1½	1 hour, 5 minutes	1¼
Buckwheat			
Groats, unroasted, whole	1	15 minutes	1¾
Groats, roasted, whole	1	13 minutes	1½
Kasha	2½	12 minutes	2

A steam cooker simplifies the process because the only step consists of adding the grain, unheated water, and seasoning to the cooker, which then regulates the temperature as needed to produce perfect rice. Regardless of which method is used, water is absorbed, after which the rice finishes cooking through the trapped steam (35).

Grain Consistency

If a pan is used, adding the grain to hot water results in a fluffier product; adding it to cold water yields a stickier

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grain. Stirring also affects stickiness, so the grain is initially stirred only as much as is necessary to disperse it and the salt evenly in the water. Stirring can be avoided by pouring the grain in a zigzag fashion over the entire surface of the boiling water for a more even distribution. Most grains should be stirred as little as possible while cooking. Stirring can cause a gummier texture because it makes the starch granules rupture prematurely. The exception to this rule is risotto, an Italian rice dish prepared by constant stirring.

Adding Seasonings

Regardless of the preparation method, grains are usually bland unless seasoning ingredients are added at the beginning of the cooking process. Chicken- or beef-flavored soup stock or bouillon can be used instead of water, giving the grain a slight chicken or beef flavor.

Factors Influencing Grain Cooking

The form of grain, the presence of the bran or hull, the pH of the water, and the desired tenderness are factors that influence the amount of water to be used, the heat intensity, and the cooking time. Any reduction in particle size through cracking, rolling, cutting, or flaking decreases the heating time. For example, cracked wheat cooks in 15 minutes, whereas whole wheat berries may take over an hour. Removing the bran or hull also drastically cuts heating time. Brown rice takes about twice as long to cook as white rice, while barley with its hull intact takes about 35 minutes longer than pearl barley. A more alkaline environment, such as the one created by using hard tap water, causes grains to cook at a faster rate and possibly to overcook because of increased breakdown of the cellulose.

Hot Breakfast Cereals

Hot breakfast cereals account for 7% of all breakfast cereals. The most commonly consumed hot breakfast cereals are oatmeal, farina, hominy or corn grits, cream of rice, and bulgur. They are available in three forms: regular, quick-cooking, and instant. Most people like cereals prepared to a thick yet moist consistency, which can be varied by using more or less water. To prevent clumping, particularly when preparing the more finely granulated cereals such as farina and grits, it is best to sprinkle the cereal slowly over the boiling water while stirring so that each grain has a chance to be surrounded with hot liquid. Another way to prevent clumping is to mix the cereal with cold water to make a slurry before adding it to the hot water. After all the cereal is added, maintain a slow boil and stir occasionally until the grains are translucent. There are virtually no clumping problems with instant breakfast cereals, which simply require the addition of boiling water and a bit of stirring. One cup of uncooked cereal yields about four to six servings when cooked.

Determining Doneness

After the minimum amount of covered cooking time has passed, the grains are tested for doneness by tasting. The grain should be tender but have a slightly resistant core. Undercooked grains are difficult to chew and have a starchy, raw flavor. Overcooked grains may form a mushy, formless mash. Too much water contributes to stickiness, sogginess, and loss of nutrients, but insufficient water causes dry, toughened textures, and may even allow the grain to burn.

Standing Time

Once cooked, the grain should stand for 10 to 15 minutes. This standing time allows steam to further separate the granules, creating a light, airy texture. To further this goal, after removing the saucepan from the heat, a fork can be used to fluff the grain by gently and quickly forming a pyramid with the grain in the pan. The fork handle is inserted into the pile in four places, moving it back and forth each time to create a ¼-inch tunnel for steam to escape from the pyramid. Placing a paper towel flat over the pan and then covering the pan with its lid allows the paper towel to absorb the rising steam. A modified version of this method is often used in the Middle East to ensure a light and fluffy grain.

Sautéing and Baking

Although they are not used as frequently as the boiling method, two other procedures for preparing grains are both intended to add flavor to the finished dish—sautéing in oil and aromatics, referred to as the *pilaf method,* and baking. Grains such as rice and bulgur can be first sautéed in fat (1 tablespoon per cup of uncooked grain), after which boiling chicken broth or other stock, instead of water, is poured over the grain. It is then covered and simmered until done (35). Cereal grains can also be prepared in a casserole dish and baked in the oven if sufficient liquid is provided. The grain, usually rice, may already be cooked prior to being included with the rest of the ingredients that will be baked, but if not, boiling water is added to the dish. The casserole is usually covered to take advantage of the steam, which further aids in cooking its contents. Baking times vary according to the grain used but average 20 to 30 minutes.

Microwaving

Heating times are not significantly reduced with a microwave oven. Follow the manufacturer's directions for the amounts of water and grain required and the heating times. Microwave preparation is ideal for instant hot cereals because single servings can be prepared directly in a microwave-safe serving bowl in a one-step process.

STORAGE OF CEREAL GRAINS

Dry

Dry grains, freed of their bran and germ, are best kept in airtight wrappings or containers in a cool, dry area free of rodents, insects, and other pests. Moisture is the biggest contributor to the deterioration of grains. The relative humidity in the environment determines the grain's moisture content, as grains take up moisture until equilibrium is reached with the atmosphere's water vapor. In practice, this means that a relative humidity of 70% or less is considered safe; microbial growth will occur above 75% relative humidity, resulting in extensive grain deterioration (30). Thus, once opened, grain packages should be tightly resealed or the grain placed in another airtight container that will protect it from air or animal invasion. Most grains, when stored properly, will keep for 6 to 12 months.

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Refrigerated

Whole grains should be refrigerated in airtight containers to retard rancidity and prevent mold growth, which can be caused by moisture. Usually, only whole or cooked grains are refrigerated.

Cooked grains will keep up to a week if they are tightly covered. The best way to reheat grains is in a microwave oven or in a covered saucepan on top of the range with about 2 tablespoons of water added for each cup of grain.

Frozen

Cooked whole grains can be frozen for future use if they are tightly wrapped or placed in airtight containers. Uncooked grains should not be frozen because freezing alters the protein structure in such a way that any baked products made from the grain will not rise as high.

PASTAS

As mentioned earlier, pasta is a mixture of primarily flour starch and water that is extruded into thousands of different pasta forms such as macaroni, spaghetti, lasagna, vermicelli, and noodles (28). The Chinese developed noodles as early as 5000 BC, and Marco Polo, one of the first Europeans to reach the Orient, is credited with bringing them back from his travels and introducing pasta to Italy and the rest of Europe in the late 1200s. There is some evidence, however, of pasta having been made in Italy as early as 400 BC (24). Much later, in the late 1700s, pasta was introduced to North America by Thomas Jefferson after he visited Naples while serving as the American ambassador to France. Pasta now serves as a popular source of complex carbohydrates in many parts of the world.

Pastas are usually made from semolina, a flour derived from durum wheat, although other flours are sometimes used; flavorings and colorings can also be added (12). The protein content of durum wheat makes it best suited to withstand the pressures of mechanical kneading and manipulation during commercial pasta production, as well as the heat during preparation (41). Likewise, the protein in durum wheat flour gives pasta its elasticity and helps it maintain its shape during cooking. Thus, the higher the protein content of durum wheat, the better the quality of the pasta made from it. Durum wheat is also higher in carotenoid pigments, which contribute to pasta's rich, golden color (19). The yellow color may also be derived from egg yolks, which are a common ingredient in pasta. Most pasta manufactured in North America is also enriched with several B vitamins and iron.

Types of Pasta

Pasta is made by combining water with semolina flour and/or farina. Optional ingredients such as vegetable purées (as in spinach pasta) and a variety of seasonings may be added before the pasta is shaped and dried. The shapes by which pasta is identified are formed by placing the freshly made pasta dough in a cylinder and forcing it through holes in small discs (dies). Pasta dough is best extruded at 115°F (46°C) because temperatures higher than 140°F (60°C) will denature the protein and reduce the pasta's quality. Once pressed through the appropriate die, pasta is cut and then dried until the moisture level drops from 31% to 10 or 12% (51).

The type of disc used determines what kind of pasta is produced. Depending on the selected disc, pasta can be called spaghetti ("little strings"); linguine ("little tongues"); vermicelli ("little worms"); rigatoni ("grooved"); or fettuccine, capellini, cannelloni, tortellini, lasagna, ravioli, macaroni, noodles, wonton wrappers, and others (Figure 16-12). *Macaroni* is also used as a generic term for all types of dried pasta. There are more than 600 pasta shapes now in existence, but only about 150 are available in North America (40). "Long goods" such as spaghetti and linguini are most commonly consumed (41%), followed by "short goods" such as macaroni (31%) and noodles (15%), and specialty items such as lasagna and manicotti (13%) (29). An Italian website noted at the end of the chapter provides photos of many more different types of pasta. Different types of pasta vary not only in shape but also in their ingredients, which influences the pasta nomenclature discussed next.

Noodles

"Noodle products" are technically defined by the FDA's Code of Federal Regulation as prepared from flour (semolina, durum, farina, flour, or any combination) with at least 5.5% egg by weight, with or without water, and with or without optional ingredients (26). However, eggless noodles and others that do not meet the preceding definition are available on the market.

Asian Noodles

Asian noodles are often made from flours other than the standard semolina flour or farina and, as a result, often appear translucent or clear (16). This and the fact that they rarely contain eggs is why they are sometimes called imitation noodles in the West. Asian noodles may be made from rice, mung bean, taro, yam, corn, buckwheat, or potato flours. Examples of Asian noodles are rice, ramen, soba, chow mein, Japanese, Chinese, and bean thread noodles (40). Ramen are instant Japanese noodles that have been previously dehydrated by frying, which makes them extremely porous and much more likely to absorb water than regular noodles. Adding water to ramen instantly rehydrates them, making them popular for use in soups and luncheon noodle meals.

Whole Wheat

Pasta made from whole-wheat flour is slightly higher in nutrients and fiber than standard pasta, but it has a tougher texture and a stronger taste and tends to disintegrate if cooked too long.

Flavored

Vegetable purées made from spinach, tomatoes, or beets can be added to pasta to alter its color and flavor. Alternatively, herbs and spices such as basil, garlic, parsley, and red pepper may be incorporated into the pasta dough.

Fanciful

Unusual shapes inspired by dinosaurs, other animals, and cartoon characters have been developed to appeal to youthful consumers.

High-Protein Pasta

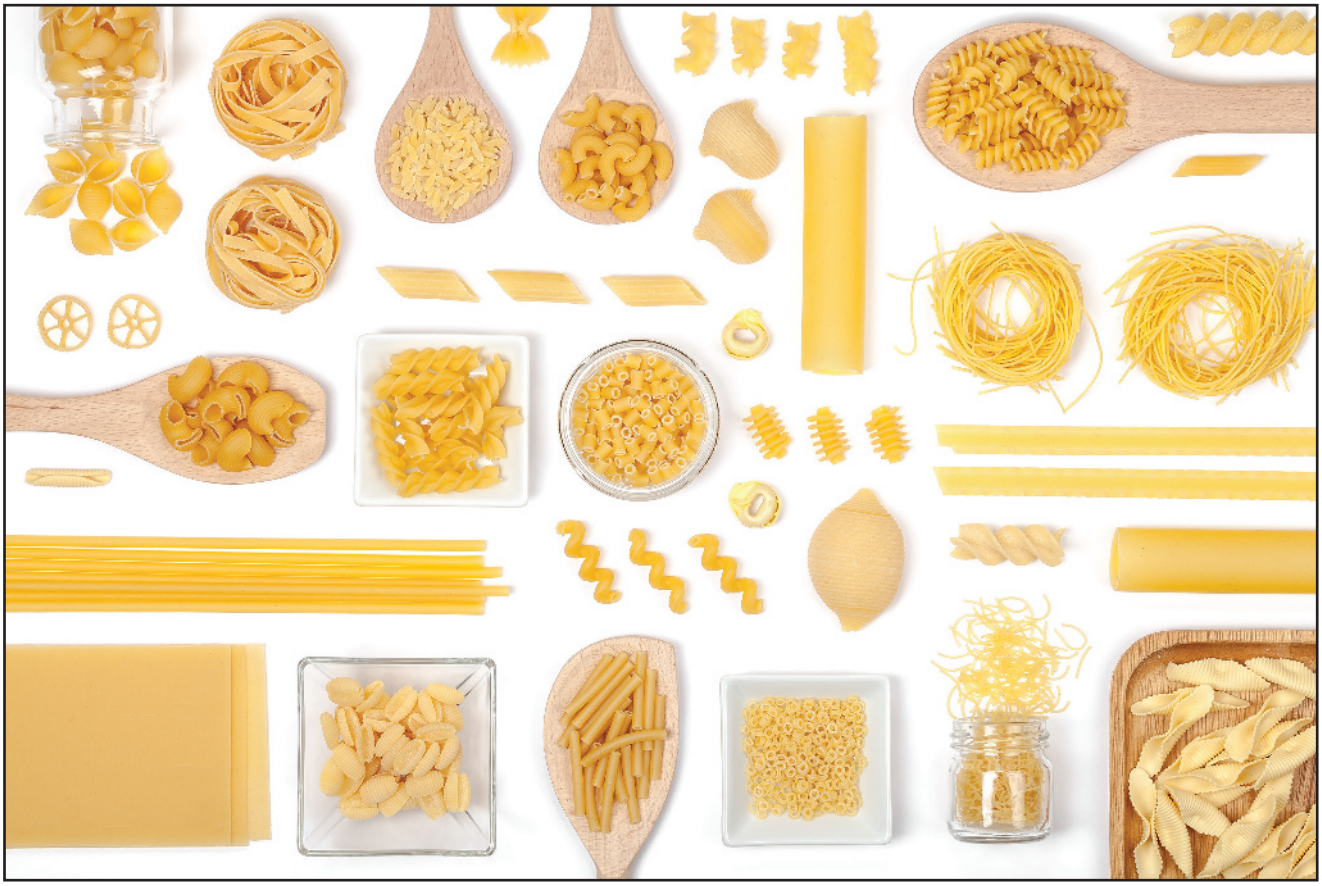
Adding soy flour, wheat germ, or dairy products yields high-protein pasta

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FIGURE 16-12 A rich array of pasta shapes and sizes is available.



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products that contain 20 to 100% more protein than standard pasta (40).

Fresh

Fresh pasta, found in the refrigerated section of the supermarket, has a higher moisture content, which gives it a softer consistency and shorter cooking time.

Couscous

Couscous looks like a grain, but it is actually "Moroccan pasta" made from semolina that has been cooked, dried, and pulverized into small, rough particles the size of rice grains (6). Traditionally, lamb stew and many Middle Eastern dishes were served over a bed of couscous. Middle Eastern or Israeli couscous is larger than regular couscous and resembles small balls of pasta. It is usually toasted before preparation and retains a firm bite after cooking. In another part of the world, people in many African countries consume their couscous with milk for breakfast or as a starch with lunch or dinner (2).

PREPARATION OF PASTA

Moist-Heat Preparation

Pasta is easy to prepare by boiling (Figure 16-13). It is dropped into lightly salted boiling water, stirred to keep the strands or pieces from sticking together, and heated until it reaches the **al dente** (ahl-den-tay) stage. If the pasta sits in water that is not hot enough, it will become gummy and sticky. Stir during the first minute or two of cooking because pasta pieces touching each other can merge into a bigger piece. Properly prepared pasta is not excessively sticky, and when it is done, it is drained and ready to serve.

During heating, the majority of pastas expand to two or three times their original size. Flat noodles are an exception in that they increase in size only by half. The pasta-to-cooking-water ratio should ensure that the pasta is heated in plenty of water: 4 quarts of water per pound of pasta is recommended. Using a large enough pot or pan prevents boilovers. It also prevents using less than the amount of required water that will drop in temperature more easily than a larger amount of water, and the less than boiling temperature may result in clumpy or gummy pasta. The water should remain at boiling temperature through the entire cooking period, and both undercooking and overcooking should be avoided. Undercooked pasta is identified by a white core of stiff, ungelatinized starch in the center, whereas overcooked pasta is mushy and limp in consistency and very bland (Chemist's Corner 16-3).

Al dente "To the tooth" in Italian; refers to pasta that is tender, yet firm enough to offer some resistance to the teeth.

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FIGURE 16-13 Preparing pasta.



1 In a large, heavy pot, bring 4 quarts of water for each pound of pasta to a full rolling boil. Add salt to taste.



2 For long pasta, add to boiling water in batches, pushing batch down as pasta softens; this avoids breaking. Short pasta can be added all at once.



3 Stir, carefully separating pasta pieces. Cover, return to boil, and then immediately remove lid. Stir gently while cooking to prevent pieces from sticking together.



4 Cook pasta until tender but slightly firm (al dente). Taste to test doneness. Drain pasta, but do not rinse because starchy surface holds sauce better.

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CHEMIST'S CORNER 16-3

Cloudy Pasta Water

Cooking water becomes cloudy as pasta cooks because some of the pasta's starch leaks out into the water. Sauce prepared using this starch-enriched water "sticks" better to the pasta. The "gummy" nature of starch is responsible for the improved adhesion of the sauce (53).

Water with an alkaline pH tends to cause stickiness (39). Adding about a tablespoon of vegetable oil to the water may prevent the pasta pieces from sticking together, but it can contribute to an oil-surfaced pasta causing sauces to slide off or preventing flavor penetration. Pasta may be rinsed with water after cooking to prevent sticking, but this may remove any B vitamins added during enrichment that have not already been lost in the cooking water.

Stickiness is influenced by the amount of water on the pasta's surface, the degree of force used to press the pasta through the disc, and, most importantly, the age of the pasta. Using older pasta is not recommended because water is lost from the surface of pasta as it ages, causing a simultaneous loss in lubrication and increased stickiness (51).

For most regular pasta, cooking time is approximately 10 minutes, but fresh pasta and Asian noodles can take as little as 3 minutes. If cooked pasta needs to be held before serving, it is placed in a colander over a pot of hot, steaming water, or it can be cooled and later briefly dropped in simmering water to be reheated, and then drained and served. Pasta should be slightly undercooked if it is to be stir-fried, baked, or added to soup, stews, or casseroles. Figure 16-14 shows the amount of pasta to use for a 1-cup serving.

Microwaving

Like grains, pasta can be prepared in a microwave oven, but again, there is no significant savings in time as compared to the conventional method. Follow the manufacturer's instructions for the recommended amounts of water and pasta and the required heating times. The pasta is stirred into very hot water, covered with a casserole lid or plastic wrap, and heated for the recommended amount of time. It should be stirred halfway through the cooking period, drained immediately when done, and served. Many microwavable single-serve pasta entrees are being marketed.

STORAGE OF PASTA

The storage of pasta depends on whether it is dried, fresh, or cooked. Dried pasta should be tightly wrapped and stored in a cool, dry place.

NUTRIENT CONTENT

Pasta is high in **complex carbohydrates** and naturally **low in protein, fat, and cholesterol** unless it is processed with eggs or fat. Pasta, though considered by some consumers to be "fattening," is recognized by health authorities as an excellent low-fat, low-kcalorie source of complex carbohydrates—especially if made from whole wheat. Nevertheless, noodles, which are **pastas made with eggs, have more fat and cholesterol** than pastas without egg, and sauces made from butter, oil, cream, or meat will also add kcalories and fat. When pastas are stuffed with cheese or meat, as in tortellini and ravioli, the fat and kcalorie content soars even higher.

Traditional ramen, the Japanese noodle sold as an **instant noodle** or soup dish, is made from wheat noodles that have been **deep-fried** in highly saturated lard or palm oil and then dried, although lower-fat varieties are also available. Canned chow mein noodles have been fried in oil or fat and are high in kcalories—each cup contains about 240 kcalories and 14 grams of fat (39).

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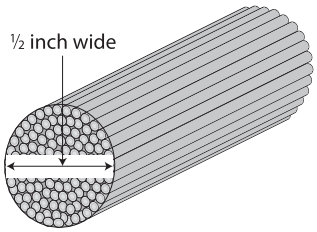
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FIGURE 16-14 How much dried pasta to cook for a 1-cup serving.



Short pasta (penne, shells, rigatoni): Use 2 ounces uncooked, or just over ½ cup.



Long pasta (spaghetti, linguine, fettuccine): Use 2 ounces uncooked, or a bunch that is ½ inch in diameter.

Fresh pasta should be kept in the refrigerator until the "use by" date. It will be at its best for about a week and will keep in the freezer for about a month. Fresh pasta stored in modified-atmosphere packages may last up to 120 days, but there is an increased risk of microbial contamination because of the long storage time (21). The additional ingredients often found in fresh Asian noodles reduce their keeping time in the refrigerator to 2 days. Cooked pasta will keep for 2 to 3 days in the refrigerator and is easily reheated in the microwave oven under vented plastic wrap or by placing it in a pot of boiling water for half a minute.

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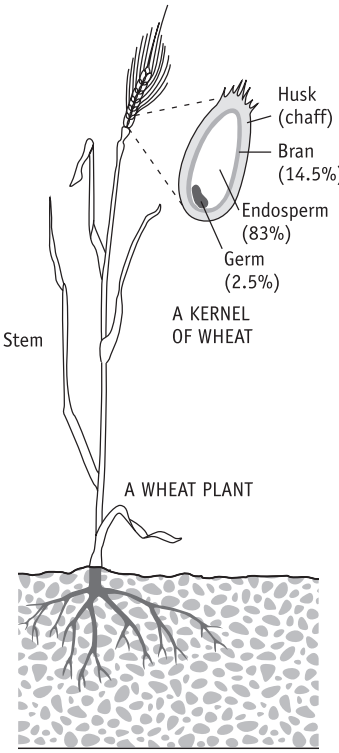
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PICTORIAL SUMMARY / 16: Cereal Grains and Pastas

Cereal grains are seeds from the grass family. Serving as the world's major food crop, they have long been regarded as "the staff of life."

COMPOSITION OF CEREAL GRAINS



Nutrition (½ cup of cooked cereal, grain, or pasta)

Kilocalories: 80

Carbohydrates: 15 grams

Protein: 3 grams

Fat: Trace

Vitamins/minerals: Low levels

Grains are incomplete proteins because they lack the essential amino acid lysine. The following are the most important grains:

- Wheat
- Rice
- Corn
- Oats
- Barley
- Millet
- Sorghum
- Rye

USES OF CEREAL GRAINS

Most cereal grains are used for the following:

- Flour
- Pasta
- Breakfast cereals
- Alcoholic beverages
- Animal feeds



TYPES OF CEREAL GRAINS

Wheat: Available as wheat berries, cracked and rolled wheat, bulgur, farina, wheat germ, and wheat bran.

Rice: Available as white, converted, instant, brown, black, red, glutinous, specialty, bran, and wild.

Corn: Can be classified according to its kernel type: dent, sweet, flint, popcorn, flour, and pod. Can be consumed as corn on the cob or kernel corn, hominy, corn or hominy grits, cornmeal, cornstarch, corn syrup, and corn oil.

Barley: Primarily used for the manufacture of beer and whiskey and for livestock feed.

Sorghum: Major cereal grain in Africa and parts of Asia.

Oats: Available as groats, steel-cut, rolled, and bran.

Rye: Second only to wheat for bread making.

PREPARATION OF CEREAL GRAINS

Heating dried cereals in water softens and gelatinizes their starch, creates an edible texture, and improves flavor. Gelatinization occurs when the starch molecules absorb water and expand. Although rice is the most commonly prepared grain in the world, all grains can be cooked in a similar manner, with just slight variations in the amount of water and length of heating. Cooking time decreases with any reduction in particle size due to cracking, rolling, cutting, or flaking.

STORAGE OF CEREAL GRAINS

Grains are best kept in airtight containers in a cool, dry area free from rodents, insects, and other pests. Whole grains should be refrigerated to retard the rancidity that can occur because of their fat content. It is important to keep grains from becoming damp and subject to mold growth. Cooked whole grains can be refrigerated or frozen for future use.

PASTAS



More than 600 pasta shapes are produced, although only about 150 are available in North America. The higher protein content of durum wheat flour, also called "semolina," makes it best suited for pasta production. Nutritionally, pasta is an excellent source of complex carbohydrates. Although it is naturally low in fat, the fat and kcalorie count go up when it is served with sauces made from butter, oil, cream, and/or meat.

Various pastas available:

Noodles: Eggs are added (at least 5.5% egg by weight).

Asian noodles: These rarely contain eggs and are often made from flours other than semolina.

Whole wheat: Made from whole-wheat flour.

Flavored: Vegetable purées are added for flavor and color.

High protein: Soy flour, wheat germ, or dairy products are added; contain 20 to 100% more protein than regular pastas.

Fresh: Has a higher moisture content and faster cooking time.

Couscous: Made from semolina that has been cooked, dried, and pulverized. Popular in Africa and the Middle East.

PREPARATION OF PASTA

Pasta is best prepared by boiling it in plenty of water and avoiding both undercooking and overcooking.



STORAGE OF PASTA

Dried pasta should be stored in an airtight container and placed in a cool dry place.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. What portion of the kernel contains most of the vitamin E in grains?
   a. Husk
   b. Germ
   c. Endosperm
   d. Bran

2. The endosperm of grains is primarily made of: _____
   a. starch.
   b. protein.
   c. lipid.
   d. vitamins.

3. Which type of wheat is typically used to make the Lebanese dish called tabouleh?
   a. Rolled wheat
   b. Whole wheat berries
   c. Bulgur wheat
   d. Farina

4. Refined grains have four vitamins and one mineral added back to them after processing. What is the name for this process?
   a. Rolling
   b. Fortification
   c. Enrichment
   d. Regulating

5. After wheat, the second-most common grain used in bread making is: _____
   a. corn (cornmeal).
   b. oats.
   c. crye.
   d. sorghum.

6. Malt is made from germinated (sprouted) _____, so it is a source of gluten.
   a. wheat
   b. oat
   c. crye
   d. barley

7. Which type of wheat is best for producing cake flour?
   a. Soft
   b. Hard
   c. Red
   d. White

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Diagram the four parts of a grain's structure.
2. What are the six different shapes that grains can be made into when producing ready-to-eat cereals?
3. Briefly define *cracked wheat, bulgur, farina, converted rice, glutinous rice, dent corn, hominy, cornstarch, cornmeal, pearled barley, malt, millet, sorghum, rolled oats*, and *amaranth*.
4. How is rice consistency affected by its starch content and size (short-, medium-, and long-grain rice)?
5. Briefly describe the basic steps for boiling/simmering grains.
6. Describe the recommended storage conditions for grains. What factor causes the greatest deterioration of grains during storage?
7. Pasta, meaning "paste" in Italian, is made from what two primary ingredients? Describe the following types of pasta, including how their ingredients or shapes differ from one another: macaroni, noodles, Asian noodles, flavored, fanciful, fresh, and couscous.
8. Describe how ramen is prepared and its nutrient content.
9. Briefly describe the moist-heat preparation process for pasta.
10. Define *al dente*.

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17



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Flours and Flour Mixtures

Flours 347

Flour Mixture Ingredients 356

Preparation of Baked Goods 365

Storage of Flour and Flour Mixtures 366

Flour is a fine powder usually made by grinding the endosperm portion of cereal grains (seeds). The most common source of flour is wheat, but any cereal grain can provide flour—oats, rye, barley, rice, corn, and others. Flour can also be made from noncereal sources such as soybeans, potatoes, cattails, taro, arrowroot, nuts, some fruits and vegetables, and other starchy foods.

The flours from these cereal and noncereal foods were not available for over 99% of the time humans have been on earth because humans were primarily hunter-gatherers. Only within the last 1% of that time has the shift to domesticating plants and animals occurred (67). About 10,000 years ago, humans are believed to have started eating a crude form of bread—a baked mixture of flour and water.

Since that time when humans first discovered how to crush grains for their starchy insides and mix them with other ingredients to provide more palatable nourishment, there have been huge increases in the number and variety of baked goods. These range from basic staples, such as **yeast breads** and **quick breads**, to desserts such as cakes, cookies, and pastries. Flours from both wheat and nonwheat sources are also important for preparing many thickened gravies, sauces, puddings, and soups.

Baked products differ tremendously in their outward appearance and taste, but the foundation of them all is a flour mixture. The simplest flour mixture is one made from flour and water. Ingredients such as milk, fat, eggs, sugar, salt, flavoring, and leavening agents may be added. Commercial manufacturers of baked products may also add certain additives. The ingredients of a flour mixture may be divided into two categories: (1) dry—flour, leavening agents, sugar, and salt/flavoring; and (2) liquid—water, milk, fat, and eggs. The types and proportions of these ingredients determine the structure, volume, taste, texture, appearance, and nutrient value of the finished baked product.

Yeast bread Bread made with yeast, which produces carbon dioxide gas through the process of fermentation, causing the bread to rise.

Quick bread Bread leavened with air, steam, and/or carbon dioxide from baking soda or baking powder.

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Chapter 5 described how to measure and combine (using various mixing methods) the ingredients of a flour mixture. The purpose of this chapter is to review the structural components of flour (starch and protein), the milling process, the flours produced from milling, the basic ingredients of flour mixtures, the differences between doughs and batters formed during preparation, and the storage guidelines for flour mixtures.

FLOURS

Flours provide structure, texture, and flavor to baked products through their various ingredients, especially starch and protein.

Starch

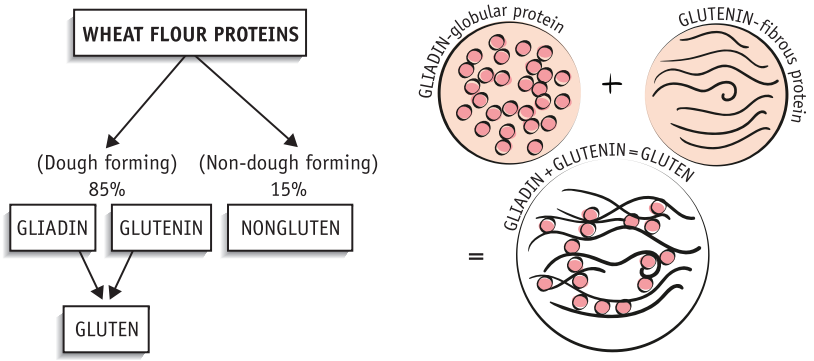
Starch is one of the compounds in flour that strengthens the baked item through gelatinization and one of the factors that contributes to **crumb** (Figure 17-1). Crumb is partially created during baking by the number and size of air cells produced, the degree of starch gelatinization, and the amount of protein coagulation (56). A fine crumb is delicate, with small, densely packed air bubbles, whereas a coarse crumb has large, often irregular air holes. A secondary function of the starch in flour is that it can be partially broken down by enzymes (amylases) into dextrin, malt, and glucose. These compounds add a slight sensation of sweetness, darken the crust color, and improve fermentation, making the mixture lighter in texture. The heat of baking, in the presence of moisture from vaporization, causes the dextrins to coat the crust with a shiny layer (56).

FIGURE 17-1 Flour from grains is the starting point of all baked products.



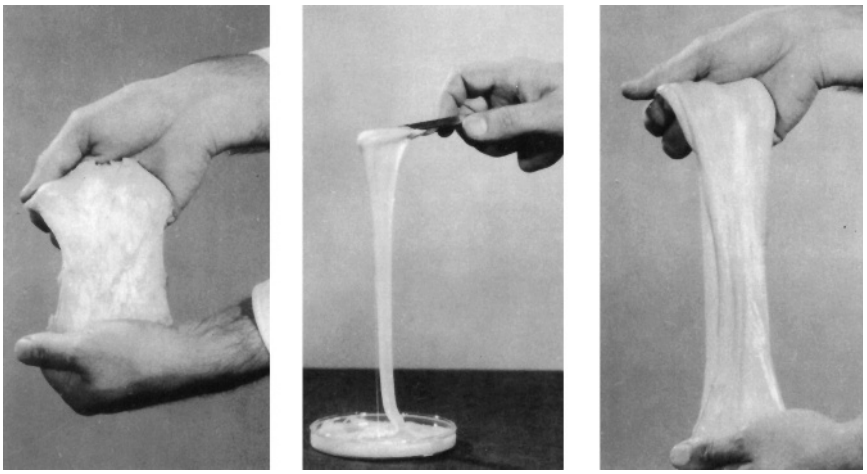
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FIGURE 17-2 Gluten is formed from the combination of two wheat flour proteins: gliadin and glutenin.



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FIGURE 17-3 Glutenin's elasticity (*left*), plus gliadin's fluidity and stickiness (*center*), combine to form gluten's consistency (*right*), which is ideal for preparing baked products.



Baker's Digest

Gluten

Other components in flour that play an important role in the structure of bakery items are the proteins that form gluten. These proteins, as well as those from eggs, contribute to the firming of the flour mixture, whereas sugar and fat act as tenderizing agents. The ability of a baked product to rise is directly related to its protein content (10). Because wheat flour has the highest concentration of the proteins that form gluten, it yields baked products with light, airy textures and is, therefore, most often preferred over other flours for baking.

Purpose of Gluten

Gases Are Trapped

When flour is mixed with water, an elastic network forms as two types of proteins in flour—gliadin and glutenin—combine to yield the protein complex gluten (Figure 17-2). Gluten is both elastic and plastic. Its ability to expand with the inner pressure of gases such as air, steam, and carbon dioxide results from the combination of glutenin's elasticity and gliadin's fluidity and stickiness (41) (Figure 17-3).

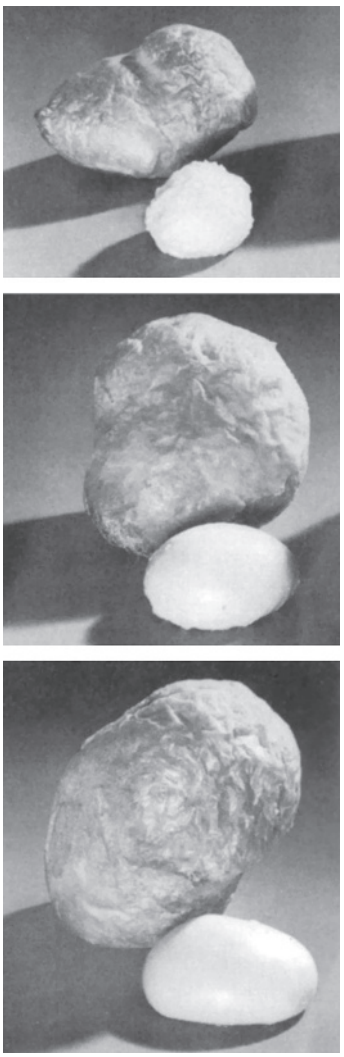
Crumb The cell structure within the interior of a baked product that is revealed when it is sliced and that affects texture. Evaluation is based on cell size (called *open*, if medium to large, or *closed*, if small), cell shape, and cell thickness (thin walls occur in fine crumb, whereas thick walls predominate in a coarse crumb).

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FIGURE 17-4 The proportion of gluten derived from cake, all-purpose, and bread doughs. The ball in front is the gluten carefully extracted by running the dough through cold water to remove the starch. It was then baked to reveal the ball in back.



Baker's Digest

Yeast A single-celled fungus (a plant that lacks chlorophyll) that is able to ferment sugars and that is used for producing food products such as bread and alcohol.

Knead To work dough into an elastic mass by pushing, stretching, and folding it.

Gases Rise

Bread dough rises as the gas resulting from the **yeast** or other leaveners, as well as the air bubbles entrapped in small pockets by **kneading,** expands and stretches the gluten strands upward and outward. Then, as the temperature rises during baking, steam, along with the expanding gases carbon dioxide and ethanol cause the gluten to expand further.

Bake Product Sets

The baked product's structure sets when the heat from baking coagulates the proteins and gelatinizes the starch. If the oven door is opened frequently or if baking is stopped prematurely before these processes can occur and set the structure, the steam may be released from the gluten complex, causing the baked product to partially collapse.

Tender Textures

In cakes and pastries, gluten formation is not desired because it will result in a tough texture. Lower-protein flours are used and/or gluten formation is partially controlled by adding more water and creating a lower-viscosity batter (21).

Separating Gluten from Flour

Gluten forms such a solid structure that it can be physically separated from the flour mixture by kneading a handful of dough under cold running water (69). This washes away the water-soluble proteins and frees the starch, which is lost down the drain, leaving a rubbery gluten mass (Figure 17-4).

Steps to Gluten Formation

The main purpose of combining the ingredients of a flour mixture prior to baking is to encourage the development of the gluten, which will contribute to the baked product's structural strength. The two major steps of gluten formation are hydrating the flour mixture and kneading the dough.

Hydration

Wetting the flour proteins is the first step in gluten formation. Gliadin and glutenin form gluten, whereas the remainder of the flour proteins, consisting largely of albumin and globulin, become part of the dough or batter (40) (Chemist's Corner 17-1). The greater the protein content in the flour, the more water will be absorbed, in part because gliadin and glutenin absorb about twice their weight in water. The water helps draw out the gluten-forming proteins from the crushed endosperm cells, and most doughs are 40% water by weight. Once hydrated, the two proteins start to form gluten's complex, intertwined network, whose inner spaces are filled with water.

How & Why?

How is gluten formed?

Gluten is not present in dry, unprocessed flour. It is formed when the addition of water causes the proteins glutenin and gliadin to combine, forming a strong, stretchy protein (36). Fats such as oil and egg yolks coat individual gluten molecules, preventing them from forming large, interconnected proteins. Sugar prevents gluten production by binding to water, preventing it from interacting with glutenin and gliadin to form the gluten protein (41).

Kneading

More kneading is required to make breads, as compared to biscuits and pastries. The physical manipulation of the flour mixture alternately compresses and stretches the dough to increase gluten development. Kneading also evenly distributes the yeasts to all their sources of food throughout the dough mass, redistributes the air bubbles, and warms the dough, increasing fermentation and carbon dioxide gas production. During kneading, the dough changes from a sticky mass to a smooth, stretchable consistency that is easily molded, yet springs back to light pressure (Figure 17-6). The "net" formed by the gluten stretches as the gases, air, steam, and carbon dioxide rise, but its elastic properties hold the general shape of the baked product.

The lipids in flour also contribute to gluten development during kneading, although their exact role is unknown. Lipids make up only about 1 to 1.5% of flour by weight, but without them, the dough will not rise. It has been suggested that lipids serve as an inner core surrounded by gluten and water

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CHEMIST'S CORNER 17-1

Classifying Plant Proteins

Proteins are divided into three types: simple, conjugated, and derived (58). Plant proteins fall into the simple protein category and are classified according to the Osborne system, which identifies proteins based on their solubility (ability to dissolve) in different solvents (Figure 17-5). The four major classification groups are albumin, globulins, prolamins, and glutelins. The albumin fraction generally consists of enzymes. Common enzymes in flour include proteolytic enzymes; oxidative enzymes, which help bleach the flour; and phytase, which breaks down phytic acid (52). Prolamins and glutelins are the major storage proteins in most cereal grains (63). Prolamins are alcohol soluble, have a high concentration of proline, and lack the essential amino acid lysine (1). The main prolamin fractions for wheat and corn are gliadin and zein, respectively (16). Glutenins are alcohol insoluble and classified as glutelins (58).

FIGURE 17-5 The Osborne classification of plant proteins is based on their solubility in different solvents.

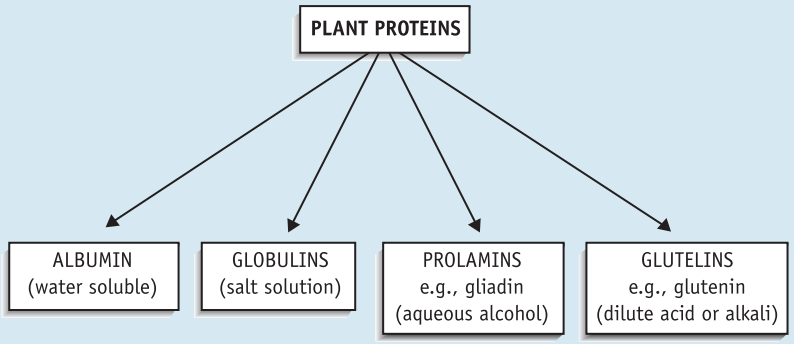


FIGURE 17-6 Dough is developed by kneading.

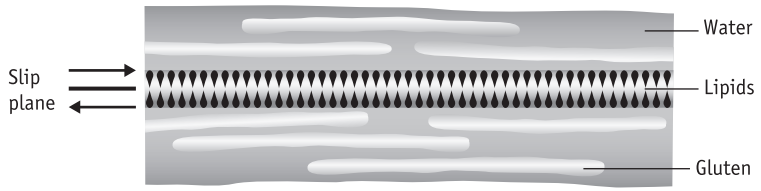


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(Figure 17-7). It has also been postulated that certain lipids link with flour proteins and gelatinized starch (41).

When kneading dough, it is important to avoid excess kneading. Too much kneading will break the gluten strands—the disulfide bonds between the gluten strands pull apart—resulting in a sticky, lumpy dough with little elasticity (66). Although it is difficult to overmanipulate a dough manually, it is fairly easy to do so when using a food processor, standing mixer, or food-service dough developer.

FIGURE 17-7 The role of lipids in gluten development. One theory is that the gluten proteins slide more easily past each other in opposite directions between lipid-containing sheets. Ultimately, this contributes to proper dough expansion.



How & Why?

How does kneading change the dough?

At the molecular level, kneading realigns protein molecules so they run roughly in the same direction and are more likely to form the cross-links that make the dough stiffer (Figure 17-8). Sulfur-to-sulfur, or disulfide, bonds also help link the gluten proteins together. Kneading physically breaks the bonds between sulfur atoms, creates new ones, and allows the gluten molecule to stretch out in length (52).

Dried Gluten

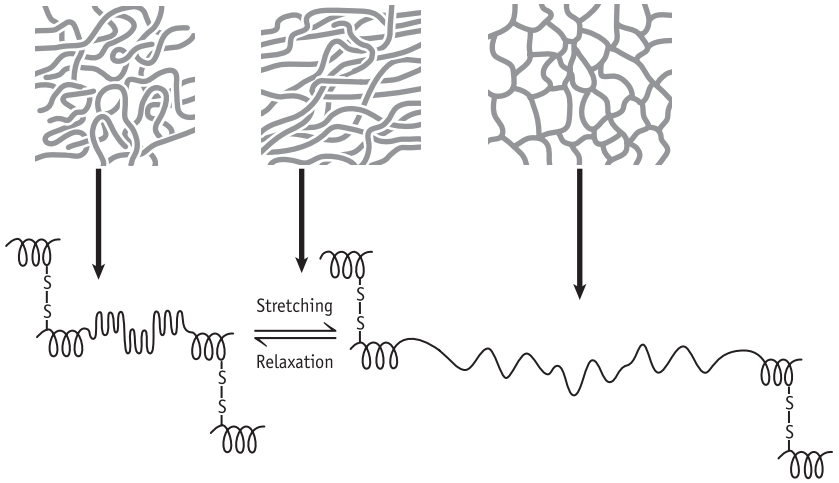
Dried gluten, sold as vital wheat gluten, is often used to increase the protein content of flours, cereals, meat analogs such as textured vegetable protein (TVP), pasta, and other bread products. It can also be used to manufacture simulated meat products for vegetarians. Adding vital wheat gluten to regular meat enhances its ability to be sliced and reduces cooking losses during processing. Increasing the gluten content of a flour will also contribute to improved texture and higher volumes during baking (55). Vital wheat gluten is added to some hamburger and hot dog buns to strengthen their structure so that they may hold heavy condiments and to

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FIGURE 17-8 Kneading realigns protein molecules. The physical pressure of kneading stretches out the gluten molecules cross-linked by sulfide bonds. Sheets of gluten (far right) give dough a smooth, fine texture.



prevent the hot dog buns from breaking at their hinges (39). Gluten improves the adhesion of batter crusts to fried foods, particularly if they are frozen.

Cereal-Grain Food Sensitivities

Four types of food reactions can occur in response to certain cereal exposures: baker's asthma, wheat allergy, celiac disease, and nonceliac gluten-sensitivity (NCGS) (11). The first three types are allergies where the immune system produces a specific type of antibody—immunoglobulin E (IgE)—that causes inflammation; and the cause of NCGS remains to be deciphered.

Baker's Asthma

This results from the inhalation of flour particles.

Wheat Allergy

Although primarily found in children (about 0.2–4%), most outgrow wheat allergies resulting from ingesting wheat that can cause rashes, hives (skin bumps), itching, swelling, breathing difficulties, wheezing, anaphylactic shock, and loss of consciousness (6).

Celiac Disease

Celiac disease is an immune disorder in which the body creates antibodies to gluten, a protein found in wheat, rye, barley, and some other grains. The resulting inflammation damages the surface of the intestinal wall, eventually causing the villi (finger-like projections important for absorption) to become "flattened" in appearance. Symptoms are often not present, but if they are, they can include abdominal bloating and pain, chronic diarrhea or soft stools, fatigue, weight loss, and, in infants, failure to thrive (growth in weight or height does not follow averages for the infant's age). Celiac disease increases the risk for thyroid problems, eye inflammation, cardiomyopathy (damage to the heart muscle), defective tooth enamel, "brain fog," nutrient deficiencies (from chronic malabsorption), osteoporosis, a blistering skin rash (dermatitis herpetiformis), neurological or psychiatric problems (10–25% of people with schizophrenia test positive for anti-gliadin antibodies and may respond positively to a gluten-free diet) (28), and cancers of the small intestine and lymphatic system (8, 37).

Approximately 1% of the U.S. population—about 1 in 142 Americans—has celiac disease, which has been known since the 1950s (6). Most people diagnosed in adulthood are in their 30s, 40s, or 50s, and the majority are female (33). Celiac disease is genetically transmitted but thought to be triggered by environmental factors such as gluten exposure and viral or intestinal infection. Those with type 1 diabetes or other autoimmune disorders and Down syndrome are at greater risk. The only treatment for celiac disease or gluten sensitivity is a gluten-free diet.

Nonceliac Gluten Sensitivity (NCGS)

The largest group of people (approximately 5–7% of the U.S. population) now reacting to cereals containing gluten are those with NCGS (6). Symptoms overlap with celiac disease but without creating antibodies to gluten or damaging the intestinal lining. The only way to diagnose this condition is to have a physician eliminate the possibility of the other three conditions, and then to go on a gluten-free diet for two weeks followed by a challenge that consists of eating a food with gluten such as bread. Although some attribute the gluten-free diet as a fad, it's difficult to imagine many people voluntarily giving up breads, pasta, pizza, pies, cakes, and cookies for life.

What Does "Gluten-Free" Mean?

The Food and Drug Administration (FDA) states that a product containing "less than 20 ppm gluten" may be labeled "gluten-free" (19). The term *gluten-free* also means that the product does not contain wheat, rye, barely, or a cross between these grains; anything derived from these grains that has not been processed to remove gluten; or anything derived from these grains that has been processed for gluten removal but still contains at least 20 ppm gluten. Fresh foods that never naturally contained gluten such as meats, fruits, vegetables, nuts, fats, eggs, and water can also be labeled "gluten-free" (7).

Milling

Milling or grinding is the process in which the grain kernel's endosperm is ground into a fine powder known as "flour." The kernel may first be freed of its bran and germ. Any grain can be milled, but wheat flour dominates the market. Other flours include rye, corn, buckwheat, and triticale flours, as well as flours made from legumes such as soybeans and peanuts.

Originally, a mortar and pestle were used to grind grain into whole-grain flour. This process did not remove any of the various kernel parts (bran, germ, aleurone, and endosperm) (60).

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FIGURE 17-9 Different types of stone mills used for grinding grain.



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The product produced by this technique is called "whole meal" and can be sifted to remove the bran. In Mesopotamia sometime around 800 BC, equipment was developed that used grinding stones moving in circles (Figure 17-9). Eventually, by using flowing water for power, mills became capable of moving one circular stone over another stone that was held stationary.

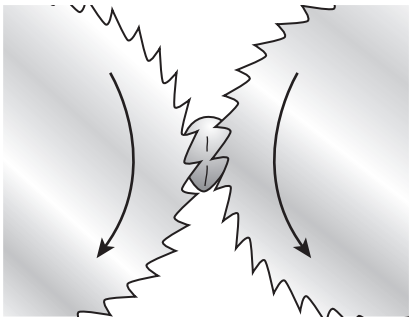
Five Steps of Milling

Modern milling of refined flour consists of five basic steps: breaking, purifying, reducing, sifting, and classifying.

Step 1—Breaking

In breaking, special machinery equipped with break rollers removes the bran and germ layers from the grain's endosperm (Figure 17-10). Each succeeding pair of steel break rollers is set closer together to remove more of the bran and germ. The result is called break flour. Break flour still has some bran attached to the endosperm layer.

FIGURE 17-10 Machine milling. Break rollers are used to separate the grain's endosperm from the bran and germ.



Step 2—Purifying

Next, the flour is moved through containers where blowing air currents remove any remaining bran. The endosperms, thus freed, or purified, from the whole grain and now free of bran, are known as "middlings."

Step 3—Reducing

At the reducing stage, ten to fifteen smooth-surfaced reduction rollers grind the middlings into flour. To prevent the starch granules from being damaged, the spaces between the rollers are progressively reduced.

Step 4—Sifting

The flour is then sifted into **streams,** and this determines how the flour is classified.

Step 5—Classifying

Flour streams range from fine, or first break, to coarse, or clear, and the types of flour obtained from them range from **patent flour** to **straight flour.** Patent flour is divided into long, medium, and short patents depending on how much of the total endosperm was milled. Short patents come from the center of the endosperm, are high in starch, and are best for making pastry flour. Long patents contain more protein from the outer areas of the endosperm and are preferred for the production of bread flours. Clear flour, which is left over from patent flour, is further subdivided into fancy clear, first clear, and second clear. The coarser clear flours are primarily used for all-purpose flour. The quality and grade of the final flour are determined by which streams were combined in its production. The protein content varies according to the origin of the stream and the type of grain used (54).

How & Why?

How is whole-grain flour produced?

The key difference between white, refined flours obtained from the grain's starchy endosperm and "whole grain" flours is that the latter also include the bran and germ. Many whole grains can be milled into flours. Essentially, whole-wheat flour is typically prepared by reconstituting, or blending back together, all the parts of the wheat in their original proportions following purification (the second step in the standard milling process). Some manufacturers, however, simply mill the entire wheat kernel together using grinding stones (refer to Figure 17-9) to yield whole-wheat flour. To obtain 4½ cups of whole-grain wheat flour, a pound of wheat berries is ground. Whole-grain flours are also derived from other grains such as rye, oat, barley, corn, rice, millet, and quinoa, to name a few. These flours and their baked products should be refrigerated because the germ's oil makes them prone to rancidity, shortening shelf life. Another difference is that when whole-wheat flour is used in flour mixtures, the bran's sharp edges slice through gluten strands, reducing the dough's ability to trap the carbon dioxide gas generated by the yeast, resulting in a more dense bread. For these reasons, many "whole grain" flours or baked products actually have some refined, white flour added.

Stream A division of milled flour based on particle size.

Patent flour Flour containing the finest streams produced during milling.

Straight flour Flour containing all the different types of streams produced during milling.

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Wet Milling

Wet milling differs from standard milling because it does not involve any mechanical breaking or grinding (54). The process is called "wet" because grains are soaked in water to soften the seed kernel, making it easier to separate its components. For example, corn kernels are commonly wet milled to produce pure starch and other by-products from corn. In this process, corn kernels are cleaned, steeped (soaked in water for 20 to 30 hours until they double in size), coarsely milled, separated, finely milled, screened, and separated again. The 99.5% pure cornstarch can be further processed into syrups, which can be converted to high-fructose corn syrup produced via enzymatic isomerization of the glucose in corn syrup to fructose. Corn syrups can also be dried to produce corn syrup solids composed of glucose and maltodextrins. Another product that can be derived from corn syrup is crystallized fructose. The starch from corn can also be saccharified to dextrose, which is most commonly fermented to ethanol.

Wheat Flour Classifications

The gluten-forming properties of wheat make it the most commonly milled grain and the major source of flour for bread making (68). The only other flour that comes close to wheat flour in its utility for producing baked goods is rye, but even that has to be mixed with about one-fourth wheat flour.

Wheat flours are classified according to their protein or mineral content. Flours in the United States and the United Kingdom are not standardized, so they are distinguished by the percentage of their protein content. Germany and France use flour type numbers based on the flour's mineral or ash content.

Percent Protein Content

Table 17-1 shows how wheat flours are defined by their percent protein content. Soft wheats have the least protein and highest starch content, making them ideal for the tender, fine crumb of crackers, cakes, and pastries. Hard wheats, with their higher protein content, yield high-protein flours preferred for making yeast bread (10). Durum wheat, with the most protein, is milled into semolina flour, which is used primarily for pasta.

TABLE 17-1 Percent Protein of Various Wheat Flours*

Flour	% Protein
Gluten	41
Whole wheat (hard)	14
Durum wheat (hard)	13
Bread (hard)	11
All-purpose	10
Pastry (soft)	9
Cake (soft)	8

*As protein increases, so does the "hardness" of the flour.

Mineral Content

Ash or mineral content is the portion of the food (or any organic material) that remains after it is burned at very high temperatures (incinerated). The mineral content of the endosperm, which is primarily starch, is much lower than that of the grain's germ or bran. Flours containing more minerals derived from the outer part of the grain will have a higher number. For instance, in Germany, the amount of ash is measured in milligrams of ash per 100 grams of dry flour and will vary from 405 (pastry flour; about 0.4% ash) to 1600 (whole wheat; 1.5% ash). French flour type numbers are lower because they are based on milligrams of ash per 10 grams of dry flour; Type 45 is standard pastry flour, and Type 150 is whole-wheat flour.

Types of Wheat Flour

Despite a percent protein content classification, flours in the United States are identified by their common names. Flours vary based on the specific types of wheat used for their particular qualities, blending of different combinations, and the streams selected during milling. Some of the more common flour types are discussed next.

Whole-Wheat Flour

Whole-wheat flour, also known as graham or entire-wheat flour, is made from the entire wheat kernel, including the bran, germ, and endosperm. One drawback to using whole-wheat flour alone in bread making is that the bran's coarse granules cut the gluten strands, decreasing the final volume of the bread. The flour is finely ground to reduce this effect and is often combined, usually half and half, with white flour for the same reason. A whole-wheat baked item with no added white flour will be dense and heavy. Whole-wheat flour contains fat from the germ, so it requires refrigeration to prevent rancidity.

Whole-Wheat Flour as a Functional Food

According to the Dietary Guidelines for Americans committee, increased intake of whole grains, including whole-wheat flour, may reduce risk of cardiovascular disease and is associated with lower body weight (64). The beneficial effects of whole grains are due in large part to their fiber content. High-fiber diets are associated with lower risk of heart disease, type 2 diabetes, and other diseases (14). The Academy of Nutrition and Dietetics recommends a daily fiber intake of 25 grams for adult women and 38 grams for adult men. However, the average daily intake is estimated at only 17 grams per day (14).

Bread Flour

The higher gluten content of bread flour makes it ideal for making yeast breads and hard rolls that require elastic gluten for multiple rising periods. Most bread flour is a long-patent white flour made primarily from hard winter wheat and milled primarily for commercial purposes, although it's also available in grocery stores.

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White Flour

White flour is made from only the endosperm of wheat grain.

Semolina

Durum wheat has the highest protein content (9 to 18%) of all wheats because it is made from hard winter durum wheat. Grinding the yellow endosperm results in semolina, which is a coarsely ground flour best suited for the manufacture of hard pasta products. Disulfide, hydrogen, and hydrophobic bonds link the proteins in semolina flour, producing the viscoelastic properties of pasta (21). This cohesiveness is desirable in pasta because it prevents the dough from breaking apart during boiling. Asian noodles are made from nondurum wheat flour (48).

Couscous is another product consisting of steamed balls of semolina popular in the Mediterranean Basin (but it can also be made from bread wheat, sorghum, pearl millet, and maize) (48). Semolina pudding and other desserts can be prepared by simply adding milk, sugar, nuts, and fruits.

Durum Flour

Further grinding of semolina flour results in the finer ground durum flour that is primarily used for bread production in the Near East, Middle East, Italy, and other parts of the world (48).

All-Purpose Flour

All-purpose flour (family-type flour) is the most widely used flour in North America. It contains less protein (averages 10%) than bread flours (11%+ protein) that need strong gluten development. Blending hard and soft wheat flours yields a flour that can be used for all purposes—breads, cakes, or pastry. Despite what appears as a uniform product, the actual protein content of all-purpose flour may differ from region to region and by brand. Regional preferences have influenced manufacturers to incorporate more protein in flour sold in the northern United States, where yeast breads are more popular, as compared to the South, where biscuits requiring a softer flour are more routinely consumed.

Pastry Flour

Also called "cookie flour" or "cracker flour," cream-colored pastry flour is derived from soft wheat with short to medium patents. Its lower protein content of about 9% is preferred by commercial and professional bakers for preparing pastries, some cookies, sweet yeast doughs, biscuits, and muffins. Some people substitute a combination of all-purpose and cake flours for pastry flour.

Cake Flour

This flour used to make cakes is pure white and has a very fine, silky, soft texture. The higher gluten content of regular flour would make cakes tough, so soft, extra-short patent wheat flours are used to make cake flour. Its lower protein content of only 8% and small particle size as compared to all-purpose flour result in less gluten being formed, which gives cakes a fine grain, a delicate structure, and a velvety texture. Cake flour is treated with chlorine gas, which lowers the pH from about 6.0 to 5.0, bleaches the plant pigments, and improves baking quality (60). All-purpose flour can be used to make cakes, but they may have a slightly coarser texture and lower volume (62). Cake flour has the same amount of protein as pastry flour but more starch.

Graham Flour

Graham crackers were originally made with whole-wheat graham flour that was produced by combining a finely ground endosperm with a coarsely ground germ and bran. Most graham crackers today are imitations because they are made from regular wheat flour.

Ancient Grain Flours

The ancient wheat grains of einkorn, emmer, Kamut®, and spelt can all be milled to yield their respective flours (see Chapter 16, Cereal Grains and Pastas).

High-Gluten Flour

The terms *high-gluten flour, vital wheat gluten,* and *seitan* are often used interchangeably, yet they really represent three different products. All three contain wheat proteins that can form gluten. Two factors to consider when using gluten products are that (1) all gluten products need to be refrigerated or frozen because they contain natural fats that can become rancid, and (2) gluten causes digestive problems for people who have celiac disease or gluten sensitivity. The extensive use of vital wheat gluten in foods produced by the food industry is thought to be one of the many possible factors contributing to the increased incidence of gluten sensitivity (8).

How & Why?

How do high-gluten flour, vital wheat gluten, and seitan differ?

High-Gluten Flour. Vital wheat gluten is added to all-purpose or whole-wheat flour to create high-gluten flour. This higher-protein flour yields a chewier texture preferred for bagels, pizza crust, artisan breads, and whole-grain loaves and rolls. High-gluten flour is also called *bread machine flour* because a higher-protein dough will rise better in the machine than a lower-protein dough.

Vital Wheat Gluten. This is, in fact, powdered gluten and not "flour." Vital wheat gluten is extracted by kneading a dough (made from high-gluten or regular flour) and washing away the starch repeatedly with water until only a thick, spongy gluten mass remains. After this dries and is powdered, it can be sold under other names, including *gluten flour, instant gluten flour,* and *pure gluten flour.* It is an excellent source of plant protein because it contains 96 grams per cup. This highly concentrated protein source is an additive for regular flour and other foods. A small amount of vital wheat gluten may be used in combination with flours: 1 to 2 teaspoons for every 1 cup of white flour, or 1½ to 3 teaspoons for each cup of whole-grain flour (helps heavy breads rise). It also works as a binding agent to hold the ingredients in foods (e.g., vegetarian burgers) together. When

(Continued)

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vital wheat gluten is added to bread dough, more water is also required (about 1 tablespoon for each cup of flour) because the extra protein binds with water; this contributes to a more moist bread, making it appear more fresh to the consumer.

Seitan (say-tan). Also called "wheat meat," "mock duck," or "gluten meat," this food product is thought to have originated in China as a meat substitute for vegetarian Buddhist monks. Seitan is made by combining vital wheat gluten powder with flavoring agents (spices, vegetable powder, and/or tamari) and a liquid (water or broth) to make a dough. The springy, textured dough is then kneaded and cut it into cutlets, cubes that resemble tofu, balls, or any variety of shapes, including pieces of chicken, beef, pork, or duck. It is then cooked (boiled, baked, fried, or steamed) to a chewy, meat-like texture that absorbs the flavors used in its preparation. This is important because seitan is flavorless by itself. In Japanese tradition, seitan is prepared slightly differently by being baked into what looks like toasted and dried bread or croutons; the latter are often added to soups, especially miso soup. Ready-made seitan is sold in cans, jars, or plastic pouches.

TABLE 17-2 Types of Flour

Gluten-Containing Flours		Gluten-Free Flours	
Wheat	***Treated wheat***	***Grain or pseudo grains (nongrasses)***	***Vegetable***
Whole-wheat	Aged	Amaranth	Potato
Bread	Bleached	Buckwheat	
White	Phosphated	Corn	***Legume***
Durum (semolina)	Self-rising	Cornmeal	Garbanzo
All-purpose	Instant	Millet	Soybean
Pastry	Enriched	Montina®	
Cake		Quinoa	***Nut***
Graham	***Nonwheat grain***	Rice	Almond
Einkorn	Barley	Sorghum	Coconut (fruit)
Emmer (Farro)	Oat*	Teff	Walnut
Kamut®	Rye		
Spelt	Triticale		
High-gluten			

*Whether oats are gluten-free depends on the variety of oat and whether it has been contaminated during processing (e.g., in a facility that also processes wheat).

Types of Nonwheat Grain Flours Containing Gluten

Although most baked products are made primarily of flour from wheat, flour may be obtained from other sources such as nonwheat grains, roots, tubers, legumes (peas, beans, or lentils), or even certain nuts (Table 17-2). This discussion begins with grain flours that contain gluten and then continues with gluten-free flours derived from gluten-free grains and other plants.

Rye Flour

The lower gluten potential of rye flour contributes to a very compact bread such as pumpernickel. In addition, rye flour contains a high concentration of water-soluble carbohydrates called "pentosans," which give the flour a high water-binding capacity (9). As a result, the gases in rye bread do not expand very well (52). Wheat flours are often added to rye flour in a 1:4 ratio to create a more porous, lighter bread. The pentosans also are responsible for the characteristic stickiness of rye bread.

Triticale Flour

Triticale is a hybrid of wheat and rye grains. Its flour is best used in a 1:3 ratio with white flour for optimal bread production.

Types of Gluten-Free Grain Flours

Amaranth

Amaranth is a grain that is high in protein and fiber and has a nut-like flavor. In baked goods, it is usually combined with other types of flours (7).

Buckwheat Flour

Buckwheat flour is rich in starch and provides some proteins, antioxidants, minerals, and fiber (26). It is used primarily in pancake and waffle mixes as well as in crepes and blinis. Buckwheat flour is a popular wheat substitute in Europe, where it is used in breakfast cereals and breads (7). Buckwheat has a higher fiber content than regular wheat and better protein quality due to its high lysine content (44).

Cornmeal Flour

Cornmeal flour is made from yellow, white, and even blue varieties of corn. Several grinds from coarse to fine are available. The medium grain is polenta, and the fine grain is cornmeal. Corn contains no gluten, and its chief protein is zein, which is incapable of mimicking the elastic or plastic properties of flours with higher gluten-forming potential (5). As a result, cornbread and corn muffins do not rise well and are prone to a crumbly texture. The common solution is to add some all-purpose flour. Masa harina (Spanish for dough flour) is the traditional, finely ground cornmeal flour made from corn that was presoaked in lime or lye. It is primarily used to make corn tortillas, tamales, and other Mexican dishes.

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How & Why?

Why is folic acid now voluntarily added to masa flour?

Latina women in the United States have the highest rate of giving birth to babies with neural tube defects (NTDs) according to the Centers for Disease Control and Prevention (CDC). NTDs are birth defects to the brain, spine and spinal cord such as anencephaly (no brain) and spina bifida (incomplete development of the spinal cord). Adding folic acid to a staple food for many Latina women may reduce the risk of these birth defects (18).

Rice Flour

Naturally gluten-free rice flour is popular in Asian cultures, where it is used to make a variety of food products, including rice noodles. It can also be used as a wheat substitute in baked goods (7).

Sorghum Flour

Sorghum has a strong flavor, and is used in small doses in baked goods (7).

Gluten-Free Flour

Any number of combinations of various gluten-free flours can be combined to create a gluten-free flour, but a common combination is rice flour (white and/or brown), potato starch, and tapioca flour. A gum (usually xanthum) may be added to prevent crumbliness.

Types of Nongrain, Gluten-Free Flours

Tuber-Based: Potato Flour

Cooked potatoes that have been dried and ground yield potato flour. The starch in potato flour increases loaf volume, which is why the liquid left over from cooked potatoes is sometimes used in homemade breads. Potato flour can be combined with other nongluten flours to increase moisture content (7).

Legume-Based

Garbanzo Flour (Gram Flour or Besan)

Common in India and Italy, this flour is produced from the garbanzo (chickpea) legume.

Soy Flour

Soy flour is higher in protein and fat than other flours because its source, the soybean, is a legume. Defatted versions are available. The pale yellow flour tends to have a "beany" flavor, but it does add moisture and texture to the baked product. It contains more of the amino acid lysine than wheat and is sometimes added to wheat flour to improve its protein profile, texture, crumb, crust color, and machinability (57). Soybean flour is gluten-free, so it must be combined with wheat flour when used in baking.

Nut-Based

Almond Meal Flour

Whole almonds can be ground to a fine powder to make almond flour. It is most often used to make cookies, cakes, and desserts, and it must be stored in the freezer (7).

Coconut Flour

Coconut (botanically a fruit) can be used to create a flour with a slightly sweet taste. It is high in fiber and contains more moisture than most nongluten flours (7).

Treated Wheat Flours

Wheat flours can be treated to improve their functional properties, resulting in aged, bleached, phosphated, self-rising, instant or agglomerated, or enriched flours. Many of these are used in the production of baked products.

Aged Flour

Freshly milled flour is not white, and the resulting baked products are of poor quality. Historically, this problem was corrected by storing the flour for several months so it could age and become naturally bleached by the oxygen in the air. Natural aging is expensive, however, because of the required storage space, increased labor costs, and the risk of pest infestation.

Bleached Flour

Unbleached flour has a yellow-brown color from the xanthophyll pigments found in the endosperm, and bleaching oxidizes these components resulting in a whiter color (13). These carotenoid pigments range in color from yellow to red. Because they are fat soluble, a lipophilic bleach is required to remove them from flour. The most commonly used agents are gases (including nitrogen oxides, chlorine dioxide, and chlorine) and benzoyl peroxide, which is also used for treating acne and whitening teeth.

Chlorine gas was used as early as 1912 and is still used to bleach all-purpose flour and in cake mixes. Nitrogen tetroxide is one of the oldest successful bleaching agents and is also still in use. Benzoyl peroxide is the most commonly used agent in the United States and is a fine white powder added to flour at very low concentrations (parts per million).

Flours whitened by this method are labeled "bleached." The bleaching agents evaporate and do not leave residues or alter the nutrient value of the flour. Cake flour is always bleached with chlorine gas, which not only whitens the color but also creates a very tender, fluffy baked product. All-purpose flours may or may not be bleached. Semolina flour is never bleached because its yellow hue contributes to the color of pasta (4).

Artificial bleaching not only oxidizes the flour's carotenoid pigments, lightening its color, but also improves the flour's functionality. The oxidation that occurs during bleaching increases the number of disulfide bonds between the protein chains, improving the strength and elasticity of the gluten (24). Oxidizing agents improve the volume, texture, and crumb structure of baked products (51).

Phosphated Flour

Flour may be leavened by baking soda instead of baking powder if an acid, specifically monocalcium phosphate (no more than 0.75%), has been added. Flour thus phosphated also has the advantage of increased calcium content, with 68 to 165 mg of calcium versus 18 mg per sifted cup of unphosphated flour (15).

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Self-Rising Flour

Self-rising flour is all-purpose flour with the leavening agent and salt already added. The leavening agent in self-rising flour is a baking powder (baking soda combined with a salt, monocalcium phosphate), which also contributes a significant amount of dietary calcium. One cup of self-rising flour contains about 1½ teaspoons baking powder and ½ teaspoon salt. These amounts should be added to all-purpose flour when it is substituted for self-rising flour.

Instant or Agglomerated Flour

Instant flour mixes easily with water, readily gelatinizing without lumps, which makes it ideal for powdered soups, sauces, and gravies. This kind of flour may create a coarse texture in baked products, so it is not recommended for that use. Instant flour is created by passing flour through jets of steam, which wet it and allow it to stick together, or agglomerate, in very small particles. Heated chambers dry the uniformly sized particles so they flow freely and do not need to be sifted. When using it in recipes, 1 cup of all-purpose flour equals 1 cup minus 2 tablespoons of instant flour.

Enriched Flour

Enriched flour is white flour to which the B vitamins thiamine (B_1), riboflavin (B_2), niacin, and folate, as well as the mineral iron, have been added in order to reach levels established by federal standards. Calcium is an optional enrichment nutrient. Fiber and other nutrients, such as vitamin E, that are lost with the removal of the bran and germ are not replaced (17).

FLOUR MIXTURE INGREDIENTS

As detailed in this section, flour mixture ingredients may include leavening agents, sugar, salt, liquid, fat, eggs, and, in some cases, commercial additives.

Leavening Agents

Leaveners form gases that cause flour mixtures to rise. During baking, the heat further expands these gases, contributing to the baked good's structure as the starch gelatinizes and the proteins coagulate. Leaveners may be physical, biological, or chemical:

- **Physical leaveners:** Air and steam
- **Biological leaveners:** Yeast and bacteria
- **Chemical leaveners:** Baking powder and baking soda

Although flour mixtures can rise with the physical help of air and steam, most of the leavening is accomplished by carbon dioxide gas produced from either biological or chemical sources (27). The major biological sources of carbon dioxide are yeasts. Chemical leaveners, such as **baking soda** and **baking powder**, yield carbon dioxide when an alkali reacts with an acid in the presence of a liquid. In order to do its job, baking soda must have an acidic ingredient added to the flour mixture, whereas baking powder has already had the acid incorporated. Acid is often added in the form of ingredients such as buttermilk (lactic acid), sour cream, chocolate, brown sugar (contains molasses), or molasses (aconitic acid).

The type of food is the primary determinant of what type of leavening agent will be used. Yeast breads are usually leavened with biological agents such as yeast. Quick breads, as well as cakes, cookies, and pastries, are leavened physically with air or steam, or chemically with carbon dioxide generated by baking soda and/or baking powder. Regardless of the source, leavening changes the baked product's volume, crumb, texture, and, ultimately, its flavor (Figure 17-11).

Air and Steam

Air and steam are physical agents that help dough to rise. Air is incorporated into almost all flour mixtures during mixing, during the creaming of fat and sugar, by sifting dry ingredients, or by using whipped egg whites (Figure 17-12). Water incorporated into flour mixtures produces steam when heated, expanding to 1,600 times its original volume. Steam, either from liquid or from other ingredients such as egg whites, is the primary leavening agent for piecrusts, pastry, cream puffs, and popovers.

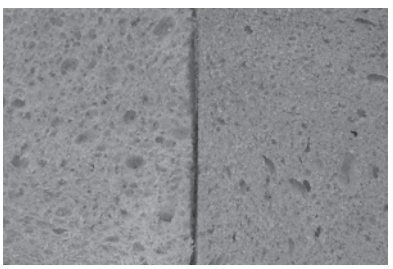
Yeast

The ability of yeasts (*Saccharomyces cerevisiae*), which are naturally found in air, water, and living organisms, to produce carbon dioxide through fermentation was probably discovered by accident. An Egyptian baker in ancient times is reputed to have set a flour-and-water dough aside in a warm place, where it became contaminated with yeasts from the air (15). The yeasts started to feed off the available sugar in the bread, producing carbon dioxide and ethanol or ethyl alcohol through the process of fermentation (Figure 17-13).

FIGURE 17-11 The role of leavening in bread volume and texture.



Unleavened Leavened



Well leavened Poorly leavened

Baker Technology

Baking soda A white chemical leavening powder consisting of sodium bicarbonate.

Baking powder A chemical leavener consisting of a mixture of baking soda, acid(s), and an inert filler such as cornstarch.

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FIGURE 17-12 The role of air as a leavening agent. Shown here are three pound cakes made without baking powder and subjected to three different degrees of air incorporation.



Baker Technology

Bread makers now add yeast directly to flour mixtures and control their growth through hydration, temperature, and salt concentration. During bread making, yeasts that have been alive but dormant become activated when they are hydrated in water at an optimal temperature, which varies according to yeast type. Once activated by the warm water, they are added to the flour mixture. After they are mixed in, the dough is kneaded and allowed to sit in a warm place as carbon dioxide generated by the growing yeast makes the dough rise. Yeasts multiply best at temperatures of 68 to 81°F (20 to 27°C), whereas fermentation is optimal at 81 to 100°F (27 to 38°C), specifically 95°F (35°C) (Figure 17-14). As the yeasts multiply and ferment in this warm environment, a small amount of sugar is sometimes added to serve as a food source for them. Adding too much sugar or salt, however, pulls water osmotically from the yeast cells and can literally dry them to death.

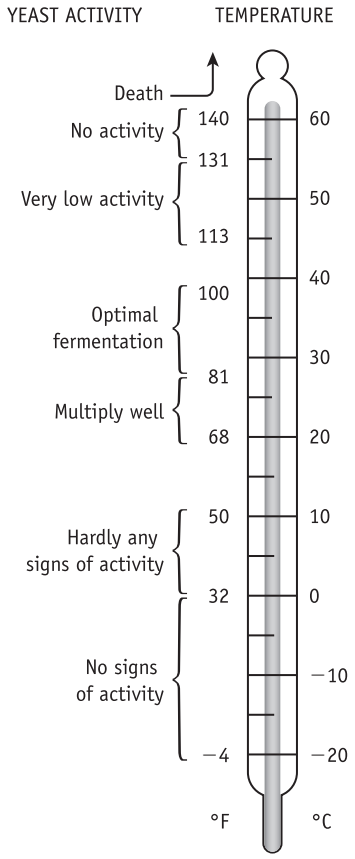
Yeasts are available in several forms and are classified on the basis of their activity. Active yeasts include baker's yeast, brewer's yeast, and yeasts for alcoholic beverages. Inactive yeasts, such as dried brewer's yeast and primary-grown yeasts, are used primarily for their nutritional value and contribution to flavor (23).

In this chapter, the focus is primarily on baker's yeasts, which are sold as dry, fresh (compressed), or instant yeast.

FIGURE 17-13 Fermentation process.

$$\text{yeast (without oxygen)} + C_6H_{12}O_6 \longrightarrow 2\ C_2H_5OH + 2\ CO_2\ \text{(gas)}$$
$$\text{veast} + \text{glucose} \longrightarrow \text{ethanol} + \text{carbon dioxide}$$

FIGURE 17-14 Yeast activity related to temperature.



How & Why?

If yeasts need sugar to ferment, how do they ferment and multiply in a flour mixture?

The yeasts feed off saccharides derived from either the flour or sugar added to the dough. Flour contains about 1.5% sugar (dry weight basis), from which the glucose is quickly fermented. In addition, an enzyme in yeast (yeast invertase) hydrolyzes starch to glucose and fructose, while flour amylases break down some starch to maltose, which is then transported into the yeast cell, where it is hydrolyzed to glucose. Sugar (sucrose) added to the flour mixture is also broken down by yeast invertase to glucose and fructose.

Dry (Active) Yeast

This is the most widely available type of yeast and is sold in small packets. This porous and free-flowing type of yeast can be stored at room temperature, but it keeps longer when refrigerated or frozen. It becomes inactive if not used before the expiration date. Water warmed to 115°F (46°C) is ideal for rehydrating and activating the dry yeast. Once hydrated, it should not be exposed to temperatures below 100°F (38°C), which lower

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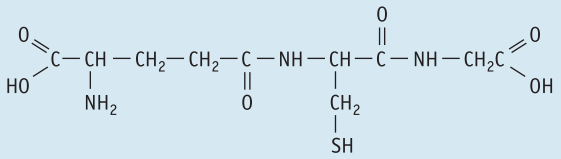
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CHEMIST'S CORNER 17-2

Cold Water and Yeast

Hydrating yeast with water that is too cool results in a sticky dough. When yeasts are hydrated below 100°F (38°C), their cell constituents tend to leach out. Specifically, glutathione is released into the dough, where this natural reducing agent disrupts the disulfide bonds between and within the protein molecules (see Figure 17-15). The proteins quickly unfold, resulting in a softer, stickier dough. This problem tends to happen with dry yeast, for which optimal water temperature for cell restoration is 104°F (40°C), but not with fresh yeast, which disperses easily in cold water.

FIGURE 17-15 Glutathione released from yeast cells results in sticky dough.



its activity and result in a sticky dough (Chemist's Corner 17-2), or above 140°F (60°C), which will kill it. In general, one package (¼ ounce or 2¼ teaspoons) of active dry yeast is enough to leaven 4 to 6 cups of flour. It contains less moisture (8%) than compressed yeast and is therefore less susceptible to deterioration.

Fresh Yeast

Also called "compressed yeast" or "cake yeast," fresh yeast is sold as a semi-solid cake with about 70% moisture. It therefore has a short shelf life and develops mold easily, so refrigeration is required. Compressed yeast is not, consequently, a favorite of consumers, but it is preferred by professionals because it dissolves easily without excessively warm temperatures and produces more consistent results. Packs that are brownish (instead of cream-white), dried out, or have a bad odor should be discarded (Figure 17-16). Compressed yeast is reactivated by the addition of warm water (85°F/29°C).

Instant, Quick-Rising, or Fast-Acting Yeast

Primarily for commercial bakers, this yeast strain reproduces more quickly than the traditional yeasts. Breads rise twice as fast with this yeast, eliminating the need for a second rising. However, there is less time for flavor to develop. Another drawback is that this type of yeast is extremely sensitive to temperature and moisture, and it requires an activation temperature between 125°F and 130°F (52°C and 54°C).

Starter A culture of microorganisms, usually bacteria and/or yeasts, used in the production of certain foods such as sourdough bread, cheese, and alcoholic beverages.

How & Why?

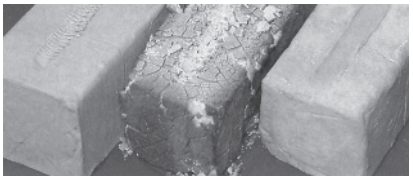
How do brewer's yeast, baker's yeast, and nutritional yeast differ?

Brewer's yeast is a brewery by-product that is used as a nutrient supplement. It is a source of B-complex vitamins, amino acids, chromium, calcium, phosphorus, potassium, and other nutrients. Brewer's yeast has a bitter taste and is made from the pulverized cells of *Saccharomyces cerevisiae* dried at high temperatures, so the yeast are killed and do not contribute to leavening.

Baker's yeast is used for leavening breads and other baked goods. It is dried at low temperatures so the yeast are not killed. It can be the same species as brewer's yeast *(S. cerevisiae),* or *Candida milleri* and *Lactobacillus sanfrancisco* for some sourdough breads.

Nutritional yeast is grown specifically for use as a supplement. Available in powder or flake form, nutritional yeast is grown on a molasses solution so it lacks the bitter taste of other yeasts—it actually has a sweet, nutty, cheesy flavor. It is the same species as brewer's yeast, dried at high temperatures so it is no longer alive. Nutritional yeast has a similar nutrient composition to brewer's yeast, but consuming more than 3 tablespoons per day may raise uric acid levels.

FIGURE 17-16 The freshness of fresh yeast is tested with a fingernail scratch on the surface.



Fresh yeast | Older yeast (dry storage) | Older yeast (airtight storage)

Baker Technology

Bacteria

Harmless bacteria that generate carbon dioxide are used as leavening agents in sourdough and salt-rising breads. These baked products depend on a **starter**. Two types of fermentation—one from bacteria and one from yeasts—contribute to the production of carbon dioxide. The bacteria also contribute a desirable, slightly sour flavor to certain baked products—a flavor that has become more and more popular in making the European-style rustic hearth breads. A sourdough starter must be kept alive and fed additional flour to keep on contributing to the leavening of breads.

Baking Soda

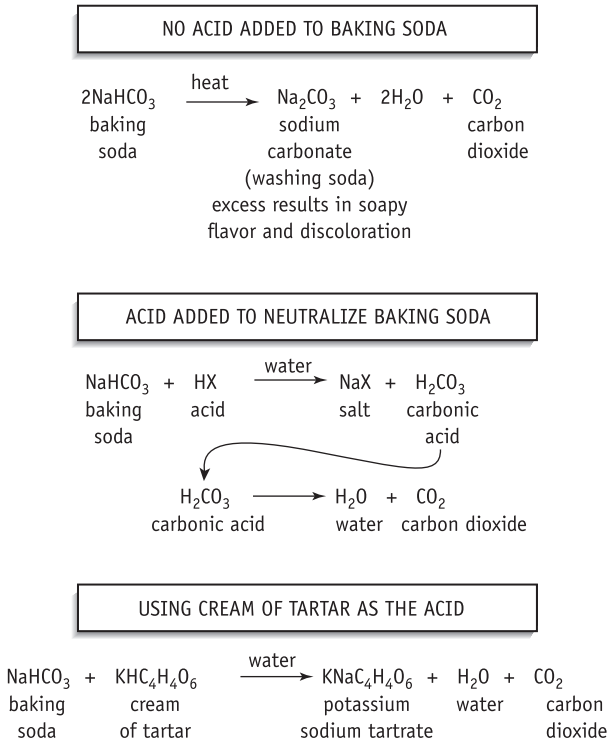
Baking soda (sodium bicarbonate), known as a leavening agent in the food industry, chemically yields carbon dioxide in the presence of moisture and an acid. Up to ¼ teaspoon of baking soda is required for each cup of flour to be leavened. Baking soda is not typically used by itself as a leavening agent because so much would be required that the flavor and appearance of the product would be adversely affected. Baking soda is only used when the flour mixture includes acidic ingredients—lemon, vinegar, buttermilk, yogurt, molasses, brown sugar, cocoa, chocolate, citrus fruits, cream of tartar (¾ teaspoon per ¼ teaspoon baking soda), or sour milk (made by combining 1 cup milk with 1 tablespoon lemon juice or vinegar, or 1¾ teaspoons cream of tartar)

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FIGURE 17-17 Baking soda reactions.



(Chemist's Corner 17-3). The acid reacts with the baking soda and creates an intermediate compound, carbonic acid, that reacts to give off carbon dioxide and water (Figure 17-17). The immediate leavening effect caused by this reaction necessitates that any baked product prepared with baking soda be placed in the oven as soon as possible after it is mixed.

Potassium Bicarbonate

Replacing the sodium in sodium bicarbonate with potassium results in a leavener for people on low-sodium diets. It may have a slight aftertaste and costs more than baking soda.

Baking Powder

Baking powder is baking soda with the acid already added. With baking powder, it is not necessary to add an acidic ingredient to the flour mixture in order to produce carbon dioxide. The inert filler in baking powder absorbs any excess moisture in the air, which would otherwise cake the powder and/or reduce its potency.

Acid in Baking Powder

Baking powder is a kind of enhanced baking soda that can be made by combining ¼ teaspoon of baking soda with ½ teaspoon of cream of tartar. In the past, cream of tartar was derived from the sediment that collected on the sides of wine casks, and was the most widely used acid in the manufacture of commercial baking powders (38). When a liquid is added to baking powder, the acid reacts with the alkaline baking soda to release carbon dioxide gas. It acts like yeast in this respect but much more quickly. The type of acid determines the speed with which carbon dioxide is produced. Federal standards require that all baking powders be formulated to be able to produce at least 12% carbon dioxide when water and heat are applied, yet many yield about 14% to allow for losses during storage (52). A nonlaboratory method to test the potency of baking powder is to mix 1 teaspoon of baking powder with ⅓ cup of hot water to see if it causes bubbling.

Types of Baking Powder

The two main types of baking powder are fast-acting, or single-acting, powder and slow-acting, or double-acting, powder. Fast- or single-acting powder is available only to commercial bakers. A flour mixture made with fast- or single-acting baking powder should be handled quickly and efficiently and placed in the oven as soon as possible because it starts to produce carbon dioxide as soon as water is added. Any delay allows carbon dioxide to escape and decreases the ability of the mixture to rise. Approximately 1½ to 2 teaspoons of single-acting powder are required for every cup of flour.

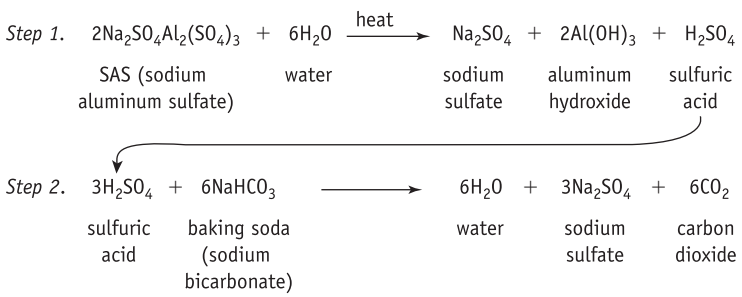
Many commercial bakers use double-acting baking powder (sodium aluminum sulfate (SAS)-phosphate powder), which reacts twice: once when it is moistened and again during heating (Figure 17-18). Approximately 1 to 1½ teaspoons of double-acting baking powder are required for every cup of flour.

CHEMIST'S CORNER 17-3

Acid and Baking Soda

Organic acids give up protons to react with the sodium bicarbonate, eventually yielding carbon dioxide. Acids contribute to the crumb structure formation by providing, during mixing, small gas-cell nuclei that serve as starting points for the carbon dioxide that will be produced (27).

FIGURE 17-18 Baking powder reactions, specifically, double-acting SAS-phosphate.



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Other types of baking powder may be used. Commercial bakers use baking powders that are specifically designed for certain baked products. Ammonium bicarbonate, for example, is used for cookies that require very little water and have a high surface area; this allows the ammonia to completely evaporate, preventing a bitter flavor (27). Sodium acid pyrophosphate (SAPP) is popular in the making of cold batters and refrigerated doughs.

Too Much/Too Little Leavening

Excess leavening results in a baked product that falls and has a low volume and/or a coarse texture. Adding more than the required amount of SAS-phosphate powder can result in a bitter taste. Too much baking soda or pockets of baking soda created by inadequate mixing with the dry ingredients will cause the production of residues of sodium carbonate, resulting in a soapy flavor and discolored brown or yellow spots. This excess alkalinity can also affect the flavor of chocolate and turn its color slightly reddish, although the color change is desirable when preparing devil's food cake (Chemist's Corner 17-4).

Too little leavening results in a compact, heavy baked product. Unfortunately, this can also occur when the baking soda or powder has lost its potency through exposure to moisture or storage for more than 6 months (38).

Too Much/Too Little Flour

Too much flour results in a lower volume, an increased number of "tunnels," and a drier, tougher crumb. A baked product made with insufficient flour often has a course texture and a weak, possibly collapsible, structure.

CHEMIST'S CORNER 17-4

The Red in Chocolate Cake

The reddish hue of chocolate cake containing excess sodium bicarbonate results from the oxidation of a polyphenol in cocoa to phlobaphene. The higher the pH of a chocolate cake is, the redder the color will be: brown (pH = 6.0 to 7.0), mahogany (pH = 7.0 to 7.5), or reddish (pH = 7.51) (43).

Sugar

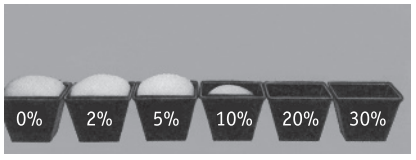
Aside from contributing sweetness, sugar also influences the volume, moistness, tenderness, color, appearance, and caloric content of baked products.

Functions of Sugar

The obvious sweetening role of sugar is apparent in baked products such as cakes, cookies, sweet breads, doughnuts, coffee cake, and sweet rolls. Dough is considered sweet if it contains more than ½ cup of sugar per 3½ cups of flour (1¼ ounces sugar per cup of flour). Many breakfast cereals contain sugar for sweetening power and also to act as a protective coating (3). Other functions of sugar in flour mixtures include the following:

- Increases the volume of cakes and cookies by the incorporation of air into the fat during creaming (especially true for granulated sugars).
- Contributes to volume by providing food for the yeast—although too much sugar (over 12%) results in a proportional decrease in volume (Figure 17-19).
- Raises the temperature at which gelatinization and coagulation occur, which gives the gluten more time to stretch, thereby further increasing the volume of the baked product and contributing to a finer, more even texture (50).
- Increases moistness and tenderness and also helps delay staling through the hygroscopic, or water-retaining, nature of sugar, thus improving the shelf life of baked products.
- Contributes to tenderness by competing with starch for the available water necessary for the hydration of flour proteins and eventual gluten development. The crust is initially very crisp but becomes softer as sugar attracts moisture from the air or crumb (56).
- Helps to brown the outer crust of baked products through caramelization and the Maillard reaction (49).

FIGURE 17-19 Sugar's influence on the volume of loaf bread.



Schunemann, and Treu. Baking: The Art and Science

Source: Schunemann C, and G Treu. *Baking: The Art and Science. A Practical Handbook for the Baking Industry.* Baker Technology, Calgary, Alberta, 1988.

Types of Sugar

Different types of sugars have different weights per cup, which should be taken into consideration when making substitutions. As discussed in Chapter 21, alternatives to sugar are available and can sometimes serve as substitutes for sugar in baked products. Although no code of federal regulations exists specifying the amounts of honey to be used in baked products, the FDA states that honey breads and rolls should contain at least 8% honey (based on flour weight) and that the honey should impart a noticeable flavor (65).

Too Much/Too Little Sugar

Baked products made with too much sugar may fall and may have a lower volume, a coarse grain, a gummy texture, and an excessively browned crust (Figure 17-20). Too little sugar results in dryness, reduced browning, lower volume, and less tenderness.

FIGURE 17-20 Excess sugar decreases cake volume and results in a gummy texture.



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Salt

Small amounts of salt are added to flour mixtures for flavoring; to produce a firmer dough; to improve the volume, texture, and evenness of cell structure; and to prolong shelf life (30). Baked products made without salt tend to be bland, so flavor is one of the most important reasons for adding salt. It also plays a large role in firming the dough by adjusting the solubility and swelling capacity of the gluten (Figure 17-21) (20). Bakers often prefer flaky sea salt to granular table salt because the greater surface area of the more fragile flakes allows for greater distribution. Some people like the ease of adding the salt to the flour, whereas others dissolve it in the liquid for greater dispersion; however, the latter increases the risk of toughness due to greater gluten formation. Slightly less gluten is formed when salt is added to the flour mixture because fat may cover up some of the granules (12).

Salt Controls Yeast Growth

In the production of yeast breads, salt helps control yeast growth. Without salt, fermentation would be too rapid and result in a sticky, difficult-to-handle dough (47). Too much salt, however, inhibits yeast activity, reducing the amount of carbon dioxide gas produced and decreasing the volume of the loaf (Figure 17-22) (61). Salt-sensitive consumers can buy salt-free breads made from special dough formulations. Bakers may alter the dough by reducing the yeast; adding acidic ingredients such as vinegar, yogurt, or acid fruit juice; and/or simply omitting the salt-containing ingredient.

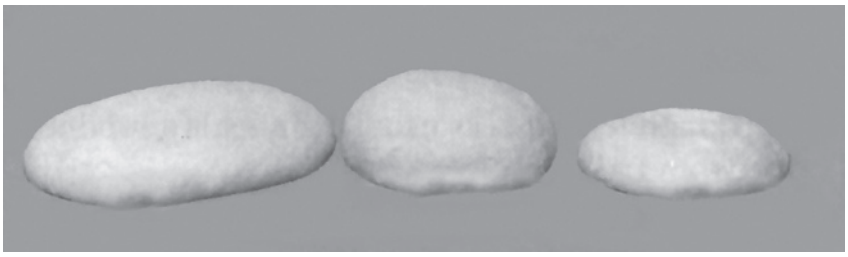
FIGURE 17-21 Salt makes dough more elastic.



Amy C. Brown

Salt was added to the dough on the left, making it much more pliable, which aids in gluten formation. No salt was added to the dough on the right.

FIGURE 17-22 Salt influences dough firmness.



Baker Technology

No salt Normal salt Double salt

Too Much/Too Little Salt

Excess salt produces a firm dough with a low volume (because of partially inhibited fermentation), dense cells, and a too-salty taste (56). Too little salt produces a flowing, sticky dough with a low volume, uneven cell structure, a lack of color, and a bland taste (43).

Flavorings

Because the basic ingredients of all baked products are the same, all would taste very similar without variations in added flavorings. Flavor extracts, cocoa, melted baking chocolate, fruits, spices, nuts, and other flavorings, seemingly limited only by the baker's imagination, may be added to vary the taste experience.

Liquid

Liquid in some form is required in flour mixtures to hydrate the flour and to gelatinize the starch. The water in the liquid also allows gluten to be formed (32), acts as a solvent for the dry ingredients, activates the yeast, provides steam for leavening, and allows baking powder or soda to react and produce carbon dioxide gas.

Milk

Milk is not necessary in a flour mixture but is usually recommended over water because it improves the overall quality of the baked product. In addition to contributing water, milk adds flavor and nutrients (complete protein, B vitamins, and calcium), and contains certain compounds that help produce a velvety texture, a creamy white crumb, and a browner crust. Doughs made with milk are easier to shape, less sticky and heavy, and retain their shape better. They also tend to expand during fermentation without overdevelopment or underdevelopment, and they retain gas better, which results in a higher volume. These positive attributes are the result of the presence of milk fat and the natural emulsifier lecithin.

The lactose in milk participates in the Maillard reaction, resulting in a browner crust. Fresh fluid milk, buttermilk, nonfat dried milk, canned milks, yogurt, and sour cream can all be used at various times in baked goods, depending on the desired end product.

Too Much/Too Little Liquid

Excess liquid may result in a very moist baked item with low volume. Too little liquid may produce a dry baked product that is low in volume and stales quickly.

Fat

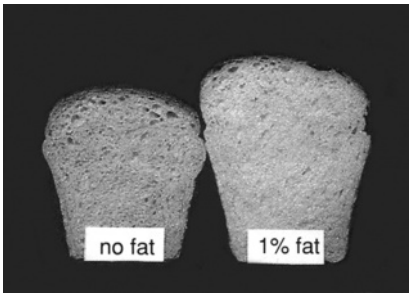
Fat incorporated into the flour mixture physically interferes with the development of gluten, creating a more tender crumb (46). In fact, the higher the fat content, the shorter the gluten strands, and the softer, more easily handled, and more pliable the dough will be. For this reason, fat is sometimes referred to as "shortening" (59). Fat lubricates the dough, preventing gluten formation through the creation of a continuous network of starch and protein (21). To maintain the correct consistency when fat is added to a flour mixture, the liquid is reduced by an amount equal to one-fifth the amount of added fat. Although fat softens the dough and enables it to rise higher, adding too much fat (over 20% of the flour's weight) makes the baked product too "short" and results in a lower volume because of an insufficient gluten structure and tearing of the crumb (56).

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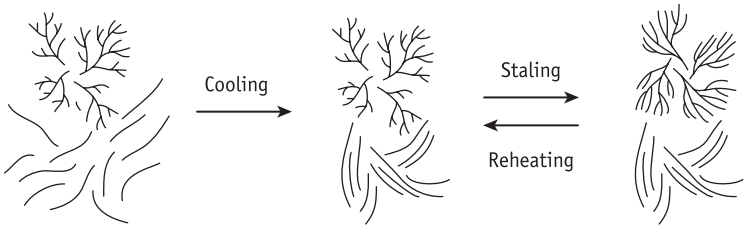
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FIGURE 17-23 Fat influences the volume and texture of loaf bread.



Baker Technology

FIGURE 17-24 How bread stales.



Fresh Baked Bread
The starch molecules, amylose (straight chain) and amylopectin (branched chain), found in bread taken right out of the oven are swollen and randomly positioned.

Fresh Bread
As the bread cools, the amylose molecules start to come together and crystallize, which changes the texture of the bread.

Stale Bread
Several days later, the amylopectin molecules come together and crystallize, further changing the texture of the bread. Reheating reverses this process to some degree.

Functions of Fat

Fat performs many functions in baked goods. It acts as a tenderizer and adds volume, structure, flakiness, flavor, color, and resistance to staling; it also plays a role in heat transfer (Figure 17-23).

Improves Volume

Fat increases the volume of the baked product because fat particles (crystals) melt during baking, making the batter more fluid and prone to expansion (46). The role of fat in improving loaf volume is also derived from its ability to stabilize large numbers of small air bubbles by adhering to their surfaces. This allows the bubbles to expand during baking without rupturing. Fat also contributes to volume because the creaming together of fats and sugars traps some air, which acts as a leavening agent during heating. The volume of baked breads is increased by about 15 to 25% using 5% shortening (3 to 5% is generally used) (59).

Improves Strength, Crumb, and Flakiness

In the process of adding volume, fats provide strength to the baked product's structure, making it more resistant to shocks that otherwise might cause it to collapse during handling. The appearance of the crumb is also affected by fat concentration. Lower-fat baked products have a fine, velvety crumb, whereas those higher in fat lose this characteristic. The flakiness in piecrusts and pastries is entirely dependent on fat being incorporated into the flour (see Chapter 24).

Improves Flavor and Color

Fat is an important contributor to flavor. The moister crumb of many baked products and the smooth mouthfeel of many fillings used in cookies or pastries is heavily dependent on the presence of fats. The color is also influenced by the fat content and the type of fat used. Croissants owe much of their flavor and color to their large butter component.

Delays Staling

Another benefit of the inclusion of fats in flour mixtures is that they delay staling in the final baked product (59). Emulsifiers also play a role here. The dry, hard, resistant, breakable crumb and crust of staled bakery items is not as evident in baked products made with fat and/or emulsifiers because these ingredients interfere with the main mechanism of staling—recrystallization of starch molecules, specifically amylopectin. Starch gelatinizes in freshly baked products, but during cooling, the randomly distributed amylose and amylopectin recrystallize. The amylose recrystallizes quickly, enabling the bread or other baked product to be sliced, whereas amylopectin takes several days and firms the crumb in the process (Figure 17-24).

Types of Fat Used in Baked Goods

The fats most commonly used in baking are shortenings, unsalted butter, and margarine. Oil and lard are sometimes used. Shortenings have a much wider useful temperature range than either butter or margarine, and they have the added benefit of containing their own emulsifiers (about 3%) and 10 to 12% gas by volume (70). They are also less expensive. The emulsifiers in the shortening distribute the fat more finely throughout the batter, whereas the gas contributes to volume (Figure 17-25).

FIGURE 17-25 Emulsifier's influence on the pore pattern and volume of loaf bread.



Baker's Digest

No emulsifier Added emulsifier

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Cakes made with hydrogenated vegetable shortenings rather than other fats have a higher volume and a finer, more even grain, but they lack the flavor that butter provides. Emulsifiers by themselves increase volume; produce a more even, finer pore; and improve the shelf life of baked goods (34). Oil coats flour too thoroughly and prevents adequate gluten development, so it is not often used in baked products, although, in some cases, oil is added to cake and quick bread recipes specifically for its tenderizing properties.

Temperature of Fat

Except when it is to be used in making piecrusts and pastries, fat should be at room temperature for baking. A completely melted fat does not incorporate air well, and a cold fat does not disperse evenly with the other ingredients. It is important to distribute the fat throughout the batter so it can make its contribution to tenderness and volume.

Lower-Fat Alternatives

The functional roles of fat in flour mixtures cannot be denied, but it elevates the total fat gram and kcalorie counts. Although many baked goods, such as cakes, cookies, and muffins, are available in lower-fat or fat-free varieties, they may provide more kcalories if the fat was replaced by large quantities of sugar (31). Chapter 22 discusses fat alternatives in more detail, but the bottom line is that fat-free doughs perform poorly, and the technology to replicate the functional properties of fat with a substitute has not yet evolved.

Too Much/Too Little Fat

Excess fat makes a batter too fluid, weakens its structure, and decreases the volume of the finished product. Too little fat makes a batter resistant to expansion during leavening and results in a tougher crumb.

Eggs

Eggs are added to some flour mixtures to enhance their structural integrity, or for their contributions to leavening, color, flavor, and/or nutrient content (Figure 17-26). The delicate structure and fine crumb of many baked goods are fortified by the coagulation of egg proteins during baking. Air may be incorporated by adding beaten whole eggs. This reaches a different level of sophistication when egg whites are whipped into a foam and incorporated into cakes such as angel food cake, meringues, cookies, or other baked products. Eggs also contribute to leavening because their liquid turns to steam when heated. Egg yolks act as emulsifiers and add flavor, nutrients, and color in the form of a yellower crumb and a browner crust. The emulsifiers, along with the fat content in an egg, delay staling and improve the shelf life of baked products. Adding eggs to a cake batter increases its nutritional content by supplying protein, the fat-soluble vitamins (A, D, E, and K), B vitamins, cholesterol, and fat. The appearance of many baked products may be enhanced with a shiny glaze made of egg white and sugar.

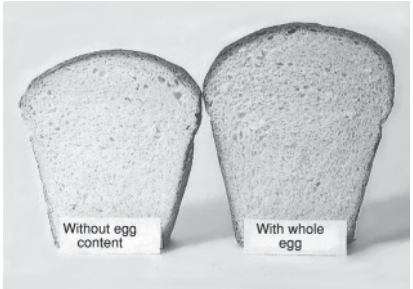
Too Much/Too Little Egg

Excess egg causes a tough, rubbery texture in the baked product. Too little egg causes insufficient volume, and inferior structural strength, color, flavor, and nutrient content.

Commercial Additives

The baking and milling industries often add commercial additives to the flour mixture to improve commercial production and the quality of the final baked product (2). Typical additives include bleaching agents (discussed previously under "Bleached Flour"), aging (maturing) agents, and dough conditioners.

FIGURE 17-26 The influence of eggs on the volume and texture of loaf bread.



Baker Technology

Aging or Maturing Agents

Bakers noticed that bread products did not rise as well if freshly milled flour was used. Better baked products were obtained by using flour that had aged or yellowed for weeks. Because waiting for flour to slowly oxidize with the air (natural aging) was not always practical due to time and space constraints, along with the danger of pest infestation, chemical maturing agents that would speed the aging process were added to the flour.

Freshly milled wheat flour, called "green" flour, must mature before it is capable of producing a strong dough (60). Maturing flour needs several weeks (up to 1 to 2 months) in the presence of oxygen, takes up valuable space, and may support mold growth. Freshly milled flour can bypass these disadvantages by being chemically aged with the addition of powdered maturing agents such as potassium bromate, ascorbic acid, and azodicarbonamide (56). For example, potassium bromate is known for providing improved gas retention, increased loaf volume, better dough-handling properties, and an improved crumb and texture (25). Most flours are aged before undergoing conditioning.

How & Why?

Why does flour have to be aged?

Aging increases the exposure to air (oxygen), which improves the strength of the resulting dough and results in faster mixing of the dough and reduced staling of the finished baked product.

Dough Conditioners

Flours are often aged with maturing agents. Likewise, flour mixtures are also conditioned by adding dough conditioners to improve their effectiveness. The reactions induced by these conditioners increase dough elasticity, improve machinability, and increase loaf volume. These additives, often mixed into dry flour, are referred to as "dough conditioners" or "dough improvers" because their effects are seen only in the dough stage. Examples of dough conditioners include reducing

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agents, oxidizing agents, emulsifiers, and enzymes. The most commonly used dough conditioners are azodicarbonamide (ADA), potassium bromate, and ascorbic acid (60). Less commonly used are calcium bromate, potassium iodate, calcium iodate, and calcium peroxide.

Reducing Agents

Reducing agents encourage gluten development and thereby shorten mixing time. They act in a manner opposite to that of oxidizing agents and actually disrupt the disulfide bonds, resulting in "disconnected" proteins that need less mixing (Chemist's Corner 17-5).

Oxidizing Agents

Benzoyl peroxide, an oxidizing agent already mentioned in the earlier discussion of bleached flour, acts to whiten the flour and improve the functionality of the resulting dough. Oxidizers work by making more sulfur available for the disulfide bonds between proteins in gluten, which strengthens the dough. Oxidizers rebuild the bonds, preventing the dough from becoming too soft and sticky. Oxidation of lipids and lipid hydrolysis, resulting in increased free fatty acid content, occurs as flour matures.

Emulsifiers

A few common commercial emulsifiers, among the many available, are lecithin, monoglycerides, and diglycerides, which function to disperse fat ingredients more evenly through the flour mixture. Gas generated by yeast is more easily trapped, reducing **proofing** time, increasing volume, and creating a more tender crust and crumb, more uniform cell structure, and an evenly textured baked product.

Mixing Time Reducers

These agents are added to reduce the time needed when mixing dough. Proteases are the most common. They work by hydrolyzing gluten proteins to smaller sizes. This results in a smaller molecular weight of the proteins and a more elastic dough (60). These reactions occur early in the mixing process. However, proteases must be added carefully—addition of excess protease results in a weak dough. Salt causes dough to tighten, resulting in increased mixing time. By adding salt after the batter is well mixed, mixing time can be reduced by 10 to 20%. Lower pH decreases mixing time and may decrease the susceptibility of dough to overmixing. The addition of organic acids, found in sourdough breads, decreases mixing time by 50%. The effect of pH is reversible.

Enzymes

Three types of supplemental enzymes are available to assist baked products: amylase, which converts starch to sugar; protease, which breaks down protein; and lipoxygenase, which bleaches the flour and strengthens the dough. Lack of natural amylase enzymes in the flour will result in baked products with a less than desirable volume, texture, and color (Chemist's Corner 17-6) (22). Supplemental amylase is now produced by fungal or bacterial fermentation, but it was once obtained from malted wheat or barley flour. Malt, in fact, is one of the oldest additives used by the baking industry. Loaf volume increases in breads made from doughs with added amylase because amylase converts some of the flour starch to sugars for the yeast, which increases gas production. It also delays starch gelatinization during baking, resulting in more oven spring. Proteases have to be added carefully because too much will break down the gluten strands, but this helps soften strong flours with higher protein contents. The lipoxygenase enzyme increases gluten strength and makes a whiter loaf by releasing oxidizers that bleach natural flour pigments.

Food Additives in Flours

The food additives listed on flour labels are different from the unlisted commercial additives added to flours to improve their functionality. For example, fat ingredients are often protected from rancidity by adding antioxidants such as butylated hydroxyanisole (BHA), butylated

CHEMIST'S CORNER 17-5

How Reducing Agents Work

The most common reductants are L-cysteine, the tripeptide glutathione (Y-L-glutamyl-L-cysteinyl-glycine), and bisulfite salts (60). L-Cysteine is found in many natural proteins, glutathione is released from yeast cells, and bisulfite results from the reaction of sulfur dioxide with water and alkali. L-Cysteine and bisulfite are the most economically viable reductants. Reductants react with disulfide bonds in dough, breaking them and reducing them to sulfhydryl groups. This results in a reduction in the molecular weight of the protein by decreasing polymerization (the formation of large protein molecules).

CHEMIST'S CORNER 17-6

Commercial Enzyme Additives

Enzyme supplementation lengthens shelf life and improves bread quality. Adding α-amylase to flours enhances the conversion of starch to maltose, which aids yeast fermentation and retards staling (45). The retrogradation thought to be responsible for staling is partially inhibited when α-amylase breaks down the size of the amylopectin molecule. Adding too much α-amylase, however, creates too many smaller molecules (dextrins) and results in a sticky dough. Proteases, which act on proteins, improve loaf uniformity and grain texture, and yield a softer crumb when added to bread formulations. The breakdown of proteins catalyzed by the proteases makes the dough more elastic and easier to handle. Proteases are also thought to improve the crust color and flavor of baked products by hydrolyzing gluten, which releases more amino acids to participate in the Maillard reaction (29).

Proof To increase the volume of shaped dough through continued fermentation, that is, to allow dough to rise.

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hydroxytoluene (BHT), vitamin E, and ascorbic acid (vitamin C). In addition to rancidity, breads and other baked products are naturally susceptible to molds. Adding mold inhibitors such as calcium or sodium propionate extends the shelf life of breads. Benzoates are effective against yeasts.

PREPARATION OF BAKED GOODS

Doughs and Batters

Flour mixtures are either **doughs** or **batters,** depending on their flour-to-liquid ratio (Figure 17-27).

Doughs

Doughs are classified by their moisture content into stiff or soft doughs. A stiff dough is created by adding only ⅛ cup of liquid per cup of flour, whereas a soft dough is made more pliable by adding ⅓ cup of liquid per cup of flour. The handling styles for these doughs also vary; some soft doughs, such as those prepared for yeast breads, rolls, and biscuits, are kneaded, whereas stiff doughs may be handled differently depending on whether they are used to make pasta, pie dough, or pastry. Cookie dough is either shaped, rolled, or dropped.

Unlike batters, doughs can be refrigerated with little effect on their overall quality. This characteristic has been profitably exploited by food companies that sell convenient packages of ready-to-bake dough for products such as piecrusts, rolls, cookies, croissants, and bread sticks.

Batters

Batters have more liquid content than doughs. Like doughs, they are classified according to their moisture content; they may be either drop or pour batters (see Figure 17-27). In general, batters are best used immediately, although some refrigerator batters may be kept for a short period in the refrigerator.

Drop Batters

Drop batters are too thick to be poured, so they are "dropped." Incorporating ½ to ¾ cup of liquid per cup of flour forms drop batters that are thick enough to be dropped or pushed onto a baking sheet. Examples of foods made from drop batters include muffins, quick tea breads, cream puffs, and some coffee cakes.

FIGURE 17-27 Doughs and batters are flour mixtures that differ in their liquid content and general use.

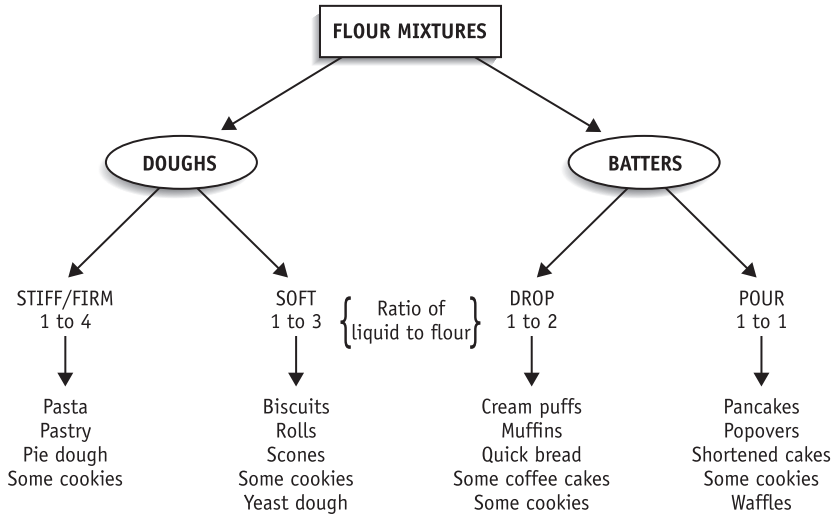


FIGURE 17-28 Batters can be spread, poured, or piped.



Spread Poured Piped

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Pour Batters

Pour batters, which average from ⅔ to 1 cup of liquid per cup of flour, are fluid enough to be poured, piped (emptied from a piping bag), or spread (Figure 17-28). Common foods prepared from pour batters include pancakes, waffles, popovers, cookies, and cakes.

Changes during Heating

After the ingredients have been mixed and, if necessary, kneaded to develop gluten, the flour mixture is ready for baking, during which several changes take place. When heat is applied, the gases, such as steam, carbon dioxide, and air, almost immediately expand, creating pressure that stretches the intricate, elastic network of gluten. The baked product rises in this fashion until the heat melts the fat; gelatinizes the starches; coagulates the flour, eggs, and/or milk proteins; and browns the outer surfaces by the caramelization of sugars, the dextrinization of starch, and/or the Maillard reaction. After all of this has been accomplished, the structure of the baked product is set and cooking is completed.

Dough A flour mixture that is dry enough to be handled and kneaded.

Batter A flour mixture that contains more water than a dough and whose consistency ranges from pourable to sticky.

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High-Altitude Adjustments

When preparing baked products at high altitudes, several adjustments are necessary. The lower atmospheric pressure lowers boiling temperatures and raises the amount of water lost through evaporation. As a result, the leavening gases in baked products meet less resistance and tend to overexpand, and the product therefore collapses more easily. Recipes can be modified by using less leavening, fat, and sugar; adding a bit more flour and liquid; and baking at higher temperatures in order to set the batter before overexpanding can cause the cells to collapse.

STORAGE OF FLOUR AND FLOUR MIXTURES

Flour should be stored in pest-proof containers and kept in a cool, dry place. White flour will keep in such conditions for about a year, whereas whole-grain flours, which still contain the fat-rich germ and can therefore turn rancid, should be refrigerated and can be held for only about 3 months (56).

Dry Storage

Keeping flour dry is important because moisture attracts insects. Even if it is kept completely dry, flour is still an attractive food source, and insects, beetles, and other pests can bore through paper, plastic bags, and even cardboard to get to it. Only metal, glass, or hard plastic, airtight containers keep pests out. In addition, some flours contain a chemical leavening agent that is triggered by moisture to release carbon dioxide. Figure 17-29 shows how the compression test can be used to determine whether a flour is adequately dry.

FIGURE 17-29 Flour compression test.



Flour is normal.



Baker Technology

Flour is too moist, and its baking quality is compromised.

Flour should be kept cool to prevent the activation of its natural enzymes, which can cause it to deteriorate if it is stored too long. At first it is advantageous for flours to age because this allows the amylase to break down starch into the smaller sugars (dextrin, malt, and glucose) that benefit the baked product (malt flour is often added to bypass this maturing stage). Storing the flour beyond its recommended storage time, however, results in a higher sugar content, which excessively browns the crust of white bread. Some flour also contains proteases, which break down its protein to the point at which the gluten-forming ability is compromised, but this is a problem only in low-gluten flours. White flour is not affected by its own proteases because it has enough initial protein. Another enzyme, lipase, breaks down any small fat component that may be present, resulting in rancid off-odors and flavors. In addition to rancidity, another drawback of fat deterioration is that the resulting baked product is usually lower in volume and has large pores (56).

Frozen

Kneaded flour mixtures can be frozen; after defrosting, they are ready to be shaped and baked. The dough may require being kneaded about 10 times after defrosting to improve its quality because frozen dough loses some of its originally retained gases while in the freezer. Extended frozen storage can lead to a gradual loss of dough strength, which is why frozen doughs have a relatively short shelf life. Freezing damages the yeast cells, which reduces their leavening power and thus results in longer proof times and smaller loaf volumes. It also reduces dough strength because ice crystals disrupt the gluten network. To overcome the problems associated with freezing dough, commercially prepared frozen doughs are made with more oxidants, emulsifiers, and gluten (35).

The storage guidelines for breads and other baked products made from flour mixtures, such as cakes, cookies, pies, and pastries, are discussed in their respective chapters.

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PICTORIAL SUMMARY / 17: Flours and Flour Mixtures

We owe the structure and texture of baked products largely to wheat flour, specifically to its starch and protein.

FLOURS

- Starch strengthens mixture through gelatinization and adds texture to the mix.
- Gluten proteins firm flour mixtures when combined with water.
- Dextrin, malt, and glucose in flour aid in fermentation, add sweetness, and help brown the crust.

Types of Flour

Gluten-Containing Flours

Wheat

Whole-wheat Bread
White
Durum (semolina)
All-purpose
Pastry
Cake
Graham
Einkorn
Emmer (farro)
Kamut®
Spelt
High-gluten

Treated wheat

Aged
Bleached
Phosphated
Self-rising
Instant
Enriched

Nonwheat grain

Barley
Oat*
Rye
Triticale

Gluten-Free Flours

Grain or pseudo grains (non-grasses)

Amaranth
Buckwheat
Corn
Cornmeal
Millet
Millet®
Quinoa
Rice
Sorghum
Teff

Vegetable

Potato

Legume

Garbanzo
Soybean

Nut

Almond
Coconut (fruit)
Walnut

*Whether oats are gluten-free depends on the variety of oat and whether it has been contaminated during processing (e.g., in a facility that also processes wheat).

PREPARATION OF BAKED GOODS

Types of Flour Mixtures:

Doughs



Soft

- Biscuits
- Yeast dough
- Some cookies
- Rolls
- Scones

Stiff/Firm

- Pasta
- Pie dough
- Pastry
- Some cookies

Batters



Drop

- Muffins
- Quick bread
- Some cookies
- Cream puffs
- Some coffee cakes

Pour

- Pancakes
- Popovers
- Shortened cakes

Changes during Heating: Baking a flour mixture expands the gases (steam, carbon dioxide, and air), which stretches the gluten network and causes the baked product to rise. During this time, the fat melts, starches gelatinize, proteins coagulate (from the flour, eggs, and/or milk proteins), and outer surfaces brown because of the caramelization of sugars, the dextrinization of starch, and/or the Maillard reaction. Heat ultimately sets the structure of the baked product.



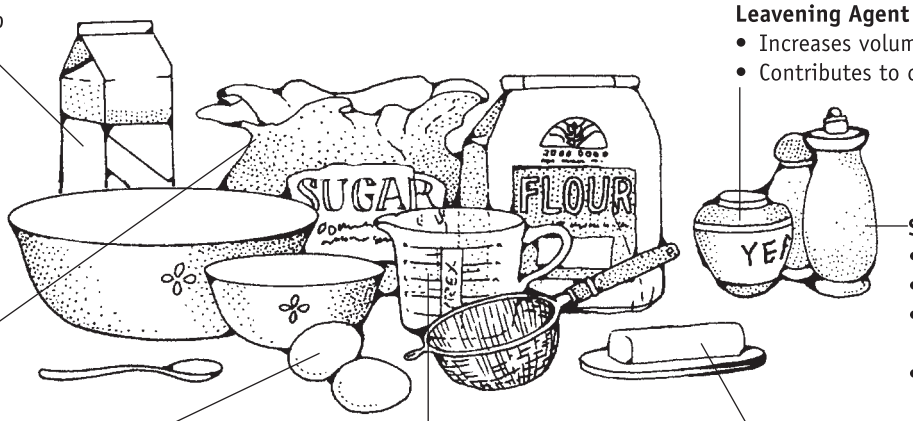
STORAGE OF FLOUR AND FLOUR MIXTURES

White flour can be kept up to a year if it is stored in a pest-proof container kept in a cool, dry place. Whole-grain flours, which contain the germ, need to be refrigerated and will keep up to 3 months. Any flour or dry flour mixture containing chemical leavening agents should be protected from moisture.

FLOUR MIXTURE INGREDIENTS

Milk
- Improves crumb and flavor
- Browns crust
- Adds nutrients

Leavening Agent
- Increases volume
- Contributes to crumb, texture, flavor



Salt
- Adds flavor
- Firms dough
- Improves volume, texture, crumb
- Prolongs shelf life

Sugar
- Sweetens
- Increases volume
- Adds moistness
- Improves color

Eggs
- Add structure
- Help leavening
- Improve color/flavor
- Add nutrients

Liquid
- Hydrates flour
- Gelatinizes starch
- Serves as a solvent for dry ingredients

Fat
- Tenderizes
- Increases volume
- Contributes structure, flakiness
- Adds flavor, color
- Increases resistance to staling

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The protein complex in wheat, barley, and some oat flours that contains gliadin and glutenin is called _____.
   a. albumin
   b. gluten
   c. quinoa
   d. glucose

2. Too much kneading will create a (an)_____ dough?
   a. soft
   b. uniform
   c. inelastic
   d. nonsticky

3. Semolina flour, made from hard winter durum wheat, is typically used to make _____.
   a. pasta
   b. bread
   c. cereal
   d. rolls

4. Using excessive leavening will produce _____in a baked product.
   a. high volume
   b. low volume
   c. smooth texture
   d. moistness

5. Aside from sweetness, sugar influences _____ of baked products.
   a. volume
   b. moistness
   c. color
   d. all of the above

6. Stiff doughs are used primarily to make _____.
   a. pasta, pastry, and pie dough
   b. biscuits, rolls, and scones
   c. cream puffs, muffins, and quick bread
   d. pancakes, popovers, and shortened cakes

7. Gluten development is promoted by which of the following types of commercial agents?
   a. Maturing
   b. Amylase
   c. Reducing
   d. Oxidizing

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. What is the essential difference between the preparation of yeast breads and that of quick breads?
2. What are the two wheat flour proteins that form gluten?
3. Describe the two major steps involved in gluten formation. How does gluten contribute to the formation of certain baked products?
4. What is the purpose of milling? Describe the sequential steps of milling?
5. Briefly describe each of the following flours: whole-wheat, white, bread, durum/semolina, all-purpose, pastry, and cake. Why are rye flour, cornmeal, and soy flour not used as extensively as wheat flour in the production of baked goods?
6. Wheat flours can be treated to improve their functional properties. Describe the following types of treated flours: aged, bleached, phosphated, self-rising, instant/agglomerated, and enriched.
7. Describe the purpose of a leavener. What are the three major types of leavening agents? What is a starter? Explain the difference between baking soda and baking powder. How do they behave differently as leaveners?
8. How do yeasts act as leaveners? List the three different types of yeast products available. What are the basic steps for incorporating yeast into a flour mixture, and what are the optimal temperatures for each step?
9. List several functions for each of the following ingredients of flour mixtures: flour, leavening, sugar, salt, liquid, milk, fat, eggs, and commercial additives.
10. What problems may occur when too little or much of each of the following ingredients is added to a flour mixture: flour, leavening, sugar, salt, liquid, fat, and eggs?
11. How do doughs and batters differ in their ingredients and their preparations?

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18



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Starches and Sauces

Starch Characteristics 369
Starch Transformations 372
Sauces 376
Storage of Starches and Sauces 382

Starchy foods are the mainstays of diets throughout the world (11). In China, Japan, India, and other Asian countries, rice is the most important staple food, followed by a wide variety of noodles. Certain African countries rely on roots, tubers, and sorghum (a grain) as the main dietary starches. The potato was so important to people in Ireland during the mid-1800s that a widespread potato blight resulted in famine and starvation for thousands.

As a complex carbohydrate, starch provides energy, and a well-balanced diet derives at least 45 to 65% of its kcalories from carbohydrates. Starches are made up of glucose molecules synthesized by plants through the process of photosynthesis, so they can be obtained only by consuming foods of plant origin. The glucose is converted to starch by the plant, and then used for energy or stored in the seeds, roots, stems, or tubers (enlarged underground stems). When foods from these sources are ingested by mammals, including humans, the digestion process converts the starch back to glucose. Starches provide 4 kcalories of energy per gram.

The food industry makes widespread use of the capability of starches to thicken foods and to act as stabilizers, texturizers, water or fat binders, fat substitutes, and emulsification aids (8, 28, 33). Starches contribute to the texture, taste, and appearance of sauces, gravies, soups, Chinese dishes, salad dressings, and desserts such as cream pies, fruit pies, puddings, and tapioca. Cornstarch can be used to manufacture the corn syrups—including high-fructose corn syrup—that are discussed with other sweeteners in Chapter 21 (15). The preparations of cream soups and pie fillings are covered in Chapters 15 and 24, respectively, whereas this chapter covers the preparation of sauces with and without starch. First, let's take a look at starch sources, their structure, and their characteristics.

STARCH CHARACTERISTICS

Sources of Starch

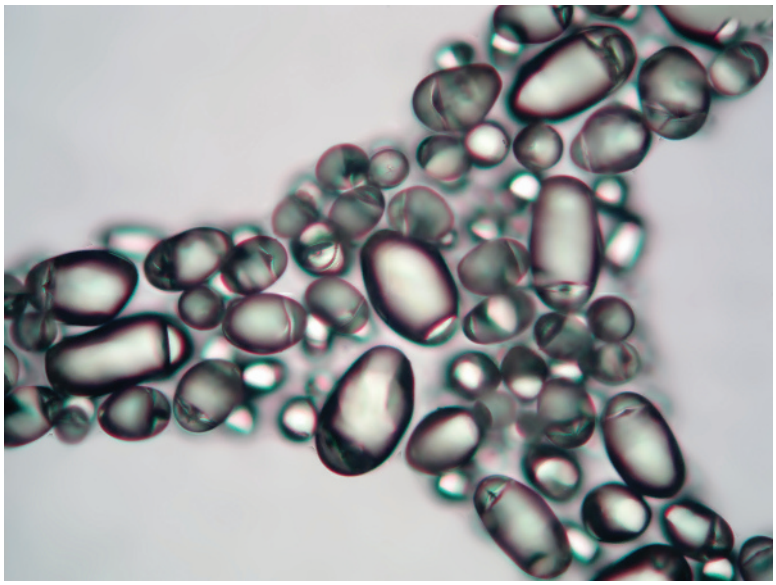
The word *starch* is derived from the Germanic root word meaning "stiff," and commercial starch lives up to the original meaning by acting as a thickening or gelling agent in food preparation. Some starches derived from plants can be considered food additives and are used in a wide variety of ways. Plants serve as the source of starch granules, which are the plant cell's unit for storing starch. Cereals such as wheat, rice, and corn are

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FIGURE 18-1 Potato starch granules are the largest in size.



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common sources of starch. Root starches include potatoes, arrowroot, and cassava (tapioca) (27). Other sources of complex carbohydrates serving as dietary starch sources include dried beans, peas, and the sago palm. Starch granules differ in size and shape, depending on their botanical origin. Potato starch granules are the largest, while corn, tapioca, rice, and taro root starch granules are progressively smaller (Figure 18-1). Knowing the source of a starch is important when preparing foods because starches vary in flavor and viscosity. For example, common starches may be ranked from greatest to least thickening ability as follows: potato, waxy starches, tapioca, arrowroot, sorghum, cornstarch, rice, and wheat.

Cornstarch

The wet milling process is used to derive starch from corn, which is the major source (over 90%) of starch in the United States (1). The dried kernels are softened by soaking them in warm water containing sulfur dioxide. Once softened, the kernels are cracked, any extraneous material is removed, and the cracked kernels are ground and screened, or sifted down to yield starch and protein. The protein is removed and the starch is filtered, washed, dried, and packaged as cornstarch.

Dextrose equivalent (DE) A measurement of dextrose concentration. A DE of 50 means the syrup contains 50% dextrose.

Starch in Food Products

Starch serves several purposes in the food industry, including as a thickening agent, an edible film, and a sweetener source (dextrose and syrup) (Figure 18-2).

Thickening Agent

Starch's main use in processed foods is as a thickening and/or gelling agent. Foods that are frequently thickened with starch include soups, sauces, pie fillings, gravies, chili, stews, cream-style corn, cream fillings, custards, fruit pie fillings, whipped toppings, and icings. Certain puddings, candies, gums, and salad dressings are also thickened with starch.

Edible Films

Starch films are used as a protective coating for chewing gums, to bind foods such as meat products and pet foods, and to act as a base on the food for holding substances such as flavor oils in chocolates.

Dextrose

Because starch consists of repeating units of glucose, it can be broken down into these individual units for use as a sweetener in the production of confections, wine, and some canned goods. The food industry refers to this glucose derived from starch as dextrose, and measures the degree of conversion from starch to glucose in **dextrose equivalents (DEs)** (30) (see Chapter 21).

FIGURE 18-2 Examples of foods containing starches.

Bakery products
- Cake mixes
- Cream pie fillings
- Cupcakes
- Frostings
- Glazes
- Fruit pie fillings
- Refrigerated cookie doughs

Breadings
- Breaded mushrooms
- Breaded zucchini
- Fried chicken
- Fried fish
- Onion rings

Beverages
- Carbonated sodas
- Fruit juices
- Fruit drink mixes

Canned foods
- Chili
- Chow mein
- Canned pastas
- Cream-style corn

Condiments

Confections
- Candies
- Fillings for chocolates
- Gum

Dairy products
- Cheese powders
- Cheese spreads
- Dips
- Sour creams
- Yogurts

Dressings
- Salad dressings
- Sandwich spreads

Frozen foods
- Ice cream
- Pasta
- Pot pies
- TV dinners

Gravy and sauces

Meat products
- Luncheon meats
- Sausage
- Turkey loafs

Preserves
- Jam
- Jelly

Soups, stews
- Chowders
- Dry soup mixes
- Soups
- Stews

Toppings
- Butterscotch
- Marshmallow

Source: Whistler and BeMiller, *Carbohydrate Chemistry for Food Scientists* (Eagen Press, 1997).

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A hydrolysis product of starch is considered a starch hydrolysate (14). These starch hydrolysates have been used as sweeteners for more than 3,000 years, starting most likely with candy made in China with the aid of maltose-bearing syrups derived from rice starch. The most common solid starch hydrolysates used now are dry maltodextrins (DE <20) and corn syrup solids (DE = 24 to 48) (29).

Starch Syrups

Over half of all the starch produced in the United States is eventually converted to syrups (10). Corn syrup made from cornstarch is added to a large assortment of foods, including soft drinks, canned fruits, jams, jellies, preserves, frozen desserts, confections, frozen fruits, fountain syrups, and many other food and beverages (1).

Starch Structure

As discussed in Chapter 3, starch is a polysaccharide consisting of long chains of repeating units of glucose molecules linked together either in the form of amylose, which is made up of primarily linear molecules, or amylopectin, whose molecules are highly branched (Chemist's Corner 18-1) (34). The amount and proportions of amylose and amylopectin found in starches vary according to the starch's plant source (Table 18-1), but most starches contain about 75% amylopectin and 25% amylose (34). High-amylose starches are 40 to 70% amylose. All starches contain some amylopectin, but a few consist entirely of amylopectin; these are known as *waxy* starches (20). It is the varying amylose content that causes texture differences in starch-containing foods (2). Starches containing higher levels of amylose tend to gel, whereas starches containing higher levels of amylopectin are considered nongelling, but are still somewhat gummy (33). Genetic engineering techniques can be used to produce any ratio of amylase or amylopectin required to achieve the starch's desired functionality (23).

TABLE 18-1 Approximate Proportion of Amylose and Amylopectin in Various Starch Sources

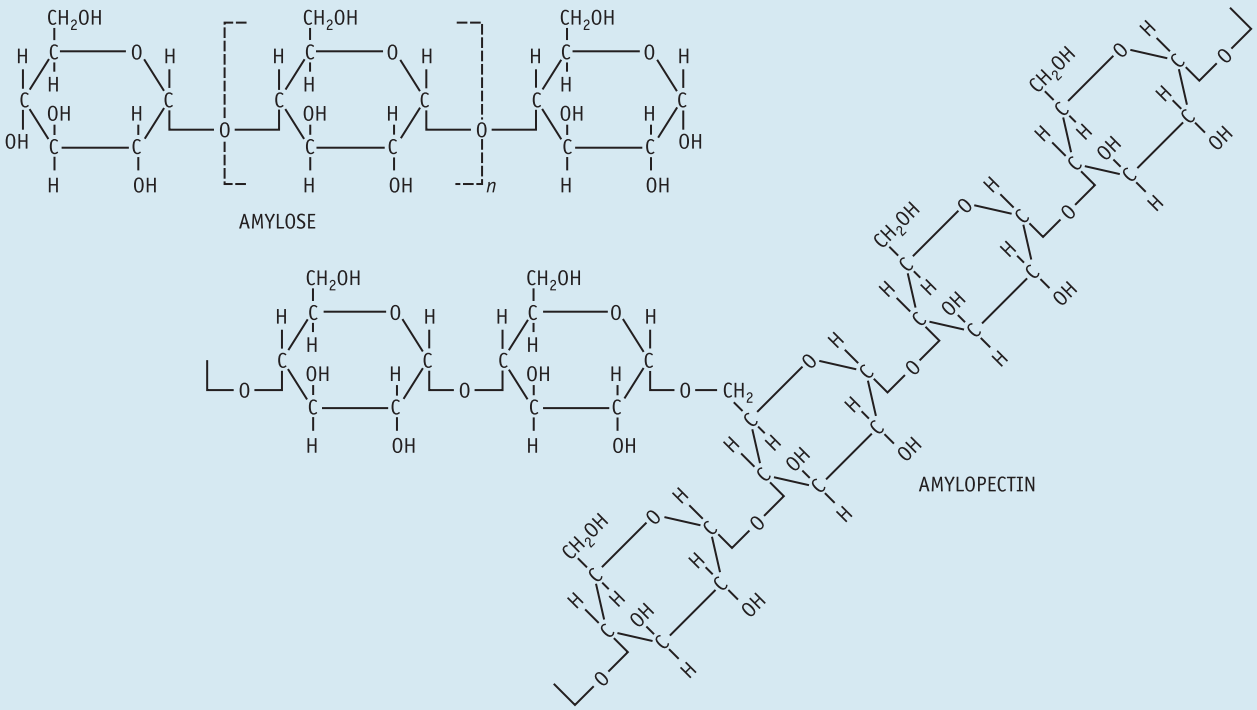
Starch	% Amylose	% Amylopectin
Potato	21	79
Tapioca	17	83
Corn	28	72
Waxy corn (maize)	0	100
Wheat	28	72

CHEMIST'S CORNER 18-1

Amylose and Amylopectin

The varying ratios of amylose to amylopectin cause the texture differences seen in different starches. Amylose consists of a linear molecule containing 500 to 6,000 glucose units linked through mostly α-1,4 linkages. Amylopectin contains many more glucose units that are highly branched and bound with both α-1,4 and α-D-1,6 linkages (Figure 18-3) (33).

FIGURE 18-3 Two types of starch.



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STARCH TRANSFORMATIONS

The capacity of starches to undergo gelatinization, gel formation, retrogradation, and dextrinization processes is what makes them so valuable in food preparation. The concentrations of amylopectin and amylose in a starch determine the degree to which these processes take place (Chemist's Corner 18-2). Starches can also be modified chemically, enzymatically, or physically to better serve specific purposes.

Gelatinization

The process of **gelatinization** contributes to the viscosity of thickened foods (sauces, custards, dressings, etc.) and the structure of baked products. Gelatinization occurs when starch granules are heated in a liquid and thereby expand (20). When the liquid is heated, the hydrogen bonds holding the starch together weaken. This allows water to penetrate the starch molecules, causing them to swell until they have increased in size many times over and their peak thickness is reached (6). Amylose migrates out of the starch granules while hydrogen bonding between the water and amylopectin increases. Water becomes less available, making the mixture thicker and more viscous.

The increased volume, viscosity, and gumminess associated with gelatinization radically change the texture of many foods. Gelatinization causes the dramatic alterations in the consistencies of pasta, rice, oats, scalloped potatoes, and most sauces, soups, and puddings that occur during cooking (17). Many custard and fruit pie fillings require starch for body and shape-holding ability. During their preparation, the gelatinization process begins when cornstarch or some other starch is added to the pie filling mixture, which is then heated until it thickens. Because cornstarch breaks down during freezing, tapioca or **modified starches** (specifically, waxy) are recommended for pies that will be frozen.

Factors Influencing Gelatinization

Gelatinization is influenced by several factors, including the amount of water, the temperature, heating time, stirring, and the presence of acid, sugar, and/or fat (Chemist's Corner 18-3). These factors need to work in synchrony in order for maximum gelatinization to occur.

Water

Sufficient water must be available for absorption by the starch. The amount of liquid needed for absorption depends on the concentrations of amylose and amylopectin in the starch (2). When preparing starchy foods such as grains or pasta, sufficient water is added to not only cover the food but also to allow for evaporation and a two to three times expansion in volume.

Temperature

Starches do not dissolve in cold or room-temperature liquids (27). In warmed liquids, the starch granules swell and burst, releasing starch particles into the liquid. Table 18-2 shows that the temperature range within which gelatinization can occur varies according to the type of starch. Thickening usually begins at approximately 140°F (60°C). Some root starches, such as tapioca, have high concentrations of amylopectin, causing them to thicken at lower temperatures. Most starches gelatinize when heated above 133 to 167°F (56 to 75°C) (10).

CHEMIST'S CORNER 18-2

Testing for Starch

Food scientists can distinguish between amylose and amylopectin starch granules by staining them under a microscope. If they turn blue, they contain more amylose. An amber-violet color indicates more amylopectin (37).

CHEMIST'S CORNER 18-3

Controlling Gelatinization

Three substances that control gelatinization are sodium sulfate, sugar, and chlorinated flour. Sodium sulfate stabilizes starch granules by increasing their gelatinization temperature (12). The large negative charge and structure of sodium sulfate increase the starch's resistance to gelatinization. High sucrose concentrations also inhibit gelatinization and may actually contribute to cakes falling if too much sugar is added to the batter. Chlorinated flour contains oxidized starch, which has a lower gelatinization temperature and is preferred for baking cakes.

Gelatinization The increase in volume, viscosity, and translucency of starch granules when heated in a liquid.

Modified starch A starch that has been chemically or physically modified to create unique functional characteristics.

TABLE 18-2 Critical Temperatures of Gelatinization

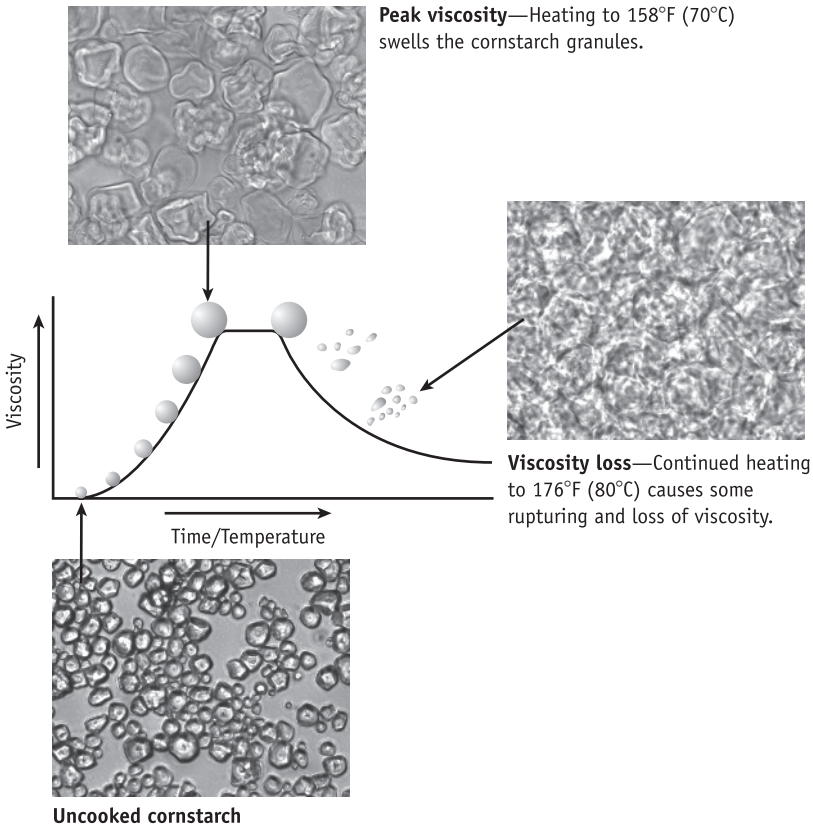
Starch Source	Critical Temperature, °F (°C)	Characteristics of Cooked Starch
Roots and tubers (potato and tapioca)	133–158 (56–70)	Form viscous, long-bodied, relatively clear pastes; weak gel upon cooling.
Cereal grains (corn, sorghum, rice, and wheat)	144–167 (62–75)	Form viscous, short-bodied pastes; set to opaque gel upon cooling.
Waxy hybrids (corn and sorghum)	145–165 (63–74)	Form heavy-bodied, stringy, clear pastes; resistant to gelling upon cooling.
High-amylose hybrids (corn)	212–320 (100–160)	Form short-bodied pastes; set to very rigid, opaque gel upon cooling.

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FIGURE 18-4 Gelatinization. Starch granules heated in liquid initially swell, increasing viscosity. Heating beyond the maximum obtainable volume ruptures the starch granules, resulting in less viscosity.



Reprinted with permission from Ratnayake, Wajira S., and Jackson, David S., "Gelatinization and Solubility of Corn Starch during Heating in Excess Water: New Insights" Faculty Publications in Food Science and Technology. Paper 118. Copyright (2006). American Chemical Society.

The temperature at which a particular starch gelatinizes generally falls within a narrow range. Larger starch granules, such as those of potatoes, gelatinize at lower temperatures, while smaller granules, such as those of wheat, gelatinize at higher temperatures.

Heating Time

Heating beyond the gelatinization temperature decreases viscosity (Figure 18-4). Starch granules break apart when continued heating stresses the bonds holding them together.

Stirring

Stirring during the early formation of the starch paste, or the gelatinizing starch mixture, is required to ensure uniform consistency and to prevent lumps from forming. Continued or too vigorous stirring, however, causes the starch granules to rupture prematurely, resulting in a slippery starch paste with less viscosity.

Acid

Acids such as lemon juice, wine, and vinegar will weaken the ability of starches to thicken. Specifically, a pH below 4.0 decreases a starch gel's viscosity. Any acidic fruit juices should be added to pie fillings or salad dressings after gelatinization has occurred. In order to maintain viscosity in canned high-acid foods, commercial food processors use chemically altered starches that are resistant to acid breakdown (see the "Cross-Linked Starch" section later).

Sugar

Sugar competes with starch for available water, delays the onset of gelatinization, and increases the required temperature (25). Factors contributing to the delayed gelatinization caused by sugars include reduced granular swelling and starch–sugar and starch–water interactions. Adding too much sugar inhibits complete gelatinization and results in a thick, runny paste. Sugars differ in their ability to delay gelatinization, with the following sugars having the greatest impact (in order from greatest to least): sucrose, lactose, glucose, and fructose.

Fat

Fat delays gelatinization by coating the starch and preventing it from absorbing water.

Gel Formation

Gelatinization must occur before the next step, gel formation, also called "gelation" (see Chapter 15) (Chemist's Corner 18-4). During this process, a fluid starch paste, called a *sol,* firms into a semi-solid paste, called a *gel*. Not all starches will gel, but among those that do, the gel forms after the gelatinized sol has been cooled, usually to below 100°F (38°C) (31). A pie filling, for example, will not solidify until it cools. Gel formation is dependent on the presence of a sufficient level of amylose molecules because amylose will gel and amylopectin will not. As they cool, the linear amylose molecules lose energy and form strong bonds, creating a three-dimensional network that traps water and increases the rigidity of the starch mass (4). Highly branched amylopectin molecules also form bonds, but they are too weak to contribute to rigidity (35). However, high amylopectin starches such as cornstarch, tapioca, potato, and wheat flour do thicken at lower temperatures, making them ideal for pie fillings and sauces. To avoid lumping, mix them with an equal amount of cold water and stir before adding them to substances that need to be thickened.

Regular cornstarch contains large amounts of amylose, which makes it a good gelling agent. Starches that contain high levels of amylose form more opaque gels than starches containing low levels, such as potato and tapioca, which result in more translucent gels. High-amylose starches have a much lower viscosity than other starches (15). Low-amylose potato starches are commonly used in European recipes, often to thicken foods such as soups and sauces in which gel formation during cooling would be undesirable (27). Arrowroot is composed of very small granules, creating very smooth sauces (27). It can be used in stir-fry sauces and fruit pie fillings. Commercially, regular cornstarch is most often used to thicken puddings and fruit juices, whereas waxy cornstarch is preferred in

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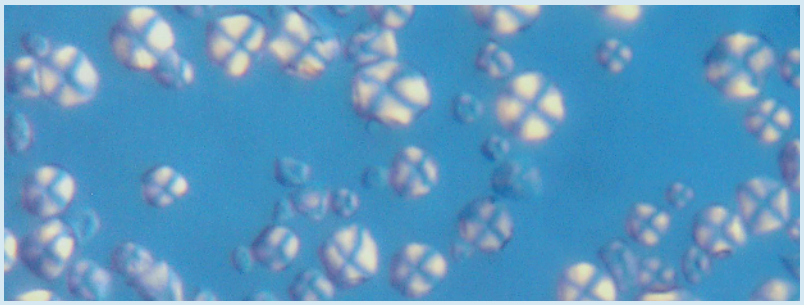
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CHEMIST'S CORNER 18-4

Gelatinization under a Microscope

The process of gelatinization can be detected by looking at the starch granules with a microscope. Starch molecules are stored within the cell's starch granules, and the high degree of order within these granules is depicted by their birefringent nature, which enables them to refract light in two directions. As shown in Figure 18-5, this birefringence is visible as what look like dark crosses when viewed with a polarized-light microscope. After gelatinization occurs, this birefringence disappears, indicating a loss of crystallinity (19).

FIGURE 18-5 Cornstarch molecules.



Jan Homann

the manufacture of canned and frozen food products. Waxy maize starches are used in many frozen foods because other starches lose some of their thickening power when frozen. Waxy hybrids, a cross between corn and sorghum, contain very little amylose and do not gel (22).

Retrogradation

As the gel cools, bonds continue to form between amylose molecules, and **retrogradation** occurs. The effects of retrogradation are illustrated by the top photo in Figure 18-9 (page 356), where it appears the pie filling is losing its structure or "leaking" also known as **syneresis** or weeping (34). Retrogradation is accelerated by freezing, so the starches used in frozen food products usually have to be low-amylose varieties, such as waxy corn or sorghum. The best way to prevent retrogradation is to use the gelled food as soon as possible.

Dextrinization

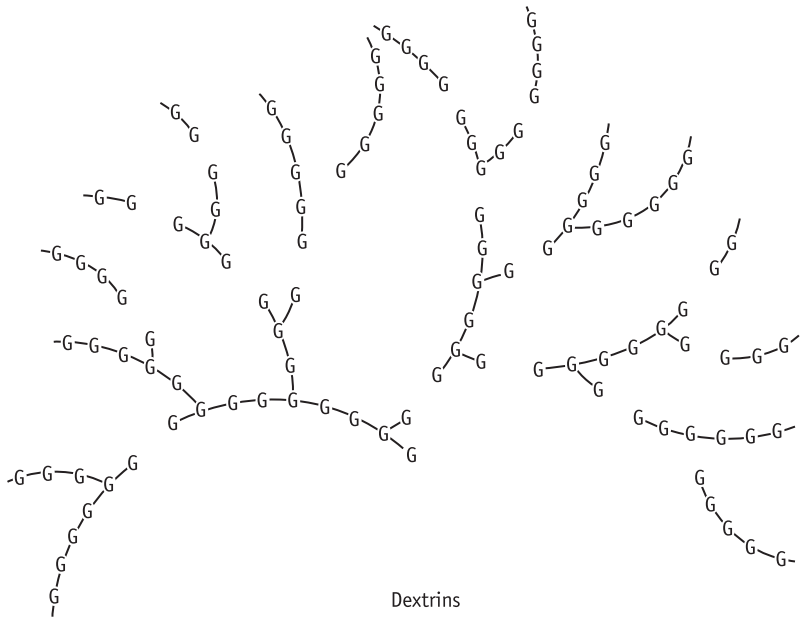
Another process characteristic of starches is **dextrinization,** which results in an increase in sweetness. A side effect is that dextrinized starches lose much of their thickening power because they have been broken down into smaller units; thus, more flour is required to thicken gravy if the flour has been browned in the gravy-making process. The traditional darkened flour used in Louisiana gumbo has almost no thickening power left, although it adds tremendous flavor to the stew.

How & Why?

Why does toasted bread taste sweeter than untoasted bread?

Toasting or browning breaks down amylose and amylopectin into dextrins (Figure 18-6), which cause toast to taste noticeably sweeter than the original bread. Gravies and cooked commercial breakfast cereals also taste sweeter than their unprocessed ingredients because of this process.

FIGURE 18-6 Dextrinization. The formation of dextrins from amylopectin. Each G represents a glucose molecule.



Retrogradation A phenomenon during the cooling of gelled starch when the amylose and amylopectin molecules "retrograde" and realign themselves. Staling in baked products and syneresis in gels may result.

Syneresis (weeping) The seepage of water out of an aging gel because of the contraction of the gel (bonds tighten between the amylose molecules). Examples are liquid seeping out of foods include aging yogurt, puddings, and gelatins.

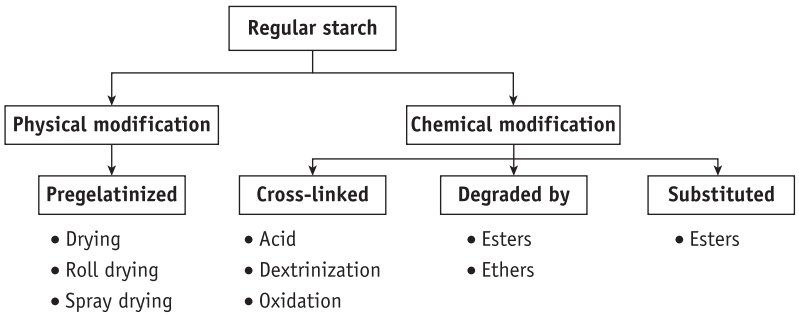
Dextrinization The breakdown of starch molecules to smaller, sweeter-tasting dextrin molecules in the presence of dry heat.

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FIGURE 18-7 Two methods of modifying starches.



Instant or Pregelatinized Starches

Regular starches can be altered to yield a wide variety of modified starches, extending their usefulness in food processing. As Figure 18-7 outlines, starches may be modified physically, enzymatically, or chemically (see the "RS4 Modified (Chemically) Starches" section later) to alter the starch's gelatinization, heating times, freezing stability, cold-water solubility, or viscosity. Examples of physically modified starches include corn or tapioca starch exposed to high hydrostatic pressure to reduce its gelatinization temperature and instant starch (20).

Instant/pregelatinized starches do not have to be heated in water to expand and gel (26). They have already been cooked and dried, so when cold water is added, they absorb it immediately and expand on the spot. Instant starches make it possible for the food industry to sell instant dry-mix puddings, gravies, and sauces. The dry-mix puddings made from instant/pregelatinized starch, listed as modified cornstarch on the ingredient label, are easily prepared by adding cold milk and mixing briefly. Mixes that require heat for preparation contain plain cornstarch.

Resistant Starches (RS)

A small amount of starch, called resistant starch, "resists" digestion by enzymes in the small intestine and therefore does not contribute kcalories (36). They are usually fermented by gut bacteria in the colon, but gas produced from bacteria can make some people experience bloating, belching, and flatus (3). Resistant starches represent less than 3% of food starches (Chemist's Corner 18-5), and some researchers suggest benefits of resistant starch may include improved glycemic (blood glucose level) management, colon health, and weight management (16, 18). Table 18-3 and Chemist's Corner 18-6 define the four types of resistant starch (5, 24). Oxidized and cross-linked RS4 (modified) starches are further described next.

CHEMIST'S CORNER 18-5

Quantifying a Food's Resistant Starches

There are four in vitro methods for quantifying resistant starches in food sources: (1) AOAC 2002.02/AACC Approved Method 32-40, (2) the Englyst method, (3) AOAC 991.43, and (4) AOAC 2001.03 (24). In the United States, most resistant starches are analyzed as total dietary fiber using the AOAC Method 991.43. In this method, the food sample is hydrolyzed with α-amylase, protease, and amyloglucosidase, followed by 78% ethanol precipitation.

CHEMIST'S CORNER 18-6

Types of Resistant Starch

Resistant starches are divided into four categories: RS1, RS2, RS3, and RS4 (18). RS1 starches are physically located within the food matrix and are thus inaccessible to enzymes in the digestive tract (24). RS2 starches are present naturally in a tightly packed radial pattern and are dehydrated (18). This structure, like that of RS1 starches, makes RS2 starches difficult for digestive enzymes to access. RS3 starches are gelatinized and retrograded starches formed when crystalline structures are formed (24). RS4 starches are modified starches created by chemical treatment, as outlined earlier in Figure 18-7 (24). A fifth type of soluble polysaccharide is "resistant maltodextrin," which is not a true starch, but is formed from the rearrangement of starch molecules to an indigestible form (24).

RS4 Modified (Chemically) Starches

Type 4 resistant starches are chemically modified starches (refer to Figure 18-7)

TABLE 18-3 Types of Resistant Starch

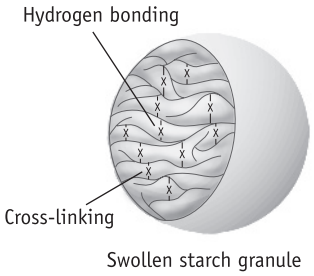
Type	Definition	Food Examples
1 or RS1	Physically inaccessible: Starch granules trapped in food that are prevented from gelatinizing	Seeds, legumes, unprocessed whole grains
2 or RS2	Ungelatinized: Indigestible because of their chemical configuration	Uncooked potato, green banana flour, high-amylose cornstarch or grains
3 or RS3	Retrograded: The heating and cooling of starches during processing renders them inaccessible to enzymatic hydrolysis	Cooked and cooled potato, bread, cornflakes
4 or RS4	Modified: Chemically altered	Commercial starch products used in processed foods (salad dressings, cheese sauces, gravies, soups, etc.)

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FIGURE 18-8 Cross-linking within the starch granule of a modified starch.



Source: CERESTAR USA.

sold only to food-service operations and food companies, not at the retail level; examples include cross-linked and oxidized starches.

Cross-Linked Starch

One of the more commonly used modified starches, cross-linked starch has been treated chemically to link the starch molecules together with cross-bridges (Figure 18-8). Cross-linking makes a starch more heat resistant and less likely to lose viscosity when exposed to heat (8), making it ideal for use in cooked or canned foods such as pizza, spaghetti, cheese, barbecue sauces, pie fillings, bakery glazes, and puddings (21). Incorporating cross-linked waxy cornstarch into a pie filling significantly improves its appearance and texture as compared to a filling made with unmodified cornstarch (Figure 18-9).

Oxidized Starch

Starches may also be modified, specifically degraded, by exposing them to chemical oxidizers. Oxidized starches become less viscous than cross-linked starches, but they are clearer and more appropriate for use as emulsion stabilizers and thickeners. The more powder-like consistency of oxidized starches also makes them ideal for dusting foods such as marshmallows and chewing gum (21).

Mother sauce A sauce that serves as the springboard from which other sauces are prepared.

FIGURE 18-9 Pies made with and without modified cornstarch.



Stacey Newman/Shutterstock.com

Pie made with unmodified cornstarch exhibits syneresis.



MSPhotographic/Shutterstock.com

Pie made with modified starch (cross-linked waxy cornstarch) exhibits good a appearance.

SAUCES

Many sauces contain starch, so it is appropriate to discuss sauces in conjunction with starches. The purpose of a sauce is to enhance a food's flavor, texture, moisture, and appearance. The sauce itself should have a good consistency, a distinctive flavor, and a shine that is characteristic of that particular sauce. The number of different sauces, with wide variations in consistency, temperature, seasoning, and richness, makes categorizing them difficult. For purposes of our discussion, sauces will be distinguished by whether they are thickened or unthickened and by their major unique ingredients. This section provides an overview of sauces along with their functions, discusses their basic ingredients and preparation methods, and finishes with safe storage advice because sauces often contain animal products (meat stock, milk/cream, and eggs).

Functions of Sauces in Foods

Sauces perform myriad functions in foods, not limited to adding moistness, flavor, texture, body (especially to soups), and appearance through their rich color and shine. Fish, meats, vegetables, and even desserts are much more appetizing and appealing when accompanied by sauces. Culturally, sauces add spice and flavor to foods from around the globe; examples include the cream- and butter-based sauces of French cooking, tarator sauces from the Middle East, Asian and Indian sauces, and the hot sauces and salsas of Latin America. Despite their positive benefits to the palate, sauce preparation is often avoided because of their delicate nature, their apparently mysterious preparation techniques, and the extra time and effort required to make them. However, a basic understanding of sauces will eliminate the mystery and open the opportunities for them to be incorporated more often in food preparation.

Types of Sauces

The major sauces used in food preparation are thickened sauces, including cheese sauce, white sauce, and some gravies; and unthickened sauces, including other gravies, hollandaise, and butter, fruit, barbecue, tartar, and tomato sauces (Table 18-4). More frequently, condiments such as mayonnaise, relish, chutney, salsa, ketchup, and mustard serve the same purpose, although they are not generally referred to as sauces.

Whether thickened or unthickened, sauces can be grouped into mother sauces and small sauces.

Mother Sauces

There are five groups of **mother sauces**, also known as grand, leading, or major sauces:

- Béchamel, or white, sauce
- Espagnole, or brown, sauce
- Hollandaise sauce
- Tomato sauce
- Velouté sauce

Small Sauces

With the exception of the tomato and hollandaise sauces, the mother sauces are not usually used as sauces by themselves but rather serve as the base for many other secondary or

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TABLE 18-4 Thickened and Unthickened Sauces

Sauce	Basic Ingredients	Uses
Thickened sauces		
Cheese sauce	White sauce with cheese added. Melted cheese with cream or milk added.	Used for egg dishes, fondues, pasta dishes, and vegetables.
Custard sauce	Eggs, milk, flavoring.	Used in a variety of desserts.
Gravy	Meat stock or juices (extracted from meat during the cooking process) with flour and possibly liquid added.	Pan gravy is served with the meat from which it was derived or with mashed potatoes, vegetables, or breads.
White sauce	Butter, flour, milk, salt, and pepper.	Basic sauce that can be as thin or as thick as desired. Can have added ingredients. It can be used for fish, poultry, and vegetables.
Variations of white sauce	Variations of white sauce are used for caramel, butterscotch, lemon, honey, and other sauces.	These sauces are used for ice creams, steamed puddings, cottage pudding, soufflés, and bread puddings.
Barbecue sauce	Ketchup, onion, vinegar, Worcestershire sauce, and other seasonings. Green pepper optional.	For steaks, burgers, ribs, barbecued ribs, etc.
Unthickened sauces		
Butter sauce	Butter, lemon juice, chopped parsley.	A sauce for fish dishes.
Chocolate sauce	Chocolate, water, and/or milk.	Used for cakes, ice cream, and parfaits.
Fruit sauces	Mostly mashed berries and sugar. Optional: egg white, butter. Added ingredients: sugar, water, cornstarch, etc. (Adding cornstarch makes these thickened sauces.) Apple Cranberry Currant jelly Orange, with or without pineapple Orange-currant Raisin	Fruit sauces are usually not cooked. They are served over ice cream, cottage cake, cheesecake, or in parfaits, etc. For game, goose, pork For turkey For game For ham or tongue For chicken, duck, ham, and lamb For ham or tongue
Gravy	"Just the juices" extracted from meat during cooking (au jus).	Over meats, especially roast beef.
Hard sauce	Butter, powdered sugar, vanilla.	Creamed butter, sugar, and vanilla or other flavoring. This sauce can be used with any hot pudding, especially steamed plum pudding at Christmastime.
Hollandaise sauce	Butter, egg yolks, boiling water, seasoning, lemon juice.	An emulsion, similar to mayonnaise, that is beaten vigorously until smooth and creamy. This aristocrat of sauces is used mostly for fish, asparagus, broccoli, and cauliflower.
Tartar sauce	Mayonnaise, capers, olives, parsley, chopped pickles.	A favorite sauce for fish.
Tomato sauce	Tomatoes, onion, cloves, flour, fat, salt, and pepper.	Tomato sauces have a wide variety of uses with pasta and ketchup dishes and meats—especially hamburgers, hot dogs, and Mexican dishes.

small sauces. Examples of small sauces include cheese, cream, curry, mushroom, and shrimp sauces (Table 18-5).

Preparation of Thickened Sauces

Thickened sauces rely predominantly on starch gelatinization for their smooth texture. Proper preparation consists of selecting the right ingredients, combining them, and slowly heating the mixture to the point of gelatinization.

Ingredients of Thickened Sauces

The three ingredients that serve as the foundation of a thickened sauce are a liquid, a thickening agent, and seasonings and/or flavorings.

Liquid

Any liquid can serve as the body of a sauce (thickened or unthickened), but the most common are the following:

- White stock from chicken, veal, or fish (velouté)
- Brown stock from beef or veal (espagnole)

Small sauce A secondary sauce created when a flavor is added to a mother sauce.

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TABLE 18-5 Selected Small Sauces Derived from Mother Sauces

Mother Sauces		Base Ingredient	Small Sauces
Béchamel (white) sauce		Milk	Cheddar cheese Cream Mornay Mustard
Espagnole (brown) sauce		Brown stock	Mushroom
Hollandaise sauce		Butter	Maltaise Mousseline
Tomato sauce		Tomato	Creole Portuguese Spanish
Velouté sauce		White stock Chicken stock Fish stock	Curry Mushroom Herb

AS Food studio/Shutterstock.com; jmattisson/Shutterstock.com; Richard Griffin/Shutterstock.com; margouillat photo/Shutterstock.com; Fanfo/Shutterstock.com

- Milk (béchamel)
- Clarified butter (hollandaise)
- Tomato juice or purée (tomato sauce)

Thickening Agent

A thickening agent, usually starch, may be added to the liquid to make it more viscous. Like gravies, sauces can be made with or without a thickening agent. Wheat flour is most frequently used as the thickening agent in North America and Europe, while cornstarch is preferred for Chinese food. The 10% by weight protein content of wheat starch creates a cloudier appearance and leaves a more floury taste than the purer starch content of cornstarch, which yields a glossy, translucent sheen. Arrowroot gives a result that is even clearer than cornstarch, but its cost limits its use. Pregelatinized or instant starches speed up the preparation process because they thicken immediately in cold water and do not have to be heated.

Seasonings/Flavorings

The most common seasonings and flavorings for starch-based sauces are salt, black pepper, white pepper, lemon juice, cayenne, herbs, and wine. Any acids in the form of vinegar, wine, tomato products, or lemon are usually added after gelatinization because acid can break down the starch.

Many restaurants use **glazes** as flavorings for sauces. The word *glaze* is from the French *glace* for "glossy." This highly flavored concentrate, which congeals when refrigerated into a shiny, rubbery mass, may be obtained from meat (5), chicken, or fish stock. Because glazes take up much less shelf space than the stocks from which they originate and last for months when refrigerated, they are very convenient to use. A demi-glace is a brown sauce often used in French cuisine that is half veal stock and half espagnole sauce, which is one of the five mother sauces in French cooking. Substituting beef or chicken results in beef demi-glace or chicken demi-glace.

Preparing Thickeners

One of the first steps in preparing a sauce is to add a starch thickener in the form of either a roux (roo), beurre manié (burr mahn-*yay*), or slurry.

Roux

Wheat flour is usually used in preparing a **roux**, rather than cornstarch, potato starch, or arrowroot. Hot liquid is gradually added to the cooked flour and butter, and this combination is cooked until it reaches the desired consistency, depending on what kind of sauce is being prepared.

Three types of roux serve as the foundation in making thickened sauces: white, blond, and brown. Variations in the heating times of the fat–flour combination cause the differences in the colors and flavors, with the most cooking producing the brown roux. As the roux cooks, it becomes darker, and its starchy taste lessens, but its ability to thicken is also reduced as the starch molecules are broken down by heat (12). Thus, the darker the roux, the more of it must be added to thicken a given amount of liquid.

Beurre Manié

In a **beurre manié,** the butter and flour are not cooked (Figure 18-10). Unlike a roux, which is added to a sauce at the beginning, a beurre manié is whisked in, bit by bit, to an already simmering sauce until it reaches its desired thickness just before serving. A beurre manié is not cooked, so it should be used in only small amounts

Glaze A flavoring obtained from soup stock that has been concentrated by evaporation until it attains a syrupy consistency with a highly concentrated flavor.

Roux A thickener made by cooking equal parts of flour and fat.

Beurre manié (burr mahn-YAY) A thickener made by blending equal parts of soft butter and flour together into a soft paste.

FIGURE 18-10 Creating a beurre manié. Equal parts of butter and flour are used to make a beurre manié (left). The blended beurre manié is whisked into the dish to be thickened (right).





Amy C. Brown

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to prevent the taste of the sauce from becoming starchy and unpleasant. A pot of stew (about 3 quarts) generally takes about 2 to 3 tablespoons of butter combined with an equal amount of flour. Once cooked, the stew needs to be taken off the heat because extended simmering can also bring out the floury taste.

Slurry

The third type of thickener, a **slurry**, is made by gradually mixing cold water, which will not cause the starch granules to expand, into either cornstarch, wheat flour, or arrowroot to make a fairly thin liquid. This slurry may then be mixed gradually into a simmering liquid sauce base. When heated (usually for 3 minutes), the starch granules expand and thicken the sauce. Typically, pan gravies are made with a slurry of flour and water. Slurry-thickened sauces are inferior to roux-thickened sauces because they are less stable, and the slurry can leave behind a starchy taste.

TABLE 18-6 White Sauce Ingredient Proportions

Sauce	Fat	Flour	Liquid	Salt	Pepper
Thin	1 Tbsp	1 Tbsp	1 C	¼ tsp	dash
Medium	2 Tbsp	2 Tbsp	1 C	¼ tsp	dash
Thick	3 Tbsp	3 Tbsp	1 C	¼ tsp	dash
Very thick	4 Tbsp	4 Tbsp	1 C	¼ tsp	dash

Preparing a Sauce from a Roux

The most common sauces that depend on the formation of a roux are white sauces and thickened gravies. A basic white sauce is a combination of butter, flour, milk, and seasonings. Whether it is a thin, medium, thick, or very thick white sauce depends on the amount of fat and flour added (Table 18-6). Veal, chicken, or fish stock can be substituted for the milk, and each will add its own distinctive flavor. Thickened gravy is easily created by adding a roux to the pan drippings of a roast.

Combining the Liquid and Roux

After the roux has been prepared by melting the fat, mixing in the flour, and gently heating the mixture until smooth and cooked to the desired degree of doneness (white, blond, or brown), the next step in sauce making is to combine the liquid with the roux. The amount of liquid added to the roux depends on the desired thickness of the sauce. The temperature of the liquid also makes a difference. It is preferable to add room-temperature or warm, not hot, liquid into a moderately hot or warm roux. Neither the roux nor the liquid should be excessively hot. If the roux is cold, the liquid may be fairly hot, but cold liquid should never be added to a cold roux, or the fat in the roux will solidify. Whatever the temperatures of the various elements, the key is to add the liquid gradually and to use a whisk to blend it into the roux.

Heating the Sauce

The next step in sauce preparation is to heat the sauce just to the boiling point and then reduce it to a simmer until its maximum thickness is reached. The brief, initial boiling for 1 or 2 minutes removes the starch flavor. If the temperature is not reduced to a medium or low heat soon enough, the result will be a burned, gritty roux with an off-taste. Simmering the mixture for up to half an hour creates a velvety, smooth texture and further reduces the starchy taste.

Adding Seasonings/Flavorings

The finishing step in the preparation of thickened sauces is the addition of other ingredients, such as cream, egg yolks, seasonings, and additional butter.

Cheese Sauce

Adding cheese to a basic white sauce creates a cheese sauce. Several problems may occur in commercial cheese sauce production, including poor texture, oiling off, syneresis, and oil streaking. Table 18-7 suggests several adjustments to remedy these problems.

Preventing Lumps

The achievement of a smooth, lump-free sauce depends on the principle of separating the starch granules from one another to prevent them from being trapped in a ball surrounded by a film of gelatinized starch. The following techniques help avoid lumps:

- The fat and flour in a roux should be blended until smooth before adding the liquid. If the flour is coated with fat in this way, it will not form lumps when it contacts the liquid.
- A small amount of sugar may be added to separate the granules, but care must be taken because too much sugar will cause the sauce to be irreversibly runny.
- A small amount of the starch (2 tablespoons) may be vigorously mixed with cold water in a lidded jar before incorporating it into the rest of the liquid to be added to the roux.

How & Why?

How are the round balls of tapioca made?

Tapioca pearls come in various sizes (2 to 10 mm) and are popular for making tapioca pudding, thickened pie fillings, and numerous desserts popular in Africa (cassava), Asia, the South Pacific, and South America. The "bubbles" in some Asian drinks are actually tapioca balls. These balls are made from a tapioca flour and water mixture that is pushed through a board with holes in it in a process similar to that used to make pasta from wheat. Unlike pasta, tapioca balls are boiled for 20 minutes and allowed to sit for the same amount of time. Doneness is tested by biting into one; if it is still starchy in the center, it needs more cooking time. Precooked (pregelatinized) tapioca cooks instantly. The balls have little taste so they are often combined with other ingredients, sweet or savory. Tapioca pudding is created by adding sugar, milk, and/or cream.

Slurry A thickener made by combining starch and a cool liquid.

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TABLE 18-7 Troubleshooting Problems in Commercial Cheese Sauce Production

Symptom	Causes	Changes to Make
Poor texture	Viscosity too thick	• Decrease level of thickening agents, and check thickening agent selections. • Reduce heat exposure during processing. • Minimize evaporation losses during processing.
	Viscosity too thin	• Increase level of thickening agent, and check thickening agent selections. • Increase heat exposure during processing.
	Lumpiness or gumminess	• Decrease level of thickening agents or whey protein concentrate. • Increase blending time for uniform dispersion and hydration of thickening agents.
	Graininess	• Ensure uniform blending. • Raise pH to avoid protein precipitation.
	Grittiness or sandiness	• Reduce level of salt in formulation. • Reduce cooking to decrease extent of protein denaturation. • Decrease lactose content to control crystallization.
Oiling off	Emulsion breakdown	• Increase levels of emulsifiers or emulsifying salts. • Use less heat. • Increase blending time to disperse ingredients more uniformly.
Syneresis, weeping	Colloidal system breakdown	• Increase stabilizer level, and check stabilizer selection. • Use more casein or cheese, or use less whey to bind water. • Use less heat to decrease the extent of protein denaturation. • Ensure proper blending to hydrate stabilizer. • Check mineral balance.
Oil streaking	Emulsion breakdown	• Increase levels of emulsifiers or emulsifying salts, use less heat, or increase blending action to disperse ingredients more uniformly.
Color streaking	Uneven color distribution	• Increase blending to disperse ingredients more uniformly.
	Poor color solubility	• Select color with solubility properties to match the system.
Skin formation	Air exposure and evaporation	• Stir and cover during usage, and cover during storage.
Rancid flavor	Lipase activity	• Check incoming ingredients for off-flavors. • Avoid mixing raw milk with pasteurized milk product.
Oxidized flavor	Oxidation	• Minimize exposure to light, and maintain cool temperatures during product storage. • Check incoming ingredients for off-flavors.
Bitter flavor	Protein breakdown to bitter peptides	• Use milder varieties of or less aged cheeses. • Check incoming ingredients for bitter notes. • Check age of cheese sauce.
Improper flavor intensity	Flavor too strong	• Use mild-flavored or less aged cheeses. • Decrease level of flavoring agents. • Decrease amount of enzyme-modified cheeses in blend.
	Too little flavor	• Use strong-flavored or more aged cheese. • Add more flavoring ingredients. • Use enzyme-modified cheese in blend.

Preparation of Unthickened Sauces

Sauces prepared without a starch or any other thickening agent are considered to be unthickened. Briefly discussed here are examples of unthickened sauces such as some gravies and butter, fruit, tartar, barbecue, and tomato sauces. Some salad dressings also fall into this category of unthickened sauces; they are discussed in Chapter 15.

Au jus Served with its own natural juices; a term usually used in reference to roasts.

Gravy

Gravy is made from the juices or drippings remaining in the pan after meat or poultry is cooked. The drippings can be served thickened and with added seasonings as described previously, or unthickened, which is commonly referred to as **au jus** (oh zhue), meaning "in its own juice." Roast beef is frequently served au jus. The basic method for making gravy from the pan drippings of roasted meat or poultry involves five steps: degreasing, deglazing, reduction, straining, and seasoning (Figure 18-11).

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FIGURE 18-11 Preparing gravy through deglazing and reducing.



Slowly heat ingredients left in pan after cooking meat or poultry.



Deglaze with water, 1 cup at a time.



Further reduce to concentrate the sauce.



Add more water, deglaze, and reduce again.

Courtesy of Amy Brown

Step 1—Degreasing

Degreasing consists of separating the liquid from the fat. After cooking, the meat or poultry is removed from the pan so the liquids and residues on the bottom of the pan can be separated from the fat. There are several possible methods of degreasing the sauce:

- Refrigerating the mixture so the fat rises to the surface, hardens, and can be removed
- Tipping the pan so the fat can be skimmed or spooned off from the pan juices
- Using special utensils that permit the fat and liquid to separate so that only the liquid is poured off (Figure 18-12)

Step 2—Deglazing

The next step in making gravy is to **deglaze** the pan. The liquid used may be water, but stock, wine, beer, milk, cream, tomato juice, or vegetable juice may also be suitable, depending on the kind of taste preferred.

Step 3—Reduction

After deglazing comes **reduction**, which concentrates the volume and flavor of the contents in the pan.

Step 4—Straining

At this point, unthickened gravies are often strained through a cheesecloth, strainer, sieve, or china cap to remove large particles.

Step 5—Seasoning

Seasoning is the last step because if it is done before reduction, the result might be an overly seasoned or salty sauce.

Hollandaise Sauce

Egg yolks added to a base of butter are the main constituents of a hollandaise sauce. A small amount of water, salt, vinegar (or lemon juice), and cayenne are also incorporated. The key to this sauce is to heat the ingredients without curdling the egg yolks; this is most easily accomplished by using indirect heat, usually in a double boiler. Hollandaise sauce is particularly susceptible to contamination because after the egg is added, it is not cooked to a temperature high enough (140°F/60°C) to kill bacteria.

FIGURE 18-12 A fat separator allows fat to rise to the top so remaining liquid can be poured out separately.



Serebryakova Ekaterina/Shutterstock.com

Barbecue Sauce

Barbecue sauces consist of tomato products and water, juice, or some other liquid as a base. Sugar, sautéed onions, vinegar, and seasonings or flavorings such as chili powder, pepper, salt, and dry mustard distinguish one barbecue sauce from another. All the ingredients are combined in a saucepan and simmered for at least 20 minutes.

Butter Sauce

The simplest butter sauce is plain melted butter, but many variations are possible. These variations, such as clarified, brown, and black, are described in more detail in Chapter 22.

Fruit Sauce

Sauces based on sugar and fruit are relatively easy to prepare. Some fruit sauces are thickened by adding cornstarch or flour and briefly heating the concoction until the starch gelatinizes.

Tartar Sauce

This sauce is prepared by adding chopped pickles, onions, capers, parsley, mustard, or shallots, or some combination of these, to a mayonnaise base. No cooking is required.

Deglaze To add liquid to pan drippings and simmer/stir to dissolve and loosen cooked-on particles sticking to the bottom of the pan.

Reduction The process in which a liquid is simmered or boiled until the volume is reduced through evaporation, leaving a thicker, more concentrated, flavorful mass; or the product of this process.

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CALORIE CONTROL
Sauces Hiding Sneaky Kilocalories

Sauces are often the sources of hidden kcalories. A dab to taste is fine, but pouring probably means excess kcalories are being piled on the plate.

- **Choose tomato-based sauces.** The water-based tomato sauce and marinara-type sauces are far lower in kcalories than sauces made from fat and flour, as shown in Table 18-8.
- **Gravy choices.** Au jus (just the juices) packs only 20 kcalories for each half cup, as compared to the 45 kcalories found in gravies made by adding flour to the juices.
- **Heavy hitters.** Look out for the 60+ kcalories in each tablespoon of tartar sauce, pesto, or regular mayonnaise.
- **Double dipping.** Two dips into a 50-kcalorie sauce or condiment equal 100 kcalories. Four dips yield 200, and eight add up to 400 kcalories (without counting the chips).

TABLE 18-8 Kilocalories in Common Sauces and Condiments (1 tablespoon)*

Under 25 kcalories	25–50 kcalories	Over 50 kcalories
Gravy (au jus) (3)	Barbecue (26)	Butter (60)
Tomato (4)	Alfredo (28)	White (60)
Soy sauce (10)	Horseradish (28)	Velouté (60)
Mustard (yellow) (10)	Guacamole (30)	Tartar (65)
Ketchup (15)	Honey mustard (45)	Pesto (78)
Mayonnaise (fat-free) (10)	Mayonnaise (light) (50)	Mayonnaise (regular) (100)
Relish (15)	Ranch dressing (50)	
Cocktail (15)	Chocolate sauce (50)	
Marinara (15)	Hollandaise (50)	
Chili (18)		
Béchamel (18)		
Fruit (plum) (20)		
Worcestershire (20)		
Gravy (regular) (30)		

*Brands will vary, so read the Nutrition Facts label.

Tomato Sauce

As one of the mother sauces, tomato sauce is a popular base for many foods. Spaghetti sauce is one of the most common and familiar tomato sauces. A number of ingredients can be added—chopped onion, tomato purée, tomato paste, canned or fresh tomatoes, cooked ground beef or poultry, and Italian herbs such as basil, oregano, sage, and marjoram. Sometimes wine or stock (chicken or beef) is included as a liquid.

STORAGE OF STARCHES AND SAUCES

The quality of dry starches deteriorates with improper storage. Like any other grain product, they should be kept in airtight containers and stored in a cool, dry place away from moisture, oxygen, light, and pests. Many foods made with starches contain eggs, milk, cream, or other dairy products, all of which make them very prone to bacterial contamination and thus to causing foodborne illness. Sauces made with these ingredients should be heated to 165°F (74°C) and kept out of the temperature danger zone (40 to 140°F/4 to 60°C for consumers; 41 to 135°F/5 to 57°C for retailers). Thickened sauces should also be prepared, served, and stored with caution. These products should be stored in the refrigerator and never left to sit for long at room temperature.

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PICTORIAL SUMMARY / 18: Starches and Sauces

As a complex carbohydrate, starch, in the form of potatoes, rice, noodles, and sorghum, is a mainstay of diets throughout the world. In food preparation, starch contributes to the texture, taste, and appearance of many foods such as sauces, gravies, cream soups, salad dressings, and desserts.

STARCH CHARACTERISTICS

Starches are derived from the seeds and roots of various plants. The size and shape of starch granules differ according to their source. Starches provide 4 kcalories per gram and are a good source of energy. Starches are used in many food products as thickening agents, edible films, and sweeteners (dextrose and syrups).



STARCH TRANSFORMATIONS



When starch granules are heated in a liquid, they absorb the liquid, swell, and increase in viscosity and translucency —a process called "gelatinization."

Factors affecting gelatinization include the following:

- **Water:** Should be sufficient for absorption by the starch.
- **Temperature:** Transition temperatures for various starches differ, but most are 133 to 167°F (56 to 75°C).
- **Heating time:** Heating beyond the gelatinization temperature decreases viscosity.
- **Acidity:** A pH below 4.0 decreases the viscosity of a starch gel. Acidic ingredients such as fruit juices should be added after gelatinization.
- **Fat:** Fat delays gelatinization by coating the starch and preventing water absorption.

SAUCES

Starches are used to thicken sauces and gravies. The basic ingredients of most sauces are liquid, an optional thickening agent, and seasonings and/or flavorings.

The wide array of sauces makes it difficult to classify them, especially as they differ so much in consistency, temperature, seasoning, and richness.

The following sauces are used in food preparation:

Thickened

- Cheese
- White sauce
- Some gravies

Unthickened

- Hollandaise
- Butter
- Fruit
- Tartar
- Barbeque
- Tomato
- Some gravies

The five groups of mother sauces:

- Velouté
- Espagnole/brown
- Béchamel/white
- Hollandaise
- Tomato

} These three serve as a base for secondary sauces.



STORAGE OF STARCHES AND SAUCES

Dry starches are stored like any other grain product—in an airtight container in a cool, dry place away from moisture, oxygen, light, and pests. Foods and sauces made with starches are particularly prone to microbial contamination when they contain eggs, milk, cream, or any other dairy product, and therefore should be stored in the refrigerator.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Amylose has a _____ structure, whereas amylopectin is _____.
   a. branched, smooth
   b. linear, branched
   c. branched, linear
   d. linear, smooth

2. What is the word used to describe the breakdown of starch molecules to smaller, sweeter-tasting molecules in the presence of dry heat?
   a. Gelatinization
   b. Dextrinization
   c. Retrogradation
   d. Deglazing

3. Starches that have been altered to affect their heating times, viscosity, or gelatinization are referred to as _____.
   a. gelled starches
   b. smooth starches
   c. tough starches
   d. modified starches

4. A roux is a thickener made by cooking equal parts flour and _____.
   a. fat
   b. water
   c. stock
   d. starch

5. What two ingredients are combined to make a slurry?
   a. Flour and hot water
   b. Flour and starch
   c. Starch and cool liquid
   d. Cool liquid and hot liquid

6. The increase in volume, viscosity, and translucency of starch granules heated in a liquid is referred to as _____.
   a. gelatinization
   b. dextrinization
   c. retrogradation
   d. deglazing

7. The seepage of water out of an aging gel because of the contraction of the gel is called _____.
   a. gelatinization
   b. dextrinization
   c. retrogradation
   d. deglazing

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Discuss the various ways in which the food industry uses starch.
2. Briefly describe the basic structure of starch. What is unique about the structure of *waxy* starches?
3. Describe the various steps in the gelatinization process.
4. Explain how the following factors influence starch gelation: temperature, heating time, stirring, acid, sugar, and fat.
5. State the difference between a gel and a sol. Define *retrogradation*. What is the best way to prevent retrogradation from occurring?
6. Describe how the following starches differ in their gelling ability: starches with high levels of amylose (regular cornstarch), starches with low levels of amylose (potato and tapioca), and waxy hybrids.
7. Explain *dextrinization*, and describe the benefits and potential side effects of this process in food production.
8. Define *modified starch*, and explain how it is used in the preparation of various food products.
9. Explain the relationship between a mother sauce and a small sauce. What are the differences among a roux, a beurre manié, and a slurry?
10. List the three ingredients that serve as the foundation of thickened sauces. Provide examples for each.

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19



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Quick Breads

Preparation of Quick Breads 385
Varieties of Quick Breads 386

Archaeological evidence suggests that the first bread eaten by our human ancestors was a quick bread. It was probably made by mixing flour with water and baking the dough on hot stones. Quick breads are called *quick* because they are baked immediately after the ingredients have been mixed. There is no waiting, as with yeast breads, for leavening (rising) to take place through the slow fermentation of yeast. Instead, quick breads are leavened during baking with air, steam, and/or carbon dioxide, which can be produced through the action of baking soda or baking powder (see Chapter 17). In short, quick breads are made quickly and without yeast, whereas yeast breads take hours because of the time required for the yeast to multiply before the cells are able to release enough gases to raise the dough.

As discussed in Chapter 17 on flour mixtures, the basic bread ingredients are flour, liquid, salt, and leavening agents. All-purpose flour is most commonly used in quick breads, but various other grain flours can be added to contribute to flavor, color, and texture. Occasionally, cake flour is used in the sweeter quick breads, such as coffee cakes. Milk is the most frequently added liquid. Quick breads may also contain added fat, eggs, and sugar, making them sweeter than breads leavened with yeast. If fat is added, it is usually in the form of butter or margarine. The proportions of these various ingredients differ depending on the specific quick bread, but Table 19-1 lists some general guidelines.

This chapter focuses on the characteristics and/or preparation of various quick breads made from pour batters (pancakes, crêpes, waffles, and popovers); drop batters (muffins, quick tea breads, coffee cakes, and dumplings); and doughs (unleavened—actually, steam-leavened—breads such as tortillas, chapatis, crisp flatbreads, and matzo; and biscuits, scones, and certain crackers that may be leavened with the action of baking powder or soda).

PREPARATION OF QUICK BREADS

The two most important considerations when preparing quick breads are the consistency of the batter and the cooking temperature. To avoid undesirable gluten development, batters are mixed only until the dry ingredients are moistened. Thinner pour batters are used to make pancakes, crêpes, waffles, and popovers. Thicker drop batters are used to produce quick breads such as muffins, Boston brown bread, corn bread, hushpuppies, quick tea bread, some

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TABLE 19-1 Quick Bread Ingredient Proportions

Baking Quick Bread	Flour	Liquid*	Fat	Sugar	Eggs	Baking Powder	Salt
Biscuits	1 C	⅓ C	2½ Tbsp	0	0	2 tsp	½ tsp
Cream puffs	1 C	1 C	½ C	0	4	0	¼ tsp
Muffins	1 C	½ C	1–2 Tbsp	1–2 Tbsp	½	2 tsp	½ tsp
Pancakes	1 C	1 C	1 Tbsp	1 tsp	1	1–2 tsp	¼–½ tsp
Popovers	1 C	1 C	0–1 Tbsp	0	2	0	½ tsp
Waffles	1 C	⅝ C	¼ C	1 tsp	1	1–2 tsp	¼ tsp

*The liquid is milk, except for in cream puffs, which use boiling water.

coffee cakes, and dumplings. Even though quick tea bread and coffee cake batters are poured from the mixing bowl into baking pans, they are still called drop batters. Doughs contain more flour than drop batters do and are kneaded briefly. They serve as the basis for unleavened breads, biscuits, and scones.

The Muffin Method

The muffin method is the basic method of preparing many quick breads and consists of three steps:

1. Sift the dry ingredients together.
2. In a separate bowl, combine the moist ingredients.
3. Stir the dry and moist ingredients together with only a few strokes, until the dry ingredients are just moistened but still lumpy.

When kneading is called for, it is very brief, approximately ten strokes. Overkneading creates too much gluten, which causes the finished bread to be dense and heavy. Unlike yeast breads, quick breads are baked immediately after the batter is mixed. For most quick breads, the pans are greased, filled two-thirds full, and baked at between 350°F and 450°F (177°C and 232°C), depending on the type of bread. The bread is done when it is brown and passes the toothpick test: inserting a wooden toothpick vertically into the center, immediately withdrawing it, and checking to see if it is completely clean of batter. If there is no batter clinging to the toothpick, the bread is done.

Additives Used in Quick Breads

Food additives are included in all kinds of baked goods, and quick breads are no exception. Calcium propionate, sodium propionate, sodium diacetate, and sorbic acid are preservatives that inhibit mold growth. Corn syrup provides the dual benefits of a sweetener and a preservative. Sucrose, or table sugar, is another sweetener used for flavoring. Polysorbates act as emulsifiers to help ingredients mix well. Sodium citrate speeds color fixation of baked goods. Tartaric acid is a common additive that controls pH.

VARIETIES OF QUICK BREADS

Quick breads can be categorized according to the flour mixture from which they originate: batter (pour or drop) or dough. Flour mixtures differ based on the amount of added water. The fluidity of the dough along with its ingredients and preparation method determine what type of quick bread is produced. This section describes the various quick breads that can be prepared from each type of flour mixture.

Pour Batters

Quick breads made from pour batters include pancakes, crêpes, waffles, and popovers. These quick breads contain enough fluid to allow their batters to actually pour. Approximately ⅔ to 1 cup of water is added for every cup of flour when making pour batters.

Pancakes



Pancakes are made from a pour batter, the consistency of which depends on the proportions of ingredients. The mixing technique and the griddle temperature are the key factors affecting pancake quality. The muffin method is used for mixing the liquid and dry ingredients. Too much stirring will result in dense, heavy pancakes, because stirring develops gluten and causes the carbon dioxide gas in the batter to escape.

To cook pancakes, a griddle or frying pan is heated and then tested by flicking a few drops of cold water onto the surface. If the water pops up and "dances" across the surface of the griddle, the temperature is just right; it is too cold if the water droplets stay on the surface and boil, and too hot if the water drops evaporate instantly. The griddle should be lightly greased, although some griddles are specially coated so that adding a film of fat is unnecessary. For each standard-size pancake, ¼ cup of batter is gently poured onto the griddle. When bubbles start to appear over most of the pancake's surface, the underside should be a delicate brown, and it is ready to turn over. Any additions, such as fruit (e.g., blueberries) or nuts, are added before turning. The second side will usually not brown as evenly as the first, which always serves as the presentation side. For best results, turn the pancakes only once and do not press down on them with the spatula, as pressure will result in a too flat, heavy product.

Crêpes



Crêpe is the French word for a thin pancake used to wrap other ingredients. The fillings in crêpes may be quite sweet—syrups, creams, or fruit—in

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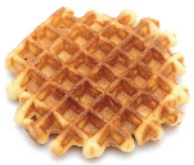
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which case the crêpes are classified as a dessert (crêpes suzette, crêpes Jacques, crêpes empire, and crêpes soufflé) or as a sweet-roll-type breakfast item (3). Blintzes are sweet crêpes that have been filled and then sautéed. Crêpes can also be filled with nonsweet (savory) preparations such as chicken, meat, seafood, and vegetable combinations.

Lacking the baking soda and/or powder used in pancakes, crêpes are much thinner. Crêpe batters are best made in advance and allowed to sit in the refrigerator for several hours or overnight to allow the flour to absorb all the liquid. The batter is then thinned with milk. A special crêpe pan, essentially a frying pan with about a 6-inch diameter, is often used, although it is not required. The pan is heated until hot, brushed lightly with melted butter, and filled with a thin layer of batter that is then spread quickly by tilting and rotating the pan. Care should be taken not to let batter slip up the sides. If the batter is too thick to pour, slightly more milk should be added; conversely, if large bubbles form as the crêpe cooks, the batter is too thin and needs more flour. The crêpe is turned with a flat spatula when it is golden brown on the bottom, after which it is heated for another minute and then gently slid from pan to plate. Crêpes are usually stacked on top of each other to prevent them from drying out while others are made.

Waffles



Waffles are made from a pour batter that contains more fat than a pancake batter. Folding beaten egg whites into waffle batter adds extra crispness and lightness. A waffle iron should be greased lightly with a vegetable spray. Most have an indicator that tells when the waffle iron has reached the proper temperature. When that temperature is reached, the batter is poured into the middle of the waffle iron for even distribution. Pouring the batter from a pitcher, ladle, or measuring cup allows proper monitoring of the batter flow. When the waffle iron is two-thirds full, the cover is closed, and the waffle is cooked for approximately 5 minutes, or until steam has stopped escaping from the waffle iron. If the lid offers any resistance, the waffle is not quite ready. Waffles are done when they are golden brown, crisp, and tender.

Waffle irons should never be submerged in water for cleaning. They should be brushed free of crust and crumbs and the outside wiped clean with a damp cloth.

Popovers



A popover is a puffy bread product that looks like an oversized, tall muffin, but with a consistency more like a warm roll. A popover has very thin, moist sides and a hollow center. The name of this quick bread comes from the behavior of the batter during baking: it expands to such a degree that it "pops over" the sides of the container. Popovers can be plain or flavored with herbs, spices, or cheese. They are made from one of the thinnest of all quick bread batters with a liquid-to-flour ratio of 1:1.

Gluten does not readily develop when there is so much liquid, so popovers rely on protein coagulation and starch gelatinization for structure. It is for this reason that at least two large eggs per cup of flour are added to a popover flour mixture (10). Lack of sufficient eggs in the mixture will result in a soggy, compact popover that will fail to expand properly. Egg proteins and starch both provide structural strength, while fat, either added as an ingredient or provided by the egg yolks, helps to make the popovers tender.

It is important not to add too much fat to the flour mixture because it will weaken the popover structure, allowing steam to escape and hindering the formation of the cavity. Too much water will have the same effect. Another crucial factor in the formation of the cavity is the depth of the pans, which should be twice as deep as those used to make muffins. Although muffin pans or custard cups can be used, special popover pans are best. These pans enable the steam to collect in such a way that if the ingredients are prepared and baked properly, they literally pop up from the baking cup. The individual cups should be heavily greased and the oven and cups preheated while the batter is being made.

The muffin method is used to combine the ingredients; however, the batter is beaten until it is smooth and free of lumps. In the case of popovers, this additional beating is desirable because it gives the finished product its characteristic chewy texture. Overmixing is not a problem because of the large amount of water, which prevents excess gluten formation. When the batter is ready, the preheated cups are filled three-quarters full of batter and immediately placed in a hot (450°F/232°C) oven for about 15 minutes. The temperature is then lowered to 350°F (177°C), and the popovers are baked an additional 20 minutes, or until the proteins coagulate and the structure is properly set. The initial high temperature setting and the preheated muffin tins create leavening by converting the water into steam. Opening the oven or removing the popovers too soon can cause them to collapse. After the popovers are baked and out of the oven, sogginess is prevented by making a small slit in the top to allow this steam to escape.

How & Why?

Why do popover batters contain so much liquid?

The high liquid concentration of this pour batter allows the popovers to be leavened with steam, creating the characteristic large cavity in the center. The large amount of liquid in popover flour mixtures also allows gelatinization of the starch during baking, which is indicated in part by the soft, gel-like texture in the inside walls of a baked popover.

Drop Batters

Drop batters do not contain as much water as pour batters—only about ½ to ¾ cup of water for every cup of flour. Examples of quick breads made from drop batters include muffins, quick tea breads, coffee cakes, and dumplings.

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Muffins



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Muffins are one of the easiest quick breads to prepare. They usually contain flour, liquid, fat, egg, sugar, salt, a leavening agent, and a flavoring ingredient that may also add texture. The general ratio of flour to liquid is usually 2:1. Muffins can be quite high in fat and sugar, with honey, molasses, brown sugar, or syrup sometimes taking the place of white sugar. White flour can be partially replaced by other cereal products, such as cornmeal, oatmeal, or whole-wheat flour.

Avoid Overmixing

One of the keys to making a good muffin is to use the muffin method in mixing the ingredients, just barely moistening the dry ingredients. Some small lumps in the batter are desirable; a smooth batter means that overmixing has occurred and that too much gluten has developed. Overmixing creates a muffin with a smooth, peaked top and an interior that is tough and riddled with tunnels (Figure 19-1). The formation of tunnels occurs as the protein in the exterior portion of the muffin coagulates with the increased temperatures of baking, while the interior is still expanding. If there is too much gluten, it continues to stretch with the pressure of the expanding gases. The tunnels form when they are finally coagulated with the heat moving toward the center of the muffin. The likelihood of tunnels is reduced by using whole-grain flours or flours other than all-purpose. The bran from whole-grain flours cuts gluten and interferes with its development, whereas the lesser amount of protein in most other flours decreases their potential for gluten development (10).

Avoid Undermixing

Although both avoiding overmixing and using the appropriate flour help avoid tunnels, undermixing leaves lumps that are too large, indicating insufficient gluten development and resulting in a crumbly muffin that falls apart. Insufficient mixing also leaves the baking powder incompletely moistened, which results in a low-volume muffin. Eggs should be beaten separately before they are added to the liquid ingredients; insufficiently beaten eggs can concentrate on the outside of the muffin, where their coagulation results in an undesirable shiny, waxy appearance (10). A summary of these and other potential problems with muffins, along with their causes, is given in Table 19-2.

FIGURE 19-1 Overstirring muffin batter results in tunnels.



Optimal stirring



Overstirred

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Added Ingredients

Fruits or nuts may be added to the batter to enhance flavor. To prevent their sinking to the bottom of the muffins, gently roll the fruit and nut pieces between lightly floured hands or thoroughly toss them in a bag containing some flour.

Baking

Once mixed, the batter and all its ingredients are ready for the muffin pan. Only the bottoms of the individual cups should be greased because ungreased sides give the dough traction as it rises,

NUTRIENT CONTENT

Quick breads consist **primarily of carbohydrate**, with varying amounts of fat depending on the type of quick bread (see Calorie Control box). They are somewhat **higher in both fat and sugar than yeast breads**, although modifying the ingredients can produce quick breads with less fat and fewer kcalories.

The nutritional profile of certain quick breads can be altered by (8, 12):

Adding Fiber

- Substitute whole-wheat flour, bran, oatmeal, or wheat germ for about one-fourth of the white flour to increase fiber content.

Reducing Sugar

- Reduce sugar by 25% by using dried fruit purées.

Reducing Fat

- Replace hydrogenated vegetable shortening with nonhydrogenated margarine or vegetable oils to decrease the saturated fat content.
- Add starches to reduce fat content (in a few commercial cases).
- Substitute two egg whites for each egg.
- Use flour blends made with a fat substitute (for commercial bakers).

However, low-fat tortillas may have poor dough-mixing properties because of a tough dough, a chewy texture, a tendency to crack during storage, and decreased shelf life (11). Adding a carbohydrate-based fat replacer (hydrolyzed rice flour) hydrated with water mimics the texture and mouthfeel of fat while improving the dough's pliability and rollability, and the tortilla's freshness.

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TABLE 19-2 Quick Bread Problems and Causes

Problems	Causes	Excessive Mixing	Oven too Hot	Oven too Cool	Too much Flour	Baked too Long
Peaked top		X				
Smooth crust		X				
Pale		X		X		
Burned			X			
Tough, "elastic"		X			X	
Tunnels		X				
Very compact		X				
Too dry			X	X		X

thereby allowing it to rise higher. The muffin cups are filled two-thirds full, and the batter is baked at about 400°F (204°C) for about 20 to 25 minutes. The muffins will slide out of their individual cups more easily if the hot pan is first placed on a wet towel.

Muffin Breads

Changes in the basic ingredients of a muffin recipe result in a variety of other quick breads, such as Boston brown bread, corn bread, hushpuppies, and a variety of tea breads.

Boston Brown Bread



Unlike most other breads, Boston brown bread is made with rye and graham flours and is steamed instead of baked. The mixture is placed in containers (coffee cans or round cylindrical baking pans are an option), covered, and placed in a pan of simmering water. The containers are then covered and allowed to steam for 2 to 3 hours, depending on the size of the container. Following steaming, the covering is removed and the bread is placed in a moderate (350°F/177°C) oven for about 15 minutes to allow the top to dry out.

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CALORIE CONTROL
Quick Breads

Low-carbohydrate diets restrict breads, cereals, and pasta because excessive intakes of these can contribute kcalories as well as approximately 15 grams of carbohydrate for each slice or cup. Although it's important to eat at least the minimum amounts of whole grains and breads for good health, it's equally critical to control this category for successful weight management.

- **Count kcalories from bread to stay within your limit.** Bread averages 80 to 200 kcalories for each slice.
- **Limit the number of portions.** For instance, three 7-inch pancakes provide 513 kcalories, but six pancakes provide 1,026 kcalories.
- **Choose smaller portion sizes.** For example:
  - Muffins: mini (1¼ inches) = 68 kcalories, medium = 444 kcalories, extra-large = 660 kcalories
  - Taco shells: taco size = 50 kcalories, salad shell = 280 kcalories
  - Flour tortillas: 6-inch diameter = 94 kcalories, 12-inch diameter = 380 kcalories
  - Pancakes: 4-inch diameter = 84 kcalories, 7-inch diameter = 171 kcalories
- **Watch the butter, margarine, or preserves.** Spreads add kcalories to breads. Fats provide about 100 kcalories for each tablespoon, and preserves add about half that amount (50 kcalories).
- **Each chip counts.** Chips (wheat, corn, etc.) are not kcalorie cheap. A few are fine because they average only 10 kcalories each, but, because they vary in size and thickness, they range from 5 to 40 kcalories each—so read the Nutrition Facts label. To find the number of kcalories for each chip, divide the total kcalories per serving by the number of chips in each serving (i.e., 150 kcalories divided by 15 chips = 10 kcalories for each chip). The small snack bags average 150 kcalories each. Never sit down to a big bag or bowl of chips because one big bag (11 ounces) yields 1,500 to 2,000 kcalories. If your snack cap is 200 kcalories, put 20 chips in a bowl for eating or in a baggie to take to school, work, or elsewhere.
- **Don't dip, just skim.** Dips help you feel full because they are primarily fat. The exception is tomato-based salsa naturally low in kcalories. Skim the chip in a high-calorie dip for taste, rather scooping up a big dollop of dip.

Dip	Serving	kcalories	Fat (g)	Carbohydrate (g)	Fiber (g)
Fat-based (e.g., Ranch)	1 Tbsp	50+	5	2	0
Salsa	1 Tbsp	5	0	2	0

- **Fiber first.** Fiber sends fullness signals to the brain, and soluble fiber stabilizes blood glucose levels. Choosing whole-grain bread products increases daily dietary fiber intake. Crisp breads deliver more grams of fiber and are tasty when served with a small serving of fruit and/or cheese.

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Corn Bread



Corn bread flour mixtures are similar to a muffin batter but include a combination of cornmeal (1¼ cups) and all-purpose flour (¾ cup). Sometimes small chunks of cheddar cheese, onions, chili peppers, corn kernels, and/or cooked meats such as ham or bacon are added. The muffin method is used to combine the ingredients, which can then be used to prepare corn bread, muffins, or sticks. To obtain the characteristic brown, crunchy crust and slightly gritty textured crumb, the pan

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should first be greased and heated to 425°F (218°C) before filling it with the batter. Baking times average 15 minutes for sticks and about 20 minutes for corn bread or muffins.

Hushpuppies



Hushpuppies are a variation of corn bread and are made from a mixed, stone-ground cornmeal drop batter. They are shaped into small round or oblong balls and deep-fried in a skillet. This bread is usually made to accompany pan-fried fish, especially trout or catfish (2). The name is thought to have come from fishermen or cowboys who threw them to their hungry, whining dogs to hush them up.

Tea Breads



Tea breads are similar to muffins, but they are baked in a loaf pan. These are the sweetest of all quick breads and are frequently sliced and served, as the name implies, at teatime or as dessert. Those most commonly encountered are banana, zucchini, nut, carrot, cranberry, and blueberry breads. These breads are usually made from a drop batter that is placed in loaf pans and baked at 350°F (176°C) for about 1 hour. However, smaller containers can be used and the baking time reduced accordingly. Most tea breads keep well if they are wrapped tightly and stored in the refrigerator.

Coffee Cakes



Coffee cakes usually contain nuts and/or raisins and are often topped with a brown sugar and butter mixture or other sweet topping. They may be mixed by the muffin method or by following the individual recipe instructions. Unlike tea breads, they are best served immediately after baking. Coffee cakes made from yeast doughs are not considered to be quick breads.

Dumplings



A dumpling is a small ball of flour (about an inch in diameter) combined with a few other ingredients. Dumplings are simmered briefly (5 to 20 minutes) in water, stock, or gravy and are commonly used as an ingredient in soups or stews. Plenty of liquid should be used to prevent them from becoming overcrowded in the pan, or they will stick together and cook unevenly. Overcooking should also be avoided because protein in the eggs usually used to bind dumplings together will toughen.

Doughs

Some quick breads are made from doughs that are briefly kneaded. The dough may be unleavened, producing a flatbread, or include leavening and used to make biscuits or scones. As explained in Chapter 17, doughs can be either stiff/firm or soft depending on the amount of water that is added to each cup of flour (⅛ and ⅓ cup of water, respectively). Doughs can be used to create quick breads, specifically unleavened (actually, steam-leavened) breads such as tortillas, chapatis, crisp flatbreads, and matzo, and those leavened with the assistance of either baking powder or soda—biscuits and scones.

Unleavened Breads

Unleavened breads are the world's oldest breads and the easiest to prepare (1). Sometimes they are called *flatbreads*, but that is an ambiguous term because some breads leavened with yeast, such as pizza, pita, and English muffins, also appear flat (7). True unleavened breads are leavened by steam rather than some other agent. Flatbreads can be steamed, oven- or skillet-baked, fried, grilled, or baked underneath the hot desert sand. Throughout the world, unleavened breads appear in different forms: tortillas and tacos in Central and South America; chapatis in India, Pakistan, and Iran; crisp flatbreads in Sweden and other Scandinavian countries; and matzo in Israel. Flatbreads represent a major form of wheat consumption in many Middle Eastern and North African countries (5).

FIGURE 19-2 Low-fat tortillas.



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Tortillas

Mexico is the home of the tortilla, an unleavened, circular bread ranging in diameter from 4 to 14 inches (Figure 19-2). Tortillas may be prepared using either wheat flour or cornmeal.



- ***Flour tortilla.*** In contrast to corn tortillas, the more pliable, softer flour tortillas are made from white flour, vegetable shortening or lard, water, and salt. After mixing, the dough is shaped into a circle, rolled or pressed into a flat, thin tortilla, and heated 30 to 60 seconds on each side on a hot griddle at 356 to 410°F (180 to 210°C) (9). Tortillas can be used to make a variety of Mexican dishes, including burritos, enchiladas, and cheese quesadillas (13).



- ***Corn tortillas.*** Corn tortillas have been a staple food in Mexico and Central America for many centuries. Today, sales of tortillas and tortilla chips continue to climb (14). The tougher-textured corn tortillas are prepared from masa, a cornmeal made from

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corn treated with lime, an alkaline solution. Commercially, tortillas are used to make nachos (deep-fried wedges of corn tortillas), tacos, enchiladas, burritos, and tostadas. Tortilla chips can thicken soups and stews.

How & Why?

Why is lime added to corn when making cornmeal?

Whole corn has a hard outer husk, which is softened by boiling it in lime (calcium hydroxide) water, holding it for about 1 hour, and steeping it at room temperature for an additional 16 to 18 hours (6). This cooked maize (nixtamal) is then cooled, washed, and ground into cornmeal. Water and some salt are then added to yield the final product called "masa." The alkaline solution also increases the nutrient content of tortillas made from masa. It increases the mixture's calcium content and simultaneously releases niacin, a B vitamin, from the corn (6, 15).

Chapatis



Common in India, Pakistan, and Iran, chapatis are one of the bread staples in these countries. They are prepared by mixing whole-wheat flour, water, clarified butter (known as *ghee* in Indian cuisine), and salt. This mixture is kneaded and rolled into very thin 6-inch circles before being heated on a hot griddle until the crust browns and blisters.

Crisp Flatbreads



Scandinavian countries are famous for their crisp flatbreads made without any added leavening. The degree of flatness varies from paper thin for Norwegian *lefse* to the thicker crisp breads of Norway, Sweden, and Finland. Rye and wheat are the two most common flours used in their preparation, and the color varies from light to dark brown.

Matzo



Because of their rapid exodus from Egypt in Biblical times, the Israelites did not have time to allow their bread to rise, so Passover (which celebrates the Exodus) is commemorated in part by consuming the unleavened bread known as matzo. Matzo meal is made from the crumbs of matzo and is used for breading and stuffing, for dumplings in Passover soup, in cakes, and as a binding agent.

Biscuits

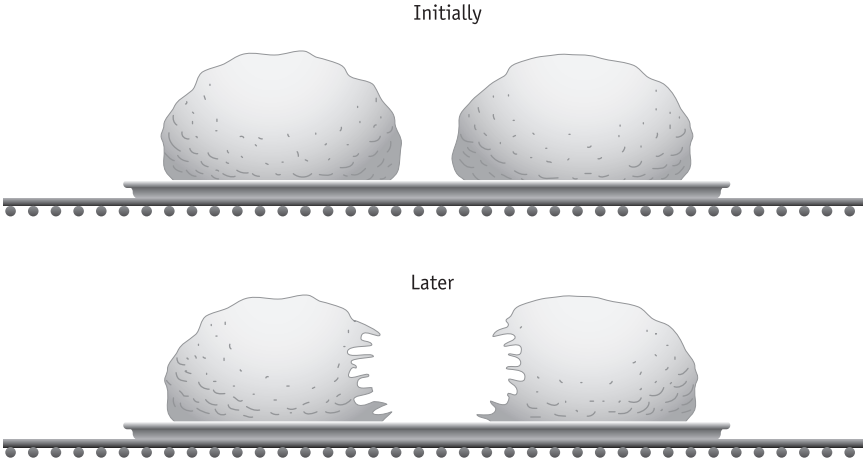


The word *biscuit* comes from the Latin term *bis cotus,* meaning "twice baked" (4). Although the technique is no longer practiced, people used to first cook biscuits in a hot oven and then dry them in a cool oven. Biscuits, which are relatively quick to prepare, rely on fat for shortening power, and on just the right amount of kneading to increase gluten formation. A biscuit dough contains flour, fat, milk, baking powder, and salt. Formerly, lard was usually the fat of choice, but butter may also be used, and margarine or hydrogenated vegetable shortening are common choices. The dough is much less sticky than muffin batter because the ratio of flour to milk is 3:1 (10).

During biscuit preparation, the dry ingredients are first mixed together; the fat is cut in with a pastry blender or two knives until particles the size of rice grains are formed; and then milk or another liquid is added to an indentation, or well, made in the center of the flour mixture. The flour is mixed only minimally in short dough (see Table 24-2 on page 474), to minimize the development of a gluten network (4). After the liquid is mixed in, the dough is then formed into a ball and placed on a lightly floured breadboard, where it is kneaded briefly, for about half a minute, until the stickiness disappears. The lack of liquid makes kneading necessary for gluten development. Overkneading causes toughening because of excess gluten formation, and it allows carbon dioxide gas to escape, resulting in a compact, less tender biscuit.

Once kneaded, the dough is rolled out on a floured surface to the desired thickness: ¼ inch for plain biscuits, ½ inch or less for tea biscuits, and 1 inch or more for shortcake. It is then cut into round shapes using a sharp-edged cutter that has been very lightly dipped in flour. The dough rounds are placed on an ungreased cookie sheet 1½ inches apart to allow for crisp sides. Inadequate spacing between the dough pieces will result in uneven or caved-in sides (Figure 19-3). Lightly brushing the tops with a thin coat of butter or margarine improves browning. Biscuits are baked at 425°F (218°C) for about 10 to 20 minutes, or until the surface turns a golden brown color.

FIGURE 19-3 Baked products placed next to one another in the oven will tear on the sides that are touching.



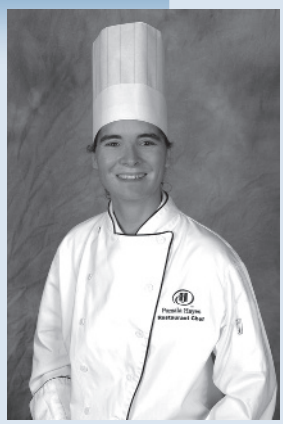
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CAREER CORNER



Pamala Hayes

Pamala Hayes

Ever since Pamala Hayes was in grade school, she has loved to prepare food. Her mother was an excellent cook, and Pamala helped her every chance she got. A unique program in her Ohio high school allowed Pamala to work several hours a day in a hotel kitchen. She liked it so much that she started working in an Argentinean restaurant. On her high school's career day, she learned about the early admissions program to Johnson & Wales University in Rhode Island, from which she graduated with an associate of science degree in culinary arts. One of her degree requirements was a 3-month internship that she completed at Disney World in Florida.

She went to work at the World Center Marriott Resort in Orlando with Marriott International, Inc., an international chain of more than 2,500 restaurants and hotels. Pamala started in the fine dining department as a pantry/pastry chef and worked her way up through grill position, sauté position, and expeditor (grill and sauté coordinator, including vegetables, soups, and garnishes). She then became the chef for one of the Hilton's many restaurants and is responsible for serving 700 people for breakfast and about 150 people for each lunch and dinner. She works five 10-hour shifts a week, but those hours go up on holidays such as Mother's Day and Easter.

Pamala says that she prefers working at hotel restaurants because she likes the "structure, stability, consistency, and security. At free-standing restaurants, there was always the looming threat of disaster, and the work environment depended so much on the manager's personality." She found many of her jobs at CareerBuilder (www.careerbuilder.com) and Monster (www.monster.com). Another major culinary employer, but one that offers dietetic internships, is Sodexo Inc. (www.sodexousa.com), which branched off from Marriott Corporation and is now the leading food-service management corporation in North America. Sodexo manages the food services (cafeteria or restaurants) in more than 6,000 corporations, large hospitals, long-term care and retirement centers, schools, college campuses, and the military.

Buttermilk, whole-wheat flour, cheese, herbs, vegetables, and other ingredients can be added or substituted to produce variations of the basic biscuit. Acidic ingredients (e.g., buttermilk) promote white interiors, whereas more alkaline ingredients (e.g., high levels of baking powder) contribute to a more creamy color.

Scones



Scones contain eggs and milk or cream, which makes them richer than ordinary biscuits. Their flavor also differs from biscuits because they often contain pieces of dried fruits such as raisins, cranberries, blueberries, apples, apricots, currants, or cherries. They are baked at about the same temperature and for the same length of time as biscuits.

The eggs are beaten separately and combined with the cream (2 tablespoons of this mixture are then set aside). Fat is cut into the dry ingredients (flour, baking powder, sugar, and salt), a well is made, and the remaining liquid ingredients are poured into it. The dry and liquid ingredients are combined with a minimum number of strokes. The dough is placed on a floured board, patted down to a ¾-inch thickness, and cut into diamonds or other shapes. To produce a sheen, the tops are brushed with the reserved egg–cream mixture. If desired, the scones can then be sprinkled lightly with sugar.

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Crackers



Crackers are baked products low in both sugar and fat (4). These crisp breads may or may not be leavened (usually, they are chemically leavened with baking soda or powder; see leavening agents in Chapter 17). Holes are pricked into cracker dough to prevent air pockets from forming and bursting during baking. Cracker texture depends on a strong gluten network developed from the protein content and dough quality.

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PICTORIAL SUMMARY / 19: Quick Breads

The first bread eaten by our human ancestors was probably a quick bread, made by adding flour to water and baking the dough on hot stones. Quick breads are baked immediately after the ingredients have been mixed and are leavened with air, steam, and baking soda or baking powder.

PREPARATION OF QUICK BREADS

The basic ingredients of any bread are flour and water or other liquid, and possibly salt and a leavening agent such as baking soda or baking powder. Quick breads usually contain added fat, eggs, and sugar.



The two most important factors when preparing quick breads are the following:

- The consistency of the batter
- The cooking temperature

The muffin method is the basic method of preparing many quick breads. It consists of three steps:

1. Sift the dry ingredients together.
2. In a separate bowl, combine the moist ingredients.
3. Stir the dry and moist ingredients together with only a few strokes, until the dry ingredients are moistened but still lumpy.

Quick Bread Problems and Causes

Problems \ Causes	Excessive mixing	Oven too hot	Oven too cool	Too much flour	Baked too long
Peaked top	X				
Smooth crust	X				
Pale	X		X		
Burned		X			
Tough, "elastic"	X			X	
Tunnels	X				
Very compact	X				
Too dry		X	X		X

For most quick breads, kneading, if called for at all, is very brief, and the pan is greased, filled two-thirds full, and baked at between 350°F and 450°F (177°C and 232°C), depending on the type of bread.

VARIETIES OF QUICK BREADS

The ratio of flour to liquid determines whether the mixture is a pour batter, a drop batter, or a dough.

Doughs contain more flour than batters and are usually lightly kneaded. Quick breads made from doughs include the following:

- Biscuits
- Scones
- Unleavened breads: tortillas, chapatis, crisp flatbreads, matzo, and certain crackers



QUICK BREADS

Pour batters are quite thin. Use for:

- Pancakes
- Crepes
- Waffles
- Popovers

Drop batters are thicker because they have more flour. Use for:

- Muffins
- Tea breads
- Coffee cakes
- Dumplings





Remember: When quick bread dough must be kneaded, this is very brief, approximately ten strokes. Overkneading creates too much gluten, which causes the finished bread to be dense and heavy.

Kneading = Ten strokes!

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The two most important factors when preparing quick breads are the batter's _____ and _____.
   a. thickness, flour
   b. flavor, liquid
   c. consistency, temperature
   d. creaminess, yeast

2. When using the "muffin method" to prepare quick breads, approximately how many strokes should you use when mixing the wet and dry ingredients together?
   a. One
   b. A few
   c. 5 to 10
   d. 20 to 25

3. What is the ratio of liquid to flour in popover batters?
   a. 1:3
   b. 2:1
   c. 2:3
   d. 1:1

4. What type of whole-wheat unleavened bread is commonly used in India, Pakistan, and Iran?
   a. Tortilla
   b. Ghee
   c. Matzo
   d. Chapati

5. To which of the following ingredients can the difference between scones and biscuits be attributed?
   a. Flour
   b. Eggs
   c. Baking powder
   d. Salt

6. A drop batter is used to prepare _____.
   a. pancakes
   b. coffee cakes
   c. crêpes
   d. waffles

7. Biscuits, scones, and unleavened breads are made from a _____.
   a. dough
   b. pour batter
   c. drop batter
   d. thick batter

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

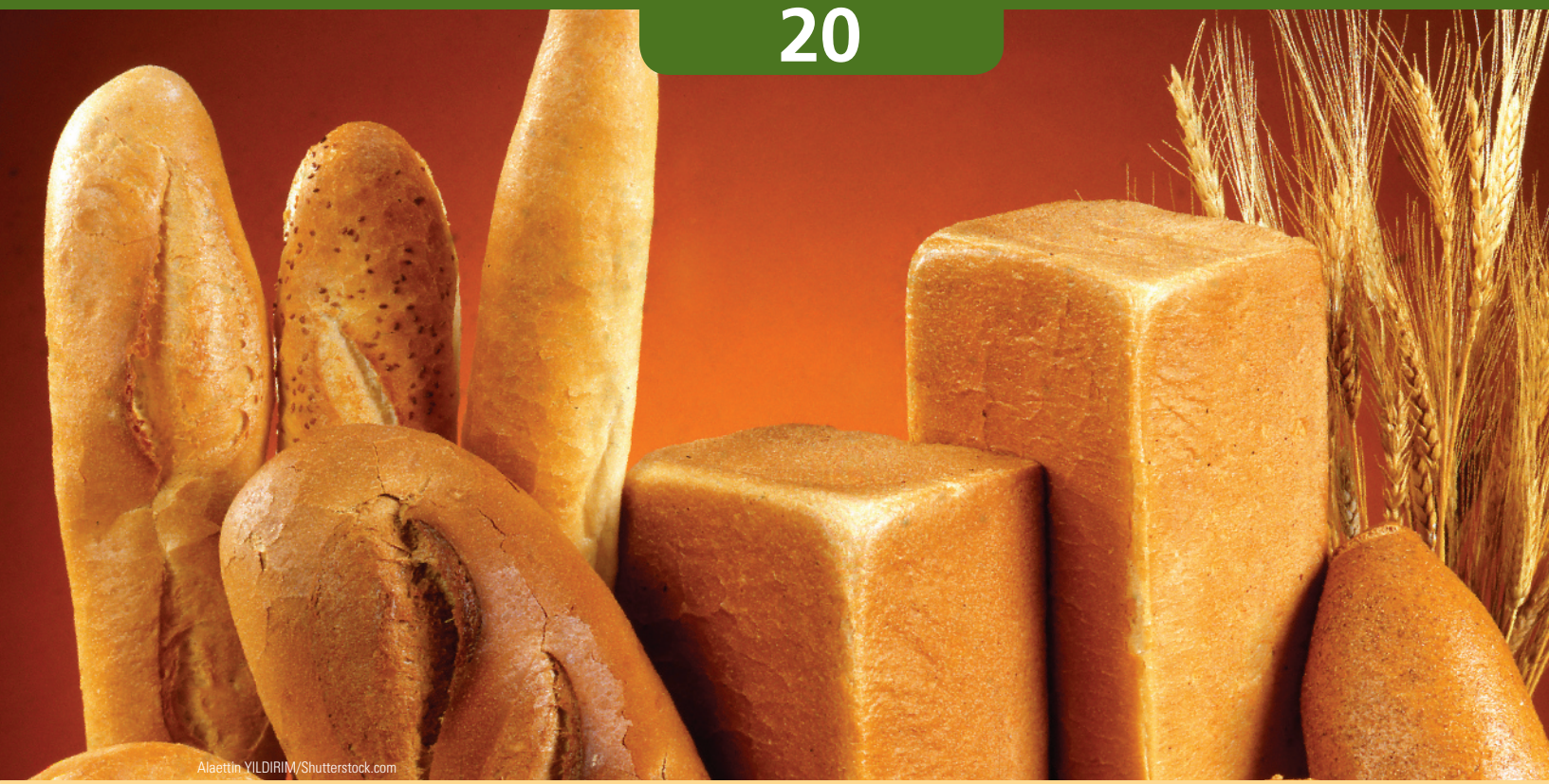
1. Why are quick breads called *quick*? Give several examples of quick breads made from drop batters, pour batters, and doughs.
2. Which mixing method is used to make most quick breads? Explain the three basic steps of this method.
3. Briefly describe how pancakes, crêpes, and popovers are prepared.
4. Why do tunnels sometimes form when preparing muffins, and how can this be avoided?
5. What type of flour is added to corn bread flour to produce a baked product? What other ingredients may be added to corn bread flour mixtures?
6. What are tea breads? Provide several examples.
7. What are dumplings?
8. Provide four examples of unleavened breads. How are unleavened breads different from other quick breads?
9. Briefly describe how biscuits are prepared.
10. How do the methods of preparing scones and biscuits differ?

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20



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Yeast Breads

Preparation of Yeast Breads 395
Types of Yeast Breads . 405
Storage of Yeast Breads 408

When breads are leavened with the carbon dioxide gas produced by yeast, they are known as yeast breads. Baker's yeast, or *Saccharomyces cerevisiae,* is a one-celled fungus that multiplies rapidly at the right temperature and in the presence of a small amount of sugar and moisture. Yeast breads have been around since long before the birth of Christ, and no one knows exactly how it happened that people came to realize that naturally occurring, airborne yeast could be used as a leavening agent. The ancient Egyptians knew the technique and preferred the light airy texture of yeast-leavened bread, and the Romans adopted this procedure, after which it became known throughout the Roman Empire. The basic principles for preparing yeast breads have not changed in the many intervening centuries. This chapter covers the preparation, types, and storage of yeast breads, including loaf breads (wheat, whole-wheat, sourdough, and malt breads), specialty breads, rolls, pita bread, bagels, English muffins, pizza crust, pretzels and bread sticks, and raised doughnuts.

PREPARATION OF YEAST BREADS

Yeast bread is prepared by mixing ingredients into a dense, pliable dough that is kneaded, allowed to rise by fermentation, and then cooked, typically by baking but sometimes by steaming or frying. Normally, the preparation of yeast bread is at least a 2½- to 3-hour operation, which is one reason that many people choose to buy rather than make bread. Sourdough breads take even longer, requiring about 8 to 10 hours to fully develop their flavor. Regardless of the time involved, most yeast breads are prepared with the same basic ingredients.

Ingredients

The fundamental ingredients of any yeast bread are flour, liquid, sugar, salt, and yeast; fat and/or eggs are optional (Table 20-1). Chapter 17, on flours and flour mixtures, explains the individual functions of these ingredients in more detail. Wheat is the most commonly used flour for making breads; rye is the next most common, followed by oat, barley, cornmeal, rice, and other flours. Because flours other than wheat have less gluten-forming ability, these

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TABLE 20-1 Yeast Bread Ingredients and Their Functions

Ingredient	Functions
Flour	Wheat flour is the most common flour used in yeast breads because it has the highest amount of gluten. Gluten is the protein that provides a firm, elastic structure to baked goods. All-purpose flour and bread flour (a specially formulated wheat flour that is high in gluten) can be used interchangeably in recipes. They are used either alone or combined with lower- or no-gluten flours, including whole wheat, rye, rice, or soy, and whole grains such as oats.
Leavening	Yeast is a living organism that is used primarily in bread baking. When yeast is mixed with liquid and some type of sugar and is kept at the proper temperature, it begins to ferment. The fermentation produces alcohol and carbon dioxide—the alcohol burns off during baking, while the carbon dioxide gas is trapped in the elastic network formed by the gluten, stretching and expanding the gluten, and causing the dough to rise. Be sure to check the package for the yeast's expiration date both before purchasing and before using the yeast. There are two major types of yeasts: • *Active dry yeast* is dehydrated and can be purchased in ¼-ounce packets (envelopes) or in jars in the baking aisle of the grocery store. It is available as (1) regular active dry yeast and (2) fast or quick-rising active dry yeast (leavens breads in one-third to half the normal time of regular yeast). • *Compressed, fresh yeast* is moist and *extremely* perishable. It is sold in 0.6-ounce and 2-ounce cakes in the refrigerated aisle at the grocery store. It should be stored in the refrigerator or freezer and then brought to room temperature before use. One ¼-ounce package yeast = 1 scant tablespoon dry yeast = one 0.6-ounce cake compressed fresh yeast.
Sugars/Other Sweeteners	Yeast breads need sugar to feed the yeast that grow and cause the bread to rise. As little as 1 or 2 teaspoons of sugar/sweetener give the yeast a boost and make the dough rise. Granulated sugar, brown sugar, honey, molasses, and maple syrup are the most common sweeteners added to bread flour mixtures. The added sugar also helps to bring out the flavors of the other ingredients in the bread. Sugar also caramelizes during baking, giving the yeast bread a nice brown crust.
Fat	The type of fat used impacts the taste and color of the baked bread. If fat is added, options include butter, margarine, shortening, and vegetable oil. Fat retards gluten development, so a bread loaf prepared with fat has a softer, smoother texture. The fat in bread also slows down moisture loss, so breads containing fat stay fresher longer than those without added fat.
Liquid	The liquid in yeast bread recipes dissolves and activates the yeast and moistens the flour so the gluten can develop. Liquid that is too hot will kill the yeast; liquid that is too cool will not activate the yeast. If the yeast is dissolved in the liquid, the temperature should be warm (105°F/41°C to 115°F/46°C for active dry yeast; 95°F/35°C for compressed, fresh yeast). If the dry yeast is combined with other dry ingredients first, then the liquid is added, the liquid should be very warm (120°F/49°C to 130°F/54°C). Both water and milk are commonly used for preparing yeast bread. Milk makes dough rise more quickly because the yeast thrives on lactose—the natural sugar in milk. This natural sugar also aids in browning the baked bread. Milk also adds flavor and nutrients, and, like fat, helps keep bread fresher longer.
Oats	Oats are a very common ingredient in whole-grain breads. They add texture and a mild nutty taste to all types of yeast breads.
Eggs	Eggs enrich the taste, texture, and color of some yeast breads, adding strength to the elastic network formed by the gluten. They are most typically used in sweet yeast bread recipes.
Salt	Although not a required ingredient, salt gives the yeast bread flavor. Moreover, salt is also added to inhibit yeast growth; otherwise, they would continue to multiply and produce too much carbon dioxide that would cause the bread to rise too much and possibly collapse.

flours must be supplemented by a certain amount of wheat flour in order to improve their baking quality (6).

Food Additives in Baked Products

Fresh bread baked from basic ingredients often does not have any additives other than those used to supplement the flour. Commercial bakers need to protect their baked products from mold, so they usually add calcium propionate or a similar mold inhibitor such as sodium propionate, sodium diacetate, or sorbic acid. Corn syrup may be added as a sweetener and preservative. Polysorbates can be used as emulsifiers, while sodium citrate assists with color fixation in baked goods. Tartaric acid is used to control pH. Hydrocolloids are actually gums that may be of vegetable, animal, microbial, or synthetic origin. They are added to many products, including breads, to improve texture and viscoelastic quality, to slow starch retrogradation, to bind water, to replace fat, to improve the quality of stored products, and as a gluten replacement (18, 19). Hydrocolloids improve mouthfeel and acceptability, increase loaf volume, decrease firmness from staling, and improve the overall shelf life of baked goods (Chemist's Corner 20-1). Other food additives that

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CHEMIST'S CORNER 20-1

Hydrocolloid Food Additives

Hydrocolloid molecules contain numerous hydroxyl groups, making them hydrophilic (water loving) (18). The resulting ability of hydrocolloids to bind large amounts of water provides stability to products that are frozen and thawed. They can also increase the volume and moisture content of bread products. Specific types of hydrocolloids used in breads include carboxymethylcellulose (CMC) and guar gum in rye flour. Sodium alginate, κ-carrageenan, xanthan gum, and hydroxypropylmethylcellulose (HPMC) improve dough stability during proofing. Certain hydrocolloids, including xanthan, alginate, guar gum, pectin, κ-carrageenan, and HPMC positively affect the gelatinization process and pasting properties of wheat flour.

may be used in baked products include, but are not limited to, those listed in Table 20-2.

Mixing Methods

The four best-known methods for mixing yeast breads are the straight dough, sponge, batter, and rapid mix methods. Regardless of the mixing method used, all ingredients should be brought to room temperature prior to mixing in order to obtain the desired dough consistency. The ingredients, their amounts

TABLE 20-2 Selected Food Additives Used in Baked Products

Food Additive	Description
Ammonium sulfate	A popular yeast nutrient
Ascorbic acid (or ascorbate)	A natural antioxidant known as vitamin C
Azodicarbonamide (ADA)	An oxidant added to dough; improves dough strength, stability, flow, and extensibility
B-complex vitamins	A group of water-soluble vitamins such as B_1 (thiamine), B_2 (riboflavin), niacin, pantothenic acid, B_6 (pyridoxine), folate, and B_{12} (cobalamin)
Bromate	An oxidant added to flour; enhances gluten development and makes the dough mixing or kneading less difficult; baking industry use has decreased in recent years
Calcium peroxide	A peroxide that slowly releases oxygen; allows production of softer and drier dough to which more water can then be added, improving machinability
Calcium propionate	A mold inhibitor in the form of a white powder; preferred because it does not affect pH (which can affect yeast development)
Calcium sulfate	A compound of sulfate and calcium used for calcium fortification of baked products, and also provides food for yeast and does not disrupt yeast activity
Cultured whey	A natural mold inhibitor (acts similarly to calcium propionate)
Diacetyl tartaric acid esters of monoglycerides and diglycerides (DATEM)	A vegetable fat derivative; increases volume in baked goods and improves dough stability and tolerance to handling
Guar gum	A natural gum added to dough; increases yield, improves/softens texture, improves handling, and increases shelf life
Maltitol	A sugar alcohol or polyol used as a lower-kcalorie sweetener in baked goods (provides slightly more than 2 kcalories/gram)
Maltodextrin	A sweetener, specifically an oligosaccharide consisting of approximately seven glucose units
Modified wheat starch	Wheat starch that has been modified for increased stability; eases baking and results in a nicely textured finished product
Monoglycerides and diglycerides	Emulsifiers added to dough; improve mixing of the oil and water components, increase dough strength, and enhance texture and increase volume of the bread
Monocalcium phosphate	Provides food for yeast, conditions dough, and produces acids, which lower pH and thus inhibit mold growth
Olestra	A kcalorie-free fat substitute
Sodium bicarbonate	Baking soda
Turmeric	A spice; used primarily as a yellow colorant

Source: www.bread.com/glossary

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TABLE 20-3 Excessively Firm or Soft Dough Problems

Excessively Firm	Excessively Soft
Difficult to mix	Tend to "flow"
Difficult to weigh	Sticky to work with
Slower fermentation	Dough pieces easily lose their shape
Difficult to shape	Finished product remains fairly flat
Poor symmetry in baked goods	Decreased volume
Pale crust	Crumb shows uneven, large cells
Crumb shows dense cells	Deep brown crust has a streaky texture

and types, and how much the dough is mixed determine the dough's consistency. It is important for the dough to reach the desired degree of cohesion because this influences the dough's handling characteristics and the final quality of the baked item (Table 20-3).

Straight Dough Method

The straight dough method consists of placing all the ingredients into a bowl at the same time and then mixing them. For automatic mixing, various dough attachments are available (Figure 20-1). Whether by hand or by machine, the dough is kneaded to develop the gluten and then allowed to rise once or twice before being shaped into a loaf or other form.

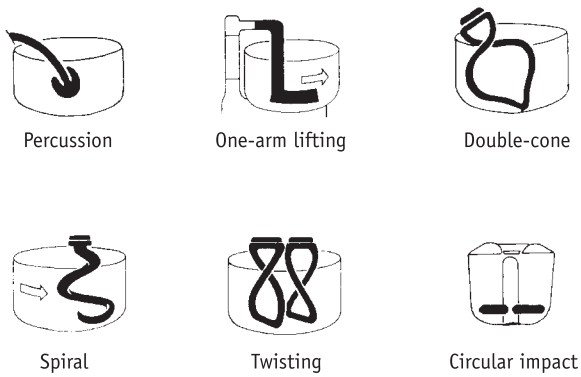
Sponge Method

Combining the yeast with water and slightly over one-third of the flour creates a foamy, bubbly mixture that looks like a sponge. This is allowed to ferment in a warm place for half an hour to an hour in order to become foamy and spongy, after which all the remaining ingredients (sugar, fat, and remaining flour), except salt, are added to the mixture. Salt inhibits the yeast, so it is added last, after yeast activity is well under way (30). Then the dough is treated as a straight dough through kneading, bowl proofing, shaping, pan proofing, and baking.

Batter Method

The batter method is the simplest of all the mixing techniques and requires no kneading after the ingredients have been mixed. It is a good method for the rapid production of the kinds of bread products required in food-service operations. After the ingredients are combined, they are beaten by hand, or by electric mixer or dough hook, to develop the gluten. The batter is ready when it no longer sticks to the sides of the bowl but is still sticky itself. The batter method saves time and is often used for preparing rolls and hot dog and hamburger buns, although it may result in a bread with a more coarse and porous texture.

FIGURE 20-1 Types of dough mixers.



Source: Schunemann C, and G Treu. *Baking: The Art and Science: A Practical Handbook for the Baking Industry.* Baker Technology, Calgary, Alberta, 1988.

Rapid Mix

The rapid mix method differs from the others in that it is used primarily with bread-making machines, kitchen appliances designed to make bread making easier. Inside the bread machine is a nonstick pan with a kneading paddle, usually located on the bottom. Ready-to-use bread mixes often come with these machines. If using a recipe, the simplified process consists of placing warmed water, bread flour, yeast, and salt into the container, closing the lid, and pressing a button. The machine mixes and kneads the bread dough, allows it to rise, then bakes it in the same pan. Fresh bread can be completed within 2 to 4 hours. For those who prefer more "hands-on" bread making, the dough mixture can be beaten by hand; alternatively, it can be mixed in the bread machine, then shaped by hand and baked in an oven.

Kneading

Kneading develops the dough's gluten to its maximum potential (see Chapter 17). This step of bread making involves physically handling the dough until it achieves a smooth, soft, nonsticky surface and springs back when pressed gently. (Note that some traditional bread doughs do remain somewhat sticky after kneading.) Kneading is not required if the batter method is used.

A kneading surface should be covered with a fine layer of flour, both to prevent sticking and to allow some flour to be kneaded into the dough. Kneading in too much flour should be avoided, however, because it will slow fermentation, leaving the final product dry and streaked or heavy. Hands should be lightly floured prior to lifting or tipping the dough gently out of the bowl. The ball of dough is placed on the floured surface and the farthest edge of it is lifted up and folded toward the nearest edge, as shown in Figure 20-2. The fold is then pressed with the heels of both hands in a single rhythmic, rocking motion that pushes the dough fold, first down, and then away. Short presses that are neither too heavy nor too light are best. The mass is turned a quarter of a turn, and the process is repeated. More flour may be necessary as kneading continues. To determine whether more flour is required,

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FIGURE 20-2 Kneading dough.



The dough's furthest edge is lifted up and folded toward the nearest edge.



The heels of both hands push firmly against the fold in a forward, down, and away motion.



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The dough is turned a quarter-turn, and the process is repeated.

hit the dough ball with an open hand, count to 10, and lift the hand off. If the hand sticks to the dough, it needs more flour (6). If the dough is too firm and inelastic, additional water may be required.

Observing an experienced bread baker helps in learning the right amount of pressure and stretching and the length of kneading required to yield a dough ready for rising. In about 10 minutes, the dough usually signals it is completely kneaded by the development of a shinier surface that tends to "push back" when two fingers are gently pressed against the dough to test its gluten strength. Another way to determine whether kneading is complete is to stretch some of the dough into a "gluten window" (Figure 20-3). Avoid excessively kneading the dough because it results in a baked product with a coarse texture. An overkneaded dough will "snap back" when being rolled out because of a heavy gluten network that tightens the dough. Dough may similarly resist rolling out when it is too cold, but if temperature is the cause, the problem reverses itself when the dough is allowed to warm.

FIGURE 20-3 The way to test whether dough has been sufficiently kneaded is to stretch it and see if a thin, translucent windowpane appears.



www.pinchmysalt.com

The effort and time involved in kneading can be eliminated by using a food processor or an electric mixer with a dough hook attachment (like those shown earlier in Figure 20-1). It is important, however, to first learn to recognize the correct consistency for kneaded dough because it is very easy to overknead a dough using a machine. On the other hand, it is very difficult to overwork a dough by hand.

Proofing: Fermentation Causes the Dough to Rise

During baking, to **proof** means to let the bread dough rise. Yeast bread doughs are often proofed twice—the first proofing takes place in a covered bowl and the second in a bread pan. Proofing starts with kneading the dough, and then greasing the dough's surface by rolling it gently in a lightly greased bowl. This prevents it from drying out as it rises. It is then placed in the bowl for a first proofing or shaped and placed in a pan for a second or single proofing. The proofing container is covered with a clean, moist dish or paper towel or plastic wrap, and allowed to rise (proof) in a warm, humid, and undisturbed location for approximately an hour. The optimal proofing location is both humid and slightly warmer than room temperature (approximately 85°F/30°C). Covering the container during proofing also helps to maintain humidity and prevent drying. In these conditions, the dough can rise properly, usually doubling in size. Some traditional breads are left to rise more slowly in cooler (68°F/20°C) environments.

One of the purposes of proofing is to create a dough that is adequately aerated. If the dough expands beyond what is recommended, it leads to overextension of the gluten, which causes the cell walls to break and collapse, the fermentation gas to escape, and, ultimately, a low volume in the finished product (Figure 20-4).

CHEMIST'S CORNER 20-2

Enzymes in Yeast Dough

Enzymes naturally present in flour eventually influence the flavor, color, and texture of the baked bread. During fermentation, one of these enzymes, α-amylase, starts to degrade damaged starch granules found in flour to sugars. Among these sugars are dextrins that are then converted to maltose by another enzyme called β-amylase (25). The most common commercial sources for the first enzyme, α-amylase, are fungal (*Aspergillus oryzae*), bacterial (*Bacillus subtilis*), and cereal (malted barley and wheat) (11). Maltogenic α-amylase is used in the baking industry because it has an anti-staling effect in baked products (3). Another important enzyme is the protease that breaks down the protein into peptides and amino acids. Proteases break down (hydrolyze) the protein bonds in the gluten proteins, making the dough more extendable. Sometimes professional bakers add enzymes to the flour to improve how the dough handles. However, caution must be used because excess protease enzymes will cause the bread to have decreased volume and an inferior texture.

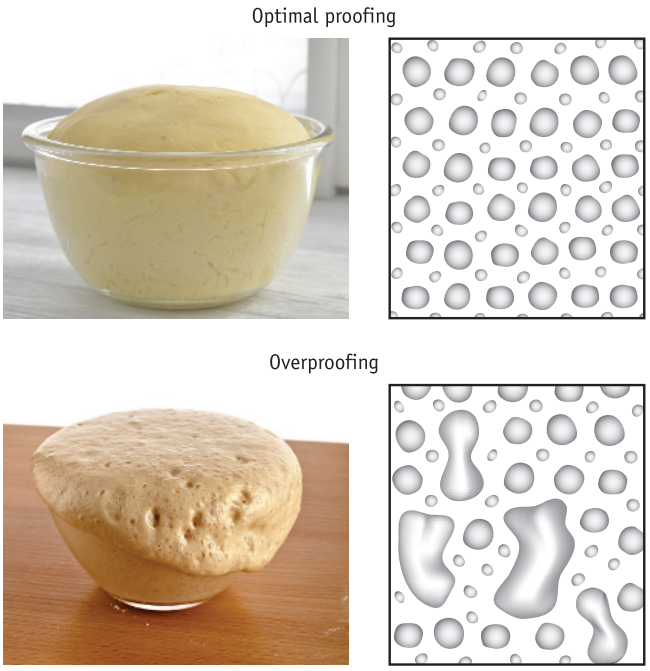
Proof To increase the volume of dough through fermentation, that is, to allow dough to rise.

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FIGURE 20-4 Overproofing produces a low-volume bread due to collapsing cells and the escape of fermentation gases.



Tanya Sid/Shutterstock.com; Madlen/Shutterstock.com

FIGURE 20-5 First fermentation rise for dough. Shaped dough placed in a humid, warm, undisturbed place for rising (*left*); risen dough ready for punching (*right*).



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ffolas/Shutterstock.com

Changes during Fermentation

As the yeast ferments, the dough will double in size (Figure 20-5) as carbon dioxide gas is produced by the yeast and as enzyme and pH changes take effect (Chemist's Corner 20-2). Longer rising times due to less yeast produces better flavors.

Dough becomes more acidic (pH of 6.0 to 5.5–5.0) during fermentation because of the formation of carbonic acid, which is created when carbon dioxide combines with water, and because of the lactic and acetic acids produced by the yeast. The increased acidity may improve gluten's ability to hydrate with water. Acids also improve flavor, extend shelf life by inhibiting staling and mold growth, and reduce the stickiness of the dough. Alcohol is another by-product produced during fermentation, but it evaporates during baking.

The amount of time it takes for the dough to rise will depend on the type and concentration of yeast, the amount of available sugars, the temperature of its environment, salt concentration, and the mixing method: it may take from 45 minutes to 2 hours, or even overnight in the case of some European-style breads.

Proof box A large, specially designed container that maintains optimal temperatures and humidity for the fermentation and rising of dough.

Optimal Fermentation Conditions

Yeasts are very sensitive to temperature extremes: they become activated at 68 to 100°F (20 to 38°C), slow down below 50°F (10°C), and die if exposed to temperatures at or above 140°F (60°C). Professional bakers use **proof boxes** to optimize fermentation conditions. At home, the dough can be placed in a warm corner free of drafts, in a closed oven with a bowl of hot water on the shelf below, or in the oven after it has been heated for a minute or so, until the warmth is just beginning to be felt, and then turned off. Temperature is important because doughs that are too cool ferment too slowly, whereas those that are too hot produce breads that have a small volume, large cells, a pale crust, and a reduced shelf life. Humidity also plays an important role, as shown by the bread in Figure 20-6 that was proofed under conditions that were too dry.

Avoid Overfermentation

The first rise is completed when the dough has approximately doubled in size

FIGURE 20-6 Bread proofed in conditions that were too dry; lack of humidity results in crust problems.



Crust faults due to drafty final proofing



Baker Technology

Uneven, rough crust

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and two fingers pushed into the dough near the edge leave an indentation. As the dough rises during fermentation, the gluten stretches and becomes weaker; thus, rising should not be allowed to continue too long or the expanding dough will collapse. Allowing the dough to rise too high can also cause a coarse grain and a sour odor from the excess acid production. Overfermentation can also affect color; sugar must interact with flour proteins to create the desired browning of the crust through the Maillard reaction, and the greater sugar consumption by the yeast leaves too little available for browning. Similarly, because the Maillard reaction also contributes to the sweet, aromatic, and roasted flavors in baked products, overfermentation affects flavor (25).

Punching Down and Second Proofing

Many doughs are subjected to a second proofing, especially homemade and finer-textured breads. It improves the quality of the finished bread by imparting greater volume, a finer texture, and a more mellow yeast flavor. After the dough has risen to double its size during the first proofing, it can either be punched down while in the bowl or placed once again on a lightly floured surface and gently pushed down in the center with a clenched fist, followed by about four kneading motions (Figure 20-7). It is shaped (see next section) and left to rise a second time either in a pan or on a baking sheet.

The dough is allowed to rise again to double its size, but no more, or the gluten will overstretch and cause the bread to fall. The second proofing takes about half the time of the first. The completion of the second rising is signaled strictly by whether or not the dough has doubled its size and not by the finger indentation test.

FIGURE 20-7 Punching down the dough allows excess gas to escape and redistributes the ingredients.



ffolas/Shutterstock.com

While proofing is taking place, the oven may be preheated in anticipation of the next step—decorating and baking the bread.

How & Why?

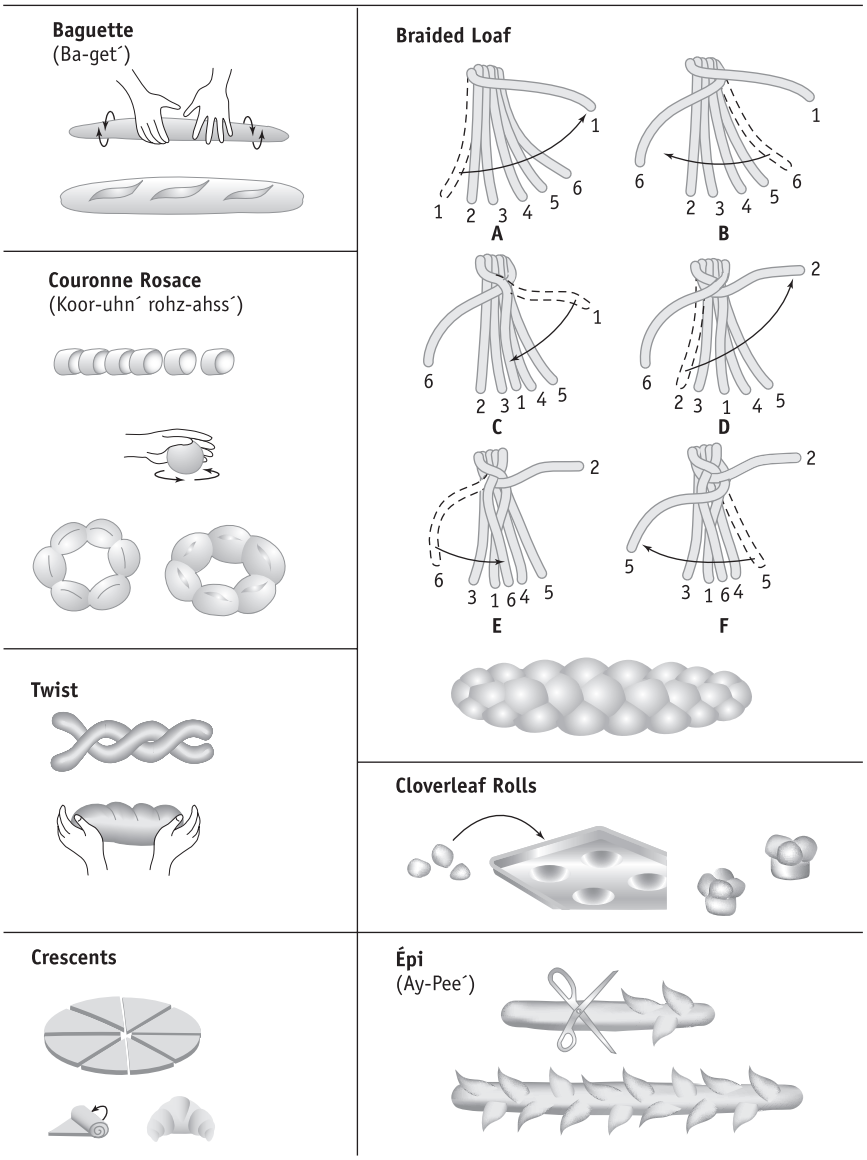
Why does dough have to be punched down after the first rising?

Punching down evens out temperatures; redistributes sugars, yeast, and gluten; breaks large air bubbles into smaller cells; and lets excess carbon dioxide gas escape. The bread would be riddled with large holes without this release of excess carbon dioxide gas.

Shaping

After the bread has risen once, it is ready for shaping. Breads can take on a wide variety of shapes. Figure 20-8 provides instructions for shaping rolls, braids, and other more unusual bread shapes. The basic loaf of bread is shaped by first dividing the dough into the desired number of portions so the pan(s) will be at least half but no more than two-thirds full of dough. The dough is shaped into an oblong, roughly rectangular, mound as long and as wide as the loaf pan. One-third of each end is then folded under the mound. All the edges are pinched together to seal the seams, and the dough is then placed in the pan so the sealed edges are on the

FIGURE 20-8 Various bread-shaping techniques.



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TABLE 20-4 The Effect of Different Pan Materials on Baking Yeast Breads

Shiny aluminum	Provides even heating but does not promote the development of bread's characteristic golden brown color and well-textured crust.
Dark heavy-weight steel	The choice of expert bread bakers. Promotes golden brown color and perfectly textured crust.
Dark nonstick	Keeps bread from sticking but tends to brown bread more quickly, especially around the edges. Reduce the oven temperature called for in any recipe by 25°F/4°C.
Insulated	Consists of two thin sheets of aluminum with a layer of air between them. Breads may brown poorly, require longer baking times, and possibly stick.
Glass	Ovenproof glass baking dishes brown the bread well, and you can see the browning of the crust on all sides. Reduce the oven temperature called for in any recipe by 25°F/4°C.
Baking stone (quarry or clay tiles, pizza stones)	Baking stones produce thick-crusted, country-style breads by replicating a brick or adobe hearth oven.

bottom, and the dough is touching all four sides of the pan. The bottom and sides of the pan may be greased with solid shortening or a nonstick cooking spray so that the bread can rise without the dough sticking to the sides, though some bakers leave the sides ungreased so that the bread will have more traction during rising. Greasing also allows the loaf to be easily removed.

Selecting a Baking Pan

Yeast breads are usually baked in loaf pans (metal or glass), but they can also be prepared using specialized loaf pans (French bread, baguette, etc.), cookie sheets, jelly roll pans, muffin tins, and even stones (pizza stones, clay or quarry tiles). Table 20-4 lists the advantages and limitations of the various pan materials.

Decorating

In preparation for baking, the bread dough may be decorated with sesame, caraway, or poppy seeds by brushing the top of the loaf with a thin layer of egg white and sprinkling the seeds on top. Many types of breads are **scored** just before baking to allow them to rise evenly without tearing the crust. Another decorative touch, which also adds flavor, is to score the top of the bread with a sharp knife and pour a bit of melted butter into the slashes. Although scoring serves the dual purposes of decoration and allowing excess steam to escape, neither is strictly necessary. Milk brushed on the surface of the loaf before or during baking will give a crust a golden brown color due to the caramelization of the milk. The technique of brushing loaves with water or introducing steam into the oven will give loaves a crispier crust.

Score To use a sharp knife or a special blade called a "lame" to create ¼- to ½-inch-deep slashes on the risen dough's top surface just prior to baking.

Oven spring The quick expansion of dough during the first 10 minutes of baking, caused by expanding gases.

Baking

A standard loaf of bread will bake in about 45 minutes. It is usually heated at 400°F (205°C) for the first 10 to 15 minutes, and then at 350°F (177°C) for the remaining 30 minutes. Temperatures and times will vary for different types of breads. The initial hot temperature contributes to **oven spring.** The initial increase in fermentation, enzyme activity, and softening of the ingredients also contribute to oven spring. If the initial temperature is not hot enough, the protein will not congeal properly, and the yeast will continue to ferment, causing the dough to spill over the sides. This can also occur when the dough has been overfermented prior to baking. Underfermented dough, however, may not have sufficient oven spring. Temperature is also important for crust thickness, which is determined in part by the amount of vapor pressure (2).

Changes during Baking

Baking changes the appearance, texture, flavor, and aroma of the dough as well as its structure. After the dough is placed in the oven, the hot temperature kills the yeast, thereby stopping fermentation. It also inactivates enzymes, vaporizes the alcohol, and coagulates the protein that firms the dough.

Protein coagulates and starch granules start to swell and gelatinize at about 140°F (60°C), but because of the limited water content, gelatinization does not proceed as far as it could. If the oven temperature is too high, the proteins will coagulate too soon, resulting in low volume; conversely, low oven temperatures will cause the structure to collapse.

If baked correctly, bread right out of the oven has an aroma all its own, but the wonderful smell is rapidly lost; this

CHEMIST'S CORNER 20-3

Bread Flavors and Aromas

Fermenting yeasts contribute to the unique flavor of baked products through the formation of volatile and nonvolatile products. Nonvolatile compounds are too large to become airborne and include amino acids and saccharides. These generate flavors via the Maillard reaction. Volatile substances contributing to the odor of fermenting dough include isobutanol, amyl alcohol, isoamyl alcohol, phenylethyl alcohol, esters, lactones, and organic acids (16). Many of the alcohols formed during fermentation, such as ethanol, n-propanol, isobutyl alcohol, and others, are lost into the air during baking (7). The odor of baked crust is derived in part from the formation of 2,5-dimethyl-4-hydroxy-3(2H)-furanone, which results from the thermal reaction between certain amino acids and sugars such as glucose, fructose, and rhamnose. Organic acids and carbonyl compounds also contribute to crust flavor. The unique flavor of French bread is thought to be due to its high level of acetic acid.

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is believed to be the result of the evaporation into the air of volatile compounds (Chemist's Corner 20-3). Other components of flavor are developed in part by the breakdown of starch to dextrins and some caramelization but primarily by the browning of the crust in the Maillard reaction. Substrates for the Maillard reaction in breads can be derived from any added milk, sugar, and/or egg.

The changes associated with baking require even heat exposure, so a minimum distance between baked items is necessary: at least 1 inch between rolls and about 3 inches between loaves (27).

Crumb Development

During baking, the dough converts from an elastic, undefined mass into a set structure with a defined bread **crumb** (12). The formation of a desirable crumb is dependent on gases produced during fermentation and proofing and air introduced during mixing and kneading.

Numerous small or medium cells result in a baked product with a fine and tender crumb, a large volume, and a longer shelf life. These cells multiply and enlarge during fermentation and proofing; during baking, they will enlarge further but will not multiply. Yeasts are not entirely responsible for cell number and size. Air incorporated into the flour mixture during mixing, punching, and kneading also contributes to the number of cells. This is why using sifted flour in baked products results in larger volumes than using unsifted flour (27).

FIGURE 20-9 Fermentation gases produce the pores of the baked bread.



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FIGURE 20-10 Crumb quality depends on cell size.



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How & Why?

How does crumb form in a loaf of bread?

The carbon dioxide produced during fermentation, proofing, and oven spring becomes many small bubbles entrapped in the gluten network (Figure 20-9). When the bread sets and the gas escapes, all that remains are the pores, or cells, forming the crumb of the baked product.

Problems with Texture

An overfermented dough, with its large cells (Figure 20-10, far right), gives the baked item a moth-eaten appearance and a coarse texture. Underfermented dough, in which the carbon dioxide was not properly distributed, results in a very dense loaf with thick cells, low volume, and a tough crust (Figure 20-10, middle). Distribution of the carbon dioxide throughout the dough to create fine cells is accomplished through mixing, punching, kneading, and shaping. Bakery products in which the cells are either abnormally small or large have shorter shelf lives (27).

Testing for Doneness

Bread can be tested for doneness by inverting the pan with one gloved hand, allowing the bread to drop into the other gloved hand so the bottom of the loaf is facing up, and tapping the bottom. If it rings hollow, it is done; if it does not, it is placed back in the pan and returned to the oven for an additional 5 to 10 minutes. Another method is to combine the hollow sound technique with an instant-read thermometer, which should read above 195°F (91°C) when inserted into the bread's interior. If the bread is not done, but the

Crumb The cell structure within the interior of a baked product that influences texture and is visible when it is sliced. Evaluation is based on cell size (called *open,* if medium to large, or *closed,* if small), cell shape, and cell thickness (thin walls occur in fine crumb, whereas thick walls predominate in a coarse crumb).

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TABLE 20-5 Problems with Yeast Breads and Their Causes

Problems	Causes	Improper mixing	Insufficient Salt	Too much Salt	Dough Weight too much for Pan	Dough Weight too Light for Pan	Insufficient Yeast	Dough Proofed too much	Dough Underproofed	Dough Temperature too High	Dough Temperature too Low	Dough too Stiff	Oven Temperature too High	Proof Box too Hot	Green Flour	Dough Chilled	Too much Sugar	Insufficient Sugar	Dough too Young	Dough too Old	Improper Molding	Insufficient Shortening	Oven Temperature too Low	Overbaked	Dough too Soft	Underbaked
Volume too low	X		X		X	X		X			X	X				X			X	X						
Volume too high		X		X			X													X			X			
Crust too thick		X	X				X																			
Dry crumb	X										X												X			
Moist crumb																									X	X
Streaky crumb																					X					
Gray crumb								X	X				X													
Lack of shred							X												X	X						
Coarse crumb	X				X		X			X									X	X	X					
Poor texture, crumbly							X						X						X	X			X			
Crust color too pale										X			X					X		X						
Crust color too dark										X		X					X		X							
Crust blisters															X				X	X	X					
Shelling of top crust								X			X				X			X								
Air pockets								X	X			X												X	X	
Poor taste and flavor		X							X											X						
Poor keeping qualities		X					X		X		X							X		X		X	X			

top is already golden-brown, it should be covered with aluminum foil or otherwise protected to prevent further browning. When done, the baked bread is set on a wire rack for cooling.

A well-prepared bread product has certain characteristics: optimal volume, color, and flavor; a symmetrical shape with closed seams; a porous, pliable, firm, and even crumb; and a golden-brown, crispy crust. Major problems that may interfere with the attainment of these attributes, and their causes, are summarized in Table 20-5.

Microwave Preparation

The use of a microwave for baking bread is not recommended; because no dry heat is available for dextrinization, the Maillard reaction, or caramelization, the crust will not brown. If a microwave oven is used, breads should be placed in a conventional oven during the last few minutes of baking to yield at least a partial crust.

NUTRIENT CONTENT

Breads are an excellent source of **complex carbohydrates**, providing about **15 grams of carbohydrate per 1-ounce slice**, as well as 0 to 3 grams of protein, **0 to 1 gram of fat, and 80 kcalories**. They may also, depending on the type of bread, contribute beneficial fiber to the diet (28). There may be up to **3 grams of fiber in a slice of whole-grain** bread, as compared to only 1 gram of fiber in a slice of white bread.

Fat. Although many yeast breads contain **very little if any fat** (about 1 gram per slice), certain types such as croissants (12 grams of fat in a 55-gram croissant), submarine rolls (4 grams of fat in a 135-gram slice), and hot dog/hamburger rolls (2 grams of fat in a 40-gram roll) contain more. Some baked products use fat substitutes to lower their fat content (5).

Specialty Breads. A wide variety of specialty breads are available, including those that are low in kcalories, low in fat, high in calcium, high in fiber, or a combination of these. Low glycemic-index breads (low-carbohydrate and/or high-fiber) may help people with diabetes maintain steady blood sugar levels (22). The term low carb, previously used for diet foods, morphed into a bread category to cover a wide variety of baked products lower in digestible carbohydrates and higher in fiber that would benefit people's energy intake, blood sugar levels, and digestive health (21). Increasingly popular are the gluten-free specialty breads discussed in more detail in the section on "Specialty Breads" later in this chapter.

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CALORIE CONTROL
Yeast Breads

Many of the calorie control hints for quick breads discussed in the previous chapter apply to yeast breads as well:

- **Control Bread Portion Sizes.** A "standard" slice of bread delivers about 80 kcalories, but loaf sizes and slice thicknesses vary. Check the Nutrition Facts label of commercial breads.
- **Choose Whole-Grain Bread for Sandwiches.** Two slices of whole-wheat bread are lower in kcalories (160 kcalories) and higher in beneficial fiber than a croissant (231 kcalories) or a submarine roll (359 kcalories).
- **Consider Thin vs. Thick Pizza Slices.** The kcalorie content of this popular bread-based food is partially based on the size and thickness of the slice and its crust. Pizza slices vary considerably among restaurants, but generally a small, thin pizza slice provides 130 kcalories and 4 grams of fat, whereas a large, thick pizza slice provides much more—400 kcalories and 11 grams of fat. You can control pizza portion sizes by choosing thinner pizza, serving yourself smaller slices, and limiting the number of slices you eat. A meal of three large, thick slices adds up to about 1,200 kcalories plus 33 grams of fat; a more reasonable portion of three small and thin or one large and thick pizza slice provides 400 kcalories and 15 grams of fat.

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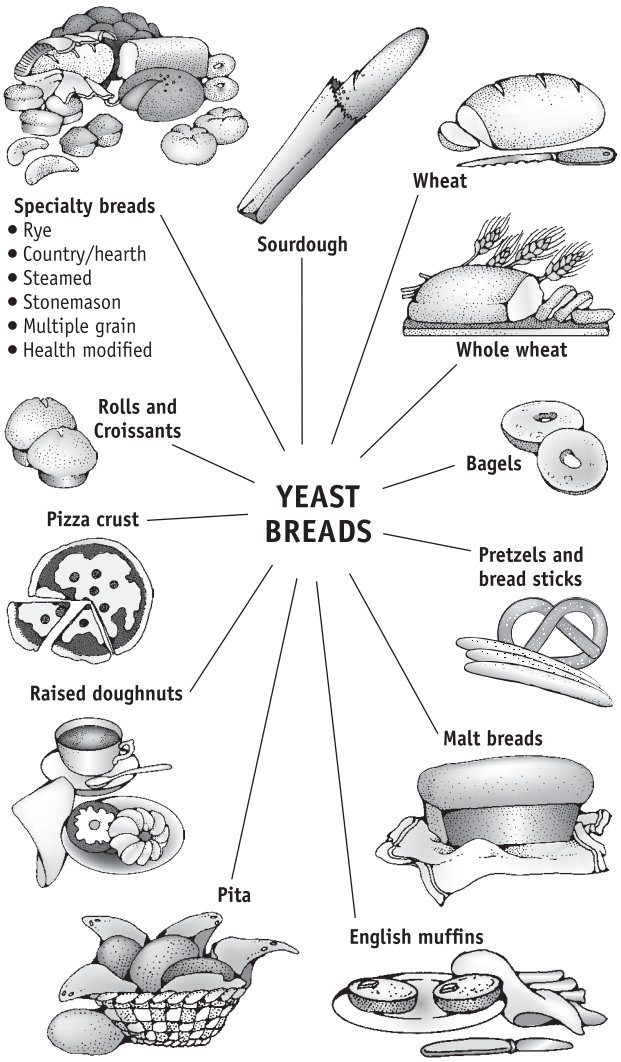
High-Altitude Adjustments

Baking at altitudes above 3,000 feet requires changes in recipe ingredient measurements, preparation time, and oven temperatures. Yeast breads rise faster at higher altitudes, where there is less atmospheric pressure pushing down on the dough, so less leavening agent will be needed. Liquid also evaporates more quickly at higher altitudes, so more may be needed. Yeast bread should not be allowed to more than double in volume. Baking temperatures are increased slightly, by about 10 to 15°F (6 to 8°C), to help coagulate the proteins and prevent the gases from overexpanding the structure.

TYPES OF YEAST BREADS

The simplest yeast bread is made from flour, water, and yeast, but this basic formula has evolved into more complicated varieties that include loaf breads (white, whole-wheat, sourdough, and malt breads), specialty breads, rolls, pita bread, bagels, English muffins, pizza crust, pretzels and bread sticks, and raised doughnuts (Figure 20-11).

FIGURE 20-11 Varieties of yeast breads.



Loaf Breads

Wheat (White) Bread

Wheat, or white, bread is made with all-purpose flour, milk, water, and small amounts of sugar, salt, and yeast. Organic wheat flour is also available,

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but research suggests that it may be better in cookie preparation (24). Fat is an optional ingredient. Almost all of the white bread in the United States has been enriched.

Whole-Wheat Bread

The bran in whole-wheat bread increases the fiber content from 1 to 3 grams per slice, but the sharp edges of the bran cut the strands of gluten in the dough, resulting in a shortened kneading time and a lower-volume loaf. If the bread is designated as "wheat bread," it has been made from a combination of whole-wheat and white flours, which produces a loaf with more volume and a lighter texture (but less fiber).

Sourdough Bread

Sourdough bread has a unique tangy taste and chewy texture because it is made with a starter (sometimes called a sponge), which consists of both yeast and lactic acid–producing bacteria. There are more than fifty species of lactic acid–producing bacteria, including *Lactobacillus plantarum,* and more than twenty-five species of yeast (14). The lower pH of sourdough bread (4.0 to 4.8, as compared to 5.1 to 5.4 pH for regular breads), which provides its characteristic texture and taste, results from the fermentation of the dough by the bacteria. Two cups of sourdough starter are equivalent to one small package of yeast. Sourdough yeast must be obtained to prepare a sourdough starter. Not ordinarily sold in the store, these unique sourdough yeasts can be purchased at various websites, gourmet cook stores, larger health food stores, cooking schools, or cooking clubs.

How & Why?

Why is sourdough bread "sour"?

The *Lactobacillus plantarum* strain of bacteria that is widely used as a starter produces lactic acid, which results in a pleasantly sour taste (9). The lower pH also makes sourdough bread less sweet by inhibiting the amylase enzymes in the flour from breaking down starch into the sweeter-tasting maltose.

Malt Breads

The malt in malt breads makes them sweeter, stickier, and heavier than other breads. Some researchers report that adding malted wheat to the dough improves bread quality (15). The added malt also contains enzymes that convert starch to sugars and digest some of the gluten. A weakened gluten structure can be avoided by using an inactive malt derivative and molasses, but the resultant bread product is then considered to be an imitation malt bread (13).

Specialty Breads

Specialty breads differ from regular varieties either in their method of preparation or in their ingredients.

Preparation Technique

Some breads that are made in a different manner include the following:

- Wood-burning oven breads that are often referred to as country loaves or hearth breads
- Steamed bread that is processed with 15 to 20% steamed rye flour
- Stonemason bread containing grain that has been treated with moisture and then crushed or cut

Pumpernickel and rye-meal breads lack a crust because they are cooked under continuous steam, a process that breaks down the starch to sugar and imparts a sweet flavor and dark-colored crumb. Swedish rye crackers are baked in flat sheets. The unique flavor and greater mold resistance of rye bread is due to the release of lactic acid by bacteria during fermentation, which acidifies the dough (23). Rye breads also have a much harder crumb than wheat breads because of the smaller number of pores and greater concentration of large particles.

Ingredient Variation

The use of unique ingredients can also result in a specialty bread. Examples include three-, seven-, or nine-grain breads made from flours other than wheat or rye, such as oat, barley, corn, rice, and others; breads prepared with extra dairy items such as butter, milk, buttermilk, whey, and yogurt; and those made with vegetable ingredients such as wheat germ, soy, bran, sesame, linseed, or spices (pepper or paprika). Note that garlic should not be added to bread dough formulations because it causes low volume and decreases the dough strength to the point at which it often breaks down during mixing. One theory behind this phenomenon is that allicin, a unique flavor compound in garlic, may interfere with the dough's disulfide bonds (20).

Nutrient Modifications

Some specialty breads have had their nutrient value altered for people with health conditions that require dietary modifications (10). Graham bread is made without salt or yeast; other breads reveal their differences in their names—low-fat, low-calorie, low-sodium, and high-fiber. Gluten-free bread is produced for people with celiac disease or gluten sensitivity (19). The term *gluten-free* means without gliadin protein, and these products are increasing in popularity. A bread that is gluten-free may still contain other proteins from flour and any dairy, eggs, or other protein-containing ingredient added to the flour mixture. Consumers avoiding gluten should be aware that products labeled "wheat-free" may not be gluten-free.

Rolls

Rolls, including Kaiser, submarine, sandwich, and others, contain the same ingredients used to make loaf bread. Some may contain additional fat, sugar, and/or eggs. The many available types of rolls vary not only in their ingredients but in their shapes as well (Figure 20-12). Some professional bakers weigh the individual dough allotments for each kind of roll to ensure uniform proportions and appearance.

Pita Bread

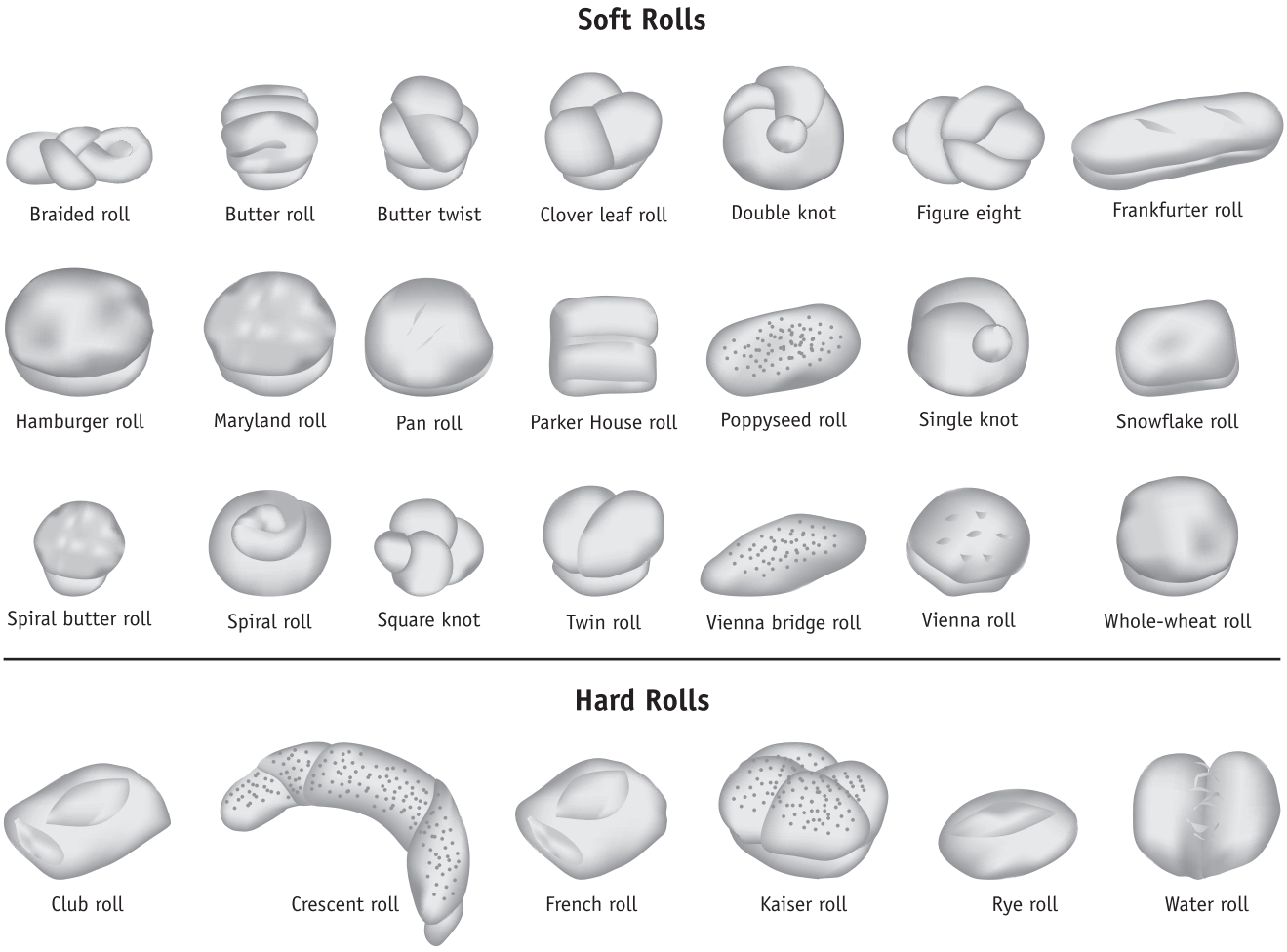
This circular Middle Eastern bread with a large hollow center is also known as *pocket bread*. It is prepared by flattening dough into thin circles about 9 inches in diameter and less than ¼-inch thick, and then baking them briefly in a very hot oven (500°F/260°C) until they form the characteristic two symmetrical halves (1). The moisture in the dough heats up so quickly at this temperature that it does not have time to escape through the pores. Instead, the dough balloons, and the bread bakes in that position, collapsing again upon removal

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FIGURE 20-12 There are many varieties of both soft and hard rolls.



from the oven. The entire process takes less than a minute. Another method is to cook the dough on a lightly greased griddle for 15 to 20 seconds, gently turn it over, continue heating for about 1 minute until bubbles appear, and then turn it back over until it balloons. Pita bread is handy in making sandwiches because it can be filled with a variety of foods, ranging from standard sandwich ingredients to vegetables and cooked meats. Almost any pita sandwich may be topped with lettuce, tomato, and onions.

Bagels

Bagels are made by cutting a basic yeast flour dough into 3-inch rounds with a ¾-inch center hole using a special bagel cutter (Figure 20-13). Bread or high-gluten flours are preferred to obtain a chewy texture. Sweeteners are often added, in the form of malt, sugar, or honey. Additional ingredients might include blueberries, raisins, sun-dried tomatoes, or cranberries. After the bagels rise, they are boiled in water, cooled, possibly brushed with an egg yolk and water mix, and then baked. The crisp, smooth exterior covering the dense and chewy interior is often covered with poppy or sesame seeds.

FIGURE 20-13 A bagel cutter.



Toscanini/Shutterstock.com

How & Why?

Why are bagels boiled before baking?

Boiling bagels creates a moist surface that does not brown as readily, so the crust remains lighter and less crunchy. The moisture also causes the starch to gelatinize into a thin, transparent coating that gives bagels their unique, soft, smooth crust texture.

English Muffins

English muffins, unlike other breads, are baked on a greased griddle or pan. These yeast breads, usually about 4 inches in diameter when baked, are made by combining water or milk, sugar, salt, flour, yeast, and a little butter. After the first

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rising, they are shaped, with or without the use of muffin rings. If muffin rings are used, they are greased, dusted with cornmeal, and filled up to ½ inch with the dough. If rings are not available, the dough is placed on a board that has been lightly sprinkled with cornmeal, where it is pressed down to a thickness of ½ inch, cut into circles about 3 inches in diameter, and moved to a greased cookie sheet. English muffins undergo their second rising before being transferred by spatula to the greased griddle or to a pan where they will be heated until lightly browned.

Pizza Crust

Pizza crust is made with yeast and hard wheat flour. It is allowed to rise only once, for 2 hours, and then baked in a very hot oven at 400°F (205°C) for about 25 minutes.

Pretzels and Bread Sticks

Bread pretzels or sticks can be formed by changing the shape of the yeast dough used to make pizza crust or other baked products. A small amount of dough is rolled into a "stick" that can then be baked into a bread stick or twisted into the shape of a pretzel. The difference between them and other baked products is that they are coated with butter and/or salt and are best consumed as soon as possible after baking.

Raised Doughnuts

Raised doughnuts are made with bread flour and leavened with yeast. They are typically deep-fried in fat or baked in an oven. Cake doughnuts, on the other hand, are made with cake flour and leavened with baking powder (and are thus a type of quick bread).

Rope The sticky, moist texture of breads resulting from contamination by *Bacillus mesentericus* bacteria.

STORAGE OF YEAST BREADS

Fresh

Freshly baked wheat bread is best when consumed within 1 or 2 days, whereas some rye breads can last an average of a week. When just out of the oven, bread can be kept warm by placing aluminum foil under the cloth in the breadbasket. If it will not be consumed right away, it should be completely cooled before being wrapped and stored in a dry, cool place at room temperature and away from sunlight (4).

Staling

Bread gradually loses freshness after it is baked. In fact, staling begins as soon as the bread leaves the oven (Chemist's Corner 20-4) (3). This unavoidable part of bread preparation is thought to be responsible for the loss of an estimated 3 to 5% of all baked breads sold in the United States (29). Staling occurs as the crust toughens, the crumb become less elastic and more firm, and the soluble starches lose moisture and flavor (17). These undesirable changes are thought to be due primarily to retrogradation (crystallization) of the starch molecules released during gelatinization. Moisture levels also play an important role in the staling of bread as water moves from the center of the loaf toward the crust (26).

Preventing Staling

Staling is best prevented by keeping the bread away from air. Several techniques include wrapping breads in plastic or paper bags, adding moisture retainers such as fat or sugar (nonfat French bread stales quickly), brushing the crust with glazes (fat or sugar), and/or freezing. The staling caused by retrogradation is reversible when the bread is warmed, but returns upon cooling. Reheating the bread in an oven at 125 to 145°F (52 to 63°C) for a few minutes re-creates many of the characteristics of fresh bread, especially if a damp cloth or paper towel is placed over the bread during reheating. Reheating in a microwave oven is not recommended, as this causes the bread to become tougher, rubbery, and more difficult to chew (8).

Fresh Bread Additives

Commercial bakers add monoglycerides and diglycerides or fat to bread doughs to help prevent staling (31) and sodium or calcium propionate to retard mold and the bacteria that cause **rope.** These bacteria, which live in the soil, can contaminate grains and the flour made from them. The spores survive baking, germinate, and feed off the carbohydrates they obtain by decomposing the bread's starch. The end result is a bread that appears fine on the outside, but is internally mushy or stringy to the point that it can be pulled into "ropes." Breads affected with rope smell like overripe melons. This condition may mistakenly be attributed to incomplete baking, but consuming rope-contaminated bread can cause vomiting and diarrhea. Rope contamination is more apt to occur in the summer months (27).

CHEMIST'S CORNER 20-4

The Chemistry of Staling

Theories as to why staling occurs include possible aggregation of amylose molecules, recrystallization of the amylopectin, and/or a transfer of moisture from the gluten to the starch (17).

Refrigerated

Bread should be refrigerated immediately in the warm temperatures and moist humidities of tropical regions. In less humid areas, refrigerating bread is not recommended because it speeds staling.

Frozen

Freezing is one of the best ways to maintain some of the texture and flavor of freshly baked bread. If crusty breads are not going to be consumed within 1 day, or soft breads within 2 days, freezing is the optimal storage method (4). Most breads can be frozen for 2 or 3 months. Before freezing, "cater wrap" the bread in two layers of plastic wrap (4). Alternatively, the bread should be wrapped in heavy-duty aluminum foil and dated. Frozen bread should be removed from the freezer and thawed at room temperature in the wrapper. Thawing in

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a hot oven results in a soggy, flavorless loaf. Home-baked bread can get back its freshly baked flavor if the top portion of the foil covering the thawed bread is opened and it is placed in an oven preheated to 250 to 300°F (121 to 149°C) for about 10 minutes. The foil will keep the loaf warm during slicing and serving.

Unbaked bread dough can be frozen for up to 2 weeks by first shaping the dough and then wrapping it in freezer paper or foil. It should thaw and rise to double its height before it is baked. It can also be placed overnight in the refrigerator and then allowed to rise for 2 hours. *Breakout* is the term used by bakers for removal of the dough from the freezer for the next day's bake. It is placed on racks to retard (defrost) overnight in a refrigerated room at 36 to 38°F (2.2 to 3.3°C). Blistering may occur if it thaws at room temperature, which allows the outside to defrost first and start to ferment while the inside is still frozen.

PICTORIAL SUMMARY / 20: Yeast Breads

The basic principles of preparing yeast breads have not changed since they were baked by ancient Egyptians, who knew the techniques and preferred the light, airy texture of yeast-leavened bread.

PREPARATION OF YEAST BREADS

As with any bread, the basic ingredients of yeast breads are flour, water (or other liquid), and a leavening agent—in this case, yeast. Sugar, salt, and fat and/or eggs are often added.

Normally, the preparation of yeast bread is at least a 2½- to 3-hour operation that involves the following steps:

Mixing: Ingredients are usually combined using one of these four common mixing techniques:

- *Straight dough method.* All ingredients are placed into the bowl at once and mixed.
- *Sponge method.* Yeast is combined with water and slightly over one-third of the flour. The "sponge" is then allowed to rest in a warm place for a half hour to an hour, and then other ingredients are added.
- *Batter method.* Ingredients are combined and beaten by hand or with an electric mixer. No kneading is required.
- *Rapid mix method.* This method is used primarily with bread-making machines. All ingredients are added simultaneously.

Kneading: The dough is handled until it is smooth, has a soft, nonsticky surface, and springs back when pressed gently.

Proofing (rising): As the yeast ferments, the dough doubles in size. Bread dough may be proofed once or twice; the final or single proofing usually occurs in or on the baking pan.

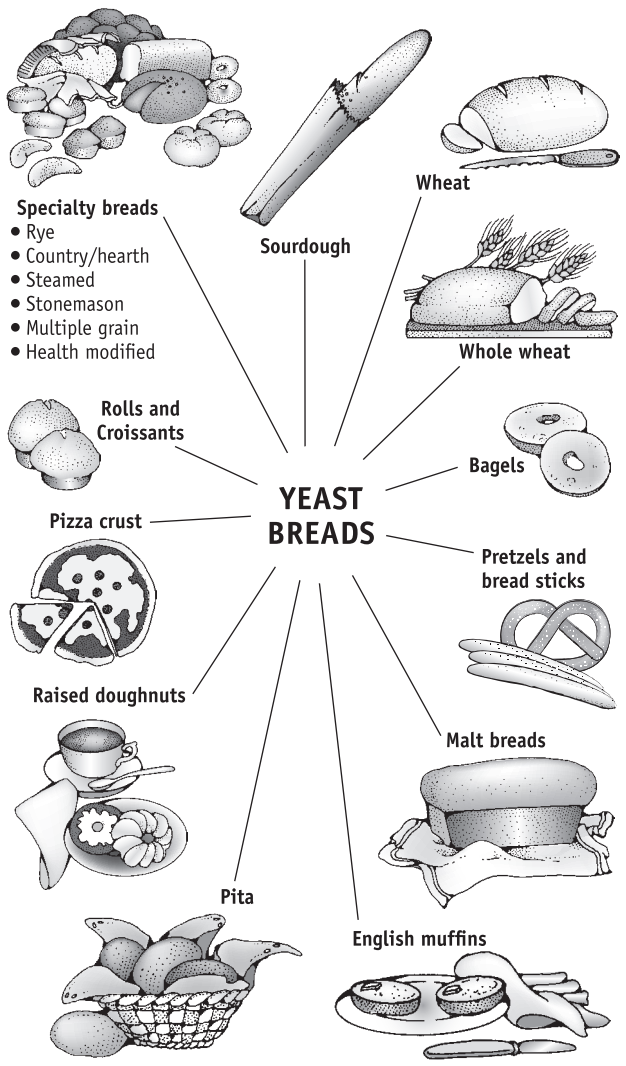
Punching down: Breads that are proofed twice need to be punched down after they double in size and allowed to rise a second time.

Shaping: Breads can take a wide variety of shapes. Usually the pan is at least half but no more than two-thirds full of dough.

Decorating: Dough may be sprinkled with seeds or brushed with egg white. Many breads are scored (cut across the top) to allow them to rise evenly without tearing the crust.

Baking: A standard loaf of bread will bake in about 45 minutes. It is usually heated at 400°F (200°C) for the first 10 to 15 minutes and then baked at 350°F (177°C) for the remaining time. The use of a microwave is not recommended because the crust will not brown. Baking time must be adjusted at high altitude.

TYPES OF YEAST BREADS



STORAGE OF YEAST BREADS

Fresh bread should be properly wrapped and stored up to 2 to 3 days in a dry place. If not used within a few days, bread should be frozen to prevent contamination and spoilage. In most cases, room temperatures are best for storing bread for short periods of time.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Breads leavened with the carbon dioxide produced by baker's yeast are known as _____.
   a. unleavened breads
   b. crisp breads
   c. yeast breads
   d. baker's breads

2. What is the term used to describe the quick expansion of dough caused by expanding gases during the first 10 minutes of baking?
   a. Quick rise
   b. Gas expanse
   c. Gas rise
   d. Oven spring

3. Whole-wheat bread contains more _____ than white bread.
   a. carbohydrates
   b. fiber
   c. fat
   d. yeast

4. When baking at altitudes above 3,000 feet, liquids need to be _____ and temperatures need to be _____.
   a. increased, increased
   b. increased, decreased
   c. decreased, increased
   d. decreased, decreased

5. Before it is baked, bagel dough is first _____.
   a. toasted
   b. microwaved
   c. boiled
   d. braised

6. The process of combining ingredients and beating them together by hand or a mixer without kneading is known as the _____ method.
   a. straight dough
   b. sponge
   c. batter
   d. rapid mix

7. Scoring a bread refers to _____.
   a. shaping the dough
   b. cutting across the top to prevent the crust from tearing
   c. punching down on the dough to release the gases
   d. rating the bread's baked flavor

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. What are the fundamental ingredients of yeast breads?
2. Briefly explain the following methods for mixing yeast breads: straight dough, sponge, batter, and rapid mix.
3. What is the purpose of kneading? How can one determine when kneading is complete?
4. What are the recommended conditions for the first rising of the dough? Approximately how much time should be allowed for the process? What are proof boxes?
5. What is the purpose of punching down the dough and allowing it to rise a second time?
6. Define the following terms: *score, oven spring, proofing,* and *rope*.
7. Describe the general baking conditions for a standard loaf of bread, including proper temperature and time frame. Describe the changes that occur during the baking of yeast bread.
8. Why is the use of a microwave not highly recommended for yeast bread preparation?
9. Briefly describe how the ingredients and/or preparation for the following yeast breads differ from those of a standard white loaf bread: sourdough bread, malt bread, English muffins, pizza crust, and pumpernickel bread.
10. Baked products start to stale the minute they leave the oven. Describe the process of staling and what can be done to prevent or delay it.
11. What causes the following problems during yeast bread preparation: low volume, poor flavor, and crust color too dark?

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21


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Sweeteners

Natural Sweeteners . . . 412

Nonnutritive Sweeteners 419

Functions of Sugars in Foods 423

Just as bears are drawn to honey, people seek ways to extract sweeteners from the natural world. Sugar cane and sugar beets deliver most of the sugar used to satisfy human taste buds (Figure 21-1). The history of people's interest in these plants dates back to Alexander the Great, who was enticed by the "honey-bearing rods" (sugar cane) he encountered near the river Indus. Christopher Columbus brought sugar cane to the West Indies, where it has been a major cash crop ever since.

FIGURE 21-1 Sugar cane and sugar beets are the primary sources of sucrose (table sugar).


Sugar cane: 12–14% sucrose

Art65395/Shutterstock.com


Sugar beets: 16–18% sucrose

Luis Carlos Jimenez del rio/Shutterstock.com

Jesuit missionaries followed by introducing sugar cane into Louisiana in 1751, and in the mid-1800s, sugar beets were planted in the United States.

Sweetening power is a major function of table sugar (sucrose), but other types of sweeteners may be used, including syrups, sugar alcohols, and **nonnutritive sweeteners.** Sugars have

Nonnutritive sweeteners Food additives requiring FDA approval that provide sweetness with no or insignificant amounts of energy (kcalories). Also known as alternative sweeteners, artificial sweeteners, noncaloric sweeteners, very-low-calorie sweeteners, sugar substitutes, sugar replacers, and intense sweeteners.

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TABLE 21-1 Functions of Sugars in Foods

Function in Foods	Baked Goods (Yeast)	Beverages	Cakes/ Cookies	Cereals	Confections	Dairy	Frozen	Jams/ Jellies	Processed Foods
Aeration	X		X						
Increasing boiling point					X				
Browning (Maillard reaction)	X		X	X					
Bulking/bodying agent		X	X		X	X	X	X	
Caramelization	X		X		X				
Crystallization			X		X				
Fermentation	X								X
Flavor enhancer		X	X	X	X	X	X	X	X
Foam formation			X		X		X		
Decreasing freezing point							X		
Glaze formation	X	X	X						
Moisture retention	X		X		X				
Preservative					X	X		X	X
Extending shelf life			X	X					X
Solubility		X			X			X	X
Sweetener	X	X	X	X	X	X	X	X	X
Tenderizer	X	X	X	X	X		X	X	

many other function in foods besides sweetness (Table 21-1). In baked goods, sugars produce a finer texture, enhance flavor, generate browning of the crust, promote fermentation of yeast breads, and extend shelf life by virtue of their ability to retain moisture. Sugars also give body to soft drinks—so much so that sugar-free drinks need additional ingredients to replace the viscosity provided by sugars (2, 30). Sugar offsets the acidic, bitter, or salty tastes of certain foods, such as tomato sauces, chocolate, and sodium-processed meats (ham, bacon, etc.).

Adding sugars to increase food palatability remains a common practice and a major use of sweeteners within the food industry. According to the *Dietary Guidelines,* "added sugars" are those sugars or syrups added to foods during processing or preparation. Added sugars include a wide variety of sweeteners such as white sugar (sucrose), brown sugar, raw sugar, honey, molasses, corn syrup, corn-sweetener, high-fructose corn syrup, invert sugar, malt syrup, maple syrup, pancake syrup, dextrose (glucose), and fructose (47).

Sugar's many important functions are discussed later in this chapter, following a look at the different types of sweeteners (natural and nonnutritive) and their nutrient contributions.

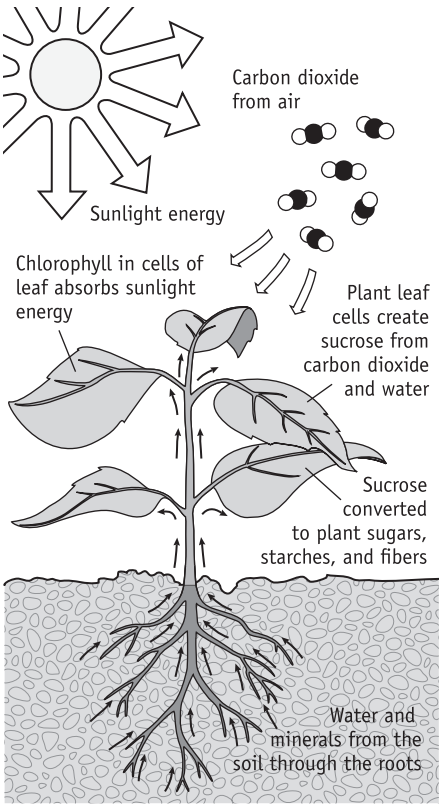
NATURAL SWEETENERS

As people searched for new ways to sweeten food, they discovered that plants produce abundant natural sugars through the process of photosynthesis (Figure 21-2). Natural sugars come from many different plants, but most of the sweeteners added to foods are extracted from sugar cane, sugar beets, maple trees, and corn. Lactose in milk is the only sweetener of animal origin, and it is not very sweet. Fruit sugars are derived from specific fruits, while honey is harvested from bees, which produce it from flower nectars.

Sweeteners can be placed into three major groups based on their different chemical structures, which influence their functions in foods and beverages:

- Sugars
- Syrups (liquids that contain sugars)
- Sugar alcohols

FIGURE 21-2 The process of photosynthesis.



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Sugars

As explained in Chapter 3, the sugars are saccharides, the best known being the monosaccharides glucose and fructose and the disaccharide sucrose (made up of glucose and fructose). After sugars have been extracted from a plant source, they become refined carbohydrates, providing a pleasing flavor and 4 kcalories per gram. The ability of sugars to sweeten makes them the number-one food additive, by weight, in the United States. Processed foods such as regular soft drinks, energy drinks, sport drinks, table sugar, candy, cake, cookies, pies, fruit drinks (fruit ades and fruit punch), dairy desserts and milk products (ice cream, sweetened yogurt or milk), and sweetened grain products (coffee cake, doughnuts, waffles, etc.) all contribute to sugar consumption (45, 47). Sugars are also found in less obvious foods, such as most commercially produced catsup (29% sugar) and fruit canned in heavy syrup (18% sugar). Many other foods that contain relatively large amounts of sugars, such as nondairy creamers (up to 65% sugar), do not taste particularly sweet.

The many kinds of sugars differ in their individual characteristics and functions in food. This section focuses on the properties of sucrose, glucose, fructose, lactose, and maltose.

Sucrose

Sucrose is the most familiar of the sugars—the one that usually comes to mind (and is often meant) when the word *sugar* or *sweetener* is used. Sucrose, or table sugar, is a disaccharide made up of glucose and fructose (see Figure 3-13 in Chapter 3). It is derived from either sugar cane or sugar beets. Sugar cane has been used as a source of sucrose for centuries. It first grew in India, where it is still a major crop. Sugar beets are a more recent addition after a German scientist first extracted sucrose in 1794. Today, sugar cane provides about 60% of the sugars consumed in the United States; white sugar beets, a relative of the red beet commonly eaten as a vegetable, provide the rest. The sucrose obtained from sugar cane and beets is extracted through a number of different refining and purifying steps after harvesting, including crushing, extraction, evaporation, and separation. Once processed, sucrose obtained from these two sources is identical.

Sucrose Extraction

Harvested sugar cane stalks are washed and then machine-shredded. Heavy steel rollers crush and squeeze the sweet juice from the cane. Water is sprayed on the cut and pulverized sugar cane, allowing more juice to seep out and be collected. The process of extracting sucrose from sugar beets differs in that they are washed, sliced, and then soaked in vats of hot water to remove the sugar. The extracted juices of both cane and beets are then heated and concentrated in evaporation tanks to create a thick syrup known as molasses. Vacuum equipment lowers the boiling point of the syrup so that it may be concentrated without burning. Large sugar crystals form as the solution becomes saturated. The crystals are then separated from the molasses liquid by a centrifuge. Centrifuges spin solutions at very high speeds to separate particles and/or liquids according to density.

Forms of Sucrose

Once refined, the sucrose is further processed to produce the commercial products known as raw, turbinado, white, powdered, fruit, Baker's Special, sanding, liquid, and brown sugars (Table 21-2). Newer sugars on the

TABLE 21-2 Different Forms of Available Sucrose

Raw sugar	The sugar that is extracted from sugar cane juice (not beets) without any further refining. As a result, it contains natural contaminants such as soil, insect parts, yeast, molds, waxes, and lint. The FDA has banned its sale to the public.
Turbinado sugar	A coarse, crunchy, amber-colored raw sugar that has been centrifuged and purified with steam. Though sometimes labeled "raw sugar," it is not truly raw. Demerara sugar is the English version of turbinado sugar that differs in its larger crystal size.
White sugar	Made by further refining raw sugar by repeatedly washing and filtering until the rinse liquid is a clear, colorless syrup. The syrup is then boiled until it crystallizes. Crystals are separated by size into "fine," or table sugar, and "superfine" or "ultrafine," which are used by the food industry for cake baking, dry mixes, candy coatings, and mixed drinks.
Powdered sugar	Made by pulverizing white granulated sugar. Also called confectioners' or icing sugar, it is frequently combined with an anticaking substance (3 to 5%) such as cornstarch, silica gel, or tricalcium phosphate to prevent caking. Powdered sugar is classified by the particle size after grinding: confectioners' 10X (ultrafine) is the finest sugar and gives smooth textures to icings; 6X (very fine) is the standard and most common confectioners' sugar used for general icings, toppings, and cream fillings; and the coarser 4X (fine) is used for dusting.
Invert sugar	A sugar (made by hydrolyzing sucrose to glucose and fructose) used to prepare glossy icings and frostings that help retain moisture in baked products without any trace of grain or grittiness.
Fruit sugar	Very finely granulated sucrose. Its uniform crystal size allows it to remain evenly disbursed in a mix. Used in dry mixes such as gelatins, puddings, and drink bases. (Note: The term fruit sugar may also be used to refer to the monosaccharide fructose, which is abundant in fruits.)
Baker's Special	Even more finely granulated than fruit sugar. Used primarily by the baking industry in cookies, cakes, and doughnuts.
Sanding sugar	Large-granule sugar often used to decorate the tops of baked goods because it does not melt during baking and it sparkles attractively.
Liquid sugar	A solution containing a highly purified sugar that is used in canned foods, beverages, confections, baked goods, frozen foods, and ice cream.
Brown sugar	Made by adding molasses syrup to white sugar. The amount and type of molasses determine the grade, with higher-grade brown sugars having a darker color and stronger flavor. These are used when strong flavors are desired, as for baked beans, minced meat, plum pudding, and gingerbread cookies.
Muscovado sugar	A softer, finer, darker brown sugar, also known as "Barbados sugar," that imparts a molasses flavor to baked goods.

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How & Why?

Why does brown sugar have a tendency to dry out and become hard?

Drying and hardening occur because the molasses film that initially covers the brown sugar, keeping it soft and pliable, hardens as soon as the water from the molasses evaporates. Airtight containers, preferably sealed plastic bags, are best for storing brown sugar. Hard sugar can be softened by draping it with a moist paper towel within its container for about 12 hours (sugar draws the moisture to itself). Brown sugar can also be temporarily softened by briefly heating it in a conventional oven at 250 to 300°F (121 to 149°C) or in a microwave oven for 30 seconds. Alternatively, a piece of bread or apple wedge may be placed in the sugar container for several hours so the brown sugar absorbs moisture from the bread (50). Storing brown sugar in a plastic bag in the refrigerator is another way to increase humidity and delay dehydration.

market include coconut and palm made from the sap of their flowers.

Lactose

The sweetness of milk comes from lactose, a disaccharide that is the least sweet of all sugars. Lactose is extracted from whey (a by-product of cheese production) for commercial use in baked products, where it aids in browning. It cannot be fermented, however, so it is rarely used in preparation of yeast bread products or alcoholic beverages that depend on fermentation. Lactose is also used as a filler in pharmaceutical products such as pills because its gritty, hard crystals flow freely and are easily compacted for tablet pressing.

Maltose

Maltose, also called "malt sugar," lends certain milkshakes and candies their characteristic malt taste. It is used primarily as a flavoring and coloring agent in the manufacture of beer. During the malting process, barley and other grains are treated to convert the grain's starch to maltose (see Chapter 27).

NUTRIENT CONTENT

White granulated sugar is **99.9% pure carbohydrate**, so table sugar or any food made with it is a source of refined carbohydrate. Granulated white sugar (sucrose) delivers **16 kcalories per level teaspoon, 23 kcalories per heaping teaspoon, 48 kcalories per level tablespoon, 11 kcalories per packet, and 9 kcalories per sugar cube**.

One health problem currently associated with excess sugar consumption is dental caries (cavities). The relationship between sugar and obesity—another widespread problem—is a subject of debate among scientists and the Sugar Association. Obesity has reached epidemic proportions in the United States, and people who go on weight-reducing diets often lose weight by cutting back on sweets. Both the Dietary Guidelines for Americans and the World Health Organization have advised that sugar intake should be **less than 10% of kcalories** with WHO stating the ultimate goal is to reduce it to 5% (47, 51). The American Heart Association recommends no more than 100 to 150 kcalories per day from sugar in women and men, respectively (22). In the United States, regular soft drinks are the main dietary source of simple sugars (13).

One way to reduce refined sugar intake is to reduce the use of table sugar and consumption of processed foods containing added sugars that might be listed on the label (Table 21-3). The words "no sugar added" on a label do not necessarily mean there are no sugars in the product, as they may be present naturally.

TABLE 21-3 Names for Added Sugars on Food Labels

- Anhydrous dextrose
- Brown sugar
- Confectioners' powdered sugar
- Corn syrup
- Corn syrup solids
- Dextrose
- Fructose
- High-fructose corn syrup (HFCS)
- Honey
- Invert sugar
- Lactose
- Malt syrup
- Maltose
- Maple syrup
- Molasses
- Nectars (e.g., peach nectar, pear nectar)
- Pancake syrup
- Raw sugar
- Sucrose
- Sugar
- White granulated sugar

Names not recognized by FDA as an ingredient name
Cane juice
Evaporated corn sweetener
Crystal dextrose
Glucose
Liquid fructose
Sugar cane juice
Fruit nectar

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Glucose

Glucose (see Figure 3-11 in Chapter 3), also known as dextrose, is the basic building block of most carbohydrates and the major sugar found in the blood. Chief plant sources of this monosaccharide are fruits, vegetables, honey, and corn syrup. In the food industry, *dextrose* is the commercial name for crystalline glucose produced from cornstarch. It is produced by treating cornstarch with heat and acids or with enzymes. Food companies often use dextrose, which is less sweet than sucrose, in cake mixes, frostings, baked goods (cookies, crackers, pretzels), custards, sherbets, candies, canned fruit, and beverages. The baking industry relies on dextrose to enhance crust color, texture, and crumb; as a component in dry mixes for baking; and to temper the sweetness of sucrose (37).

Fructose

Fructose (see Figure 3-11 in Chapter 3), also called "levulose" or "fruit sugar," is found naturally in fruits and honey and is the sweetest of all granulated sugars. (Note that the term *fruit sugar* can also refer to the fine-textured form of sucrose used in dry mixes.) Fructose is rarely used in food preparation because it causes excessive stickiness in candies (it is the most **hygroscopic** of the sugars), overbrowning in baked products, and lower freezing temperatures in ice cream. It is used primarily in the manufacture of pharmaceutical products. It is also a part of high-fructose corn syrup (HFCS), which is between 42% and 55% fructose (13).

Syrups

Syrups are sugary solutions that vary widely in viscosity, carbohydrate concentration, flavor, and price (Chemist's Corner 21-1). The more common ones include corn syrup, high-fructose corn syrup, honey, molasses, maple syrup, and invert sugar. The most frequently purchased syrups in the supermarket are maple-flavored syrups, which are primarily a blend of corn syrup, cane sugar syrup, and honey (25).

Corn Syrup

The starch of corn is used to make cornstarch, and by-products of cornstarch production include corn syrups (sometimes called glucose syrups), which are viscous liquids containing 75% sugars and 25% water. Corn syrups, rather than granulated sugar, are often used in soft drinks and processed foods to reduce manufacturing cost. They are primarily used as sweeteners, thickeners, and humectants (to retain freshness). Dried corn syrups or corn syrup solids can also be used in dry mixes for beverages, sauces, and instant breakfast drinks.

CHEMIST'S CORNER 21-1

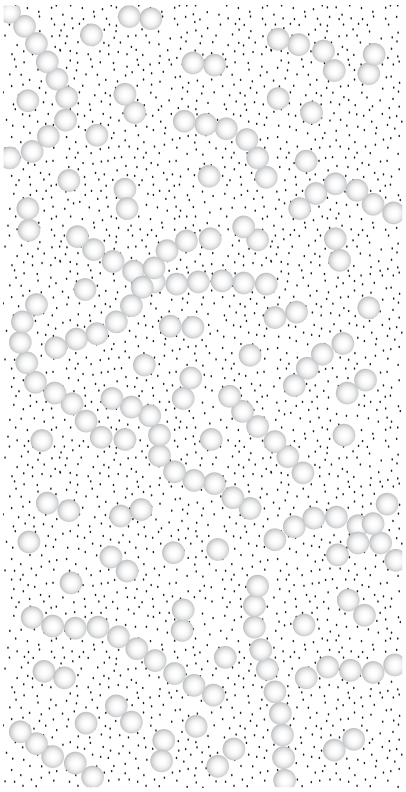
Measuring Sugar Solutions

Various instruments are used to measure the amount of sugar solids in a syrup or liquid. The concentrations of sugar solutions can be measured using a hydrometer, refractometer, or flow meter. The hydrometer relies on the Archimedes principle by comparing the weight of a plummet in a solution with its weight in water. Refractometers measure how much light is bent by the sugars in the liquid; the more concentrated the liquid is, the more light is refracted. A flow meter judges density by how quickly a liquid flows. The concentration measured by these instruments is converted into a degrees Brix value, which is the food industry's standard of identifying the sugar concentration in syrups or liquids (4).

Corn Syrup Production

Corn syrup is made commercially by adding acid or enzymes to a mixture of cornstarch and water. The mixture is then boiled, filtered, and evaporated until the right sugar concentration is achieved. Different enzymes can also be added to cornstarch to convert the starch into glucose, maltose, or small polysaccharides known as dextrins (Figure 21-3). β-Amylase enzymes yield more maltose, whereas glucoamylase enzymes result in a higher-glucose syrup, which is sweeter and less viscous. The d-Xylose isomerase enzyme transforms glucose to fructose, which is important in the manufacture of high-fructose corn syrups (HFCS). Manufacturers can adjust the characteristics of a corn syrup to their specific requirements by controlling the type of saccharides formed.

FIGURE 21-3 Corn syrup, obtained from hydrolysis of cornstarch, is a solution of sugars dissolved in water. Smaller sugars taste sweeter, whereas longer ones contribute to viscosity.



Dextrose Equivalents

Glucose that comes from corn is often referred to as dextrose. Thus, the glucose content of corn syrups is measured in units called **dextrose equivalents (DEs)** (Chemist's Corner 21-2). The lower the DE number, the less sweet and more viscous the syrup, while higher DE numbers reflect sweeter and thinner syrups (43). A complete conversion of starch to glucose has a DE value of 100. **High-conversion corn syrups** are able to promote fermentation and contribute to browning.

Hygroscopic Having the ability to attract and retain moisture.

Dextrose equivalent (DE) A measurement of dextrose concentration. A DE of 50 means the syrup contains 50% dextrose.

High-conversion corn syrups Corn syrups with a dextrose equivalent over 58.

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CHEMIST'S CORNER 21-2

Dextrose Equivalents

The dextrose equivalent (DE) value is the ratio of the number of reducing sugars (sugars with an aldehyde or ketone group) to the total number of glucose molecules.

$$DE = \frac{\text{Number of reducing sugars}}{\text{Total number of glucose molecules}} \times 100$$

DE	Conversion
28–37	Low
38–47	Regular
48–57	Intermediate
58–67	High
>68	Extra high
80–100	Crude corn sugars

CHEMIST'S CORNER 21-3

HFCS Production

HFCS is made by first treating cornstarch with α-amylase, producing shorter glucose chains called "polysaccharides." Glucoamylase is then added to break the polysaccharides into glucose molecules. Finally, the insoluble glucose isomerase enzyme is added, converting the glucose syrup to 42% fructose syrup—HFCS-42 (46). Passing HFCS-42 through an ion-exchange column concentrates the fructose, resulting in a 90% fructose syrup (HFCS-90) that is blended with HFCS-42 to create HFCS-55 (55% fructose).

How & Why?

Why isn't HFCS considered natural?

The Food and Drug Administration (FDA) does not presently define the term "natural," but it does have a long-standing policy that natural products do not contain any artificial or synthetic substance that would not normally be expected in the food (18). This includes artificial flavors or colors. Because HFCS is altered in the manufacturing process, the FDA has stated that HFCS does not qualify as natural. However, they have also stated that HFCS may be labeled "natural" if synthetic fixing agents do not come in contact with it during manufacturing. In response to consumer petitions and requests from some federal courts, in 2015, the FDA asked for information and public comments about whether and how it should officially define "natural."

The less viscous nature of high-DE syrups is due to smaller molecules such as glucose, fructose, and maltose. In comparison, lower-conversion syrups containing a higher concentration of larger molecules cannot be fermented.

High-Fructose Corn Syrup

High-fructose corn syrups (HFCSs) are different from corn syrups because a high number of glucose molecules are converted to fructose. Both start with cornstarch, but HFCS contains "higher" amounts of fructose (Chemist's Corner 21-3). Because fructose is sweeter than sucrose, less HFCS is needed to achieve the desired sweetness, so it is much cheaper to use than sucrose. Prices for sucrose from sugar cane or beets often fluctuate, with sugar cane costs partially dependent on shipping costs from equatorial regions. Conversely, corn is a common crop widely grown in the Midwest of the United States. Sucrose hydrolyzes in acidic systems, which changes the product's flavor. It is also a granular ingredient that must be dissolved in water before it can be used in foods and beverages. As a liquid, HFCS is ready for use in liquid applications, especially beverages, and can be easily transported and pumped from delivery vehicles to storage or mixing tanks. Its colorlessness also contributes to its industrial popularity (49). All of these attributes of HFCS have led to its widespread use in the United States, starting around 1970 when it began replacing sucrose as a primary sweetener in processed food products: baby foods, bakery products, canned fruits, carbonated beverages, confections, dry bakery mixes, fountain syrups/toppings, frozen fruits, fruit juice drinks, frozen desserts, jams, jellies, preserves, meat products, pickles, condiments, and table syrups. The number of sweetened soda/pop drinks accounts for 25% of all added sugars in the U.S. diet (47).

The HFCS and Obesity Controversy

The significant increases in HFCS consumption over recent decades have prompted some to suggest that HFCS is linked to the concomitant rise in obesity and its related health problems. Other researchers suggest that the increases in obesity, diabetes, and related diseases are more closely linked to the overall increase in kcalorie and sugar intakes than to HFCS specifically (19). Soft drinks and other carbohydrate-based beverages are a major source of excess kcalories that contribute to obesity. Concern over calories and health has led to a drop in HFCS, primarily from a decline in soda consumption and/or drinks manufactured with HFCS.

Honey

The world initially depended primarily on honey as a sweetener. Bees collect the thin, watery nectar of flowers, which contains sucrose, and, during the flight back to their hive, convert it through enzymatic action into fructose and glucose molecules. The bees deposit the nectar in honeycombs, where most of the water evaporates to create a thick, sweetened syrup, which is further flavored with enzymes added by the bees. It takes 2 million flowers to produce enough nectar to make 1 pound of honey, and the average worker bee makes only ½ of a teaspoon of honey in its entire lifetime.

Honey can range in color from clear to dark brown and can be fluid, viscous, or solid (41). The taste, color, flavor, and **crystallization** of honey are all influenced by the plant from which it is derived. Honey can be analyzed to determine its pollen content when its origin is in question. Honey varieties with fewer crystal nuclei will crystallize at a slower rate, resulting in larger crystals that settle at the bottom of the container. Examples of this type of honey are buckwheat and honeydew (41). Crystallized honey can be warmed to liquefy the mixture, but the honey does not usually recrystallize uniformly.

Crystallization The precipitation of crystals from a solution into a solid, geometric network.

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How & Why?

Why are there different flavors and colors of honey?

The flavor and color of the honey depend on the type of flower visited by the bees. There are more than 300 varieties of honey, the most popular being alfalfa and clover. Honeys are blended by the bees as they collect nectar from an assortment of flowers. Normally, honey is a golden amber, but the darker the color, the stronger the flavor. For example, Australian eucalyptus honey has a reddish-brown color and a strong, tangy flavor. Acacia honey, in contrast, is almost clear and has a very delicate flavor and aroma.

Honey Composition

Honey primarily consists of fructose (40%), glucose (35%), sucrose (2%), and traces of other carbohydrates such as maltose (1.5 to 4%) and a few other sugars present in less than 1% concentrations (isomaltose, turanose, trehalose, erlose, maltotriose, melezitose, and raffinose) (41). To protect the consumer from honey that has been extended by adding table sugar, the FDA limits commercial honey to no more than 8% sucrose. More than 180 other substances, including beeswax, minerals, and water (18%), are found in honey. Examples of enzymes found in honey include α- and β-amylase, glucose oxidase, catalase, phosphatase, and maltase (41).

Safety Concern

Clostridium botulinum spores are also often present in honey and pose a hazard to children under 1 year of age. Honey is therefore not recommended for infants, whose systems are not yet able to defend against the spores as those of older children and adults can.

Removing Honey from the Comb

Honey was originally sold in the comb, but now processors extract it by cutting the comb on one side and releasing the honey in a centrifuge. Honey can also be collected by crushing the combs and straining out the thick fluid. The extracted honey is heated to 140°F (60°C) for 30 minutes to destroy most microorganisms, then filtered and packaged in airtight containers. Some small producers sell unfiltered honey as well as comb honey.

TABLE 21-4 Infused Honey Recipe

1. Add 1 cup of honey to a saucepan with a flavoring (mint, ginger, lime, rosemary, cinnamon stick, orange, etc.).
2. Heat it to boiling, and immediately reduce to a simmer; simmer for 5 minutes, then let stand for 10 minutes (24 hours for cinnamon stick).
3. Strain the infused honey while it is warm.

Cooled infused honeys are good in hot or cold teas, or on overcooked carrots, French toast, seasoned pork, glazed chicken, cornbread, and numerous other foods.

Whipped, Creamed, Granular, and Infused Honeys

Whipped or creamed honey has had some of the fructose removed, resulting in a thicker consistency. Dried, granular honey is used in baked products, confections, and dry mixes. Infused honey has been heated with a flavor or herb to give it a unique taste (Table 21-4).

Storing Honey

Honey's naturally high sugar content prevents the growth of bacteria; therefore, honey can remain shelved for years without spoiling. However, it can harden when the sugar precipitates into crystals. If this occurs, it can be softened by warming the jar in hot water for an hour or by placing the opened jar in a microwave oven (low defrost).

Substituting Honey for Sugar in Recipes

Following these guidelines can allow honey to be substituted for table sugar in recipes (8):

- In baked products, no more than half the granulated sugar should be replaced with honey.
- Use 1 part honey for every 1¼ parts sugar.
- Reduce the liquid in the recipe by ¼ cup per cup of honey because honey is largely water.
- Add ½ teaspoon baking soda for every cup of honey to reduce the acidity and weight of honey.

Honey's more pronounced flavor affects the product's final flavor. Baked products will brown more (5), but adding ⅛ of a teaspoon of baking soda allows for even browning, while reducing oven temperatures by 25°F avoids overbrowning. When measuring honey, precoating the inside of a measuring cup with water or a very thin layer of vegetable oil minimizes sticking.

Molasses

Molasses is the thick, yellow to dark-brown liquid made by repeatedly boiling the juice of sugar cane or beets during sucrose extraction. For the end product to be called molasses, it must not contain more than 75% water and 5% mineral ash. Most of the sugar in molasses is sucrose. The product becomes darker with each boiling, and the syrup's final color determines its grade. Blackstrap molasses—the most concentrated in syrup and minerals—is the darkest in color and most bitter. Although available for home consumption, it is used primarily for industrial purposes and cattle feed. The thick gumminess of molasses is due to its content of fiber (hemicellulose and pectin), waxes, proteins, and dextran (52). Most commercial grades of molasses are actually blends of different types of molasses.

Foods Made with Molasses

Molasses is used in food preparation, primarily in baked products where it enhances the flavor of breads, cakes, and cookies. A few other foods that incorporate molasses are baked beans, glazes for hams and sweet potatoes, cookies, and candies such as toffees and caramels. Fermenting molasses yields rum, an alcoholic beverage that is distilled and aged for 5 to 7 years. Quicker aging (1 to 4 years) results in light rums.

Maple Syrup

Native Americans were the first to collect the sap from maple trees and boil it into a smooth, tasty syrup. Sap was originally harvested by drilling holes into a maple tree, inserting a spout, and catching the fluid in a bucket positioned under the spout. Newer methods eliminate the buckets and use a network of plastic pipelines attached to the trees. The pipeline carries the sap, a clear, almost

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tasteless, watery liquid, directly to the sugarhouse, where it is boiled down. Sap is collected in the late winter and early spring during the few weeks when the days are relatively warm, but the nights are still cold. Vermont, Maine, New Hampshire, northern New York, and parts of Canada, where the dramatic rise and fall in spring temperatures trigger the flowing of the sap, all have the ideal environment for maple syrup harvesting.

Maple Syrup Colors

The flavor and color of maple syrup develop during the boiling of the initially colorless sap. Government standards specify that maple syrup must contain at least 65.5% sugars among its other ingredients, such as acids and salts. Maple syrup is graded and sold by color and ranges from light amber, or Fancy, to the darkest color, known as Commercial. The darker the color of the maple syrup, the more pronounced its flavor. The lightest colored syrups have the most delicate flavors.

"Real" vs. Blended Maple Syrups

Forty gallons of sap produce 1 gallon of maple syrup, so most "maple syrup" sold today is not pure. A small amount of maple syrup may be blended with corn syrup and/or cane sugar syrup, or there is no real maple syrup in the ingredients but rather maple-flavored high fructose corn syrup. Many companies add artificial maple flavorings to foods, but real maple syrup has a unique flavor and smoothness not duplicated by substitutes. Pure or blended maple syrup is commonly poured over pancakes, waffles, and French toast or added as an ingredient in maple butter, cream, and candy.

Maple Sugar

Maple sugar is a product of maple syrup. It is made by further boiling the syrup until most of the water evaporates and the sugar crystallizes out of the syrup. About 8 pounds of maple sugar are produced from 1 gallon of maple syrup.

Agave Syrup

The light, easily dissolved syrup from the agave plant is often used as a substitute for sugar in health food products and mixes well with beverages. It consists primarily of fructose and glucose, is sweeter than sugar, and the delicate caramel-like taste becomes more prominent as the color shifts from light to dark. Agave plants from Mexico and South Africa are harvested for their core where the syrup is extracted.

Invert sugar An equal mixture of glucose and fructose created by hydrolyzing sucrose.

How & Why?

How is natural evaporated cane juice made?

This product is made from sugar cane grown on the Hawaiian Islands and produced from extracts in the first pressing of sugar cane (34). Natural evaporated cane juice retains some of the natural molasses, giving it a unique flavor. Two forms are available: Natural White has a hint of molasses flavor, and Premium Maui GoldTM has a rich, robust flavor. However, the FDA's current policy is that sweeteners derived from sugar cane syrup should not be declared as "evaporated cane juice" because the fluid extract of sugar cane cannot be defined as "juice" based on FDA regulations (17).

Invert Sugar

Invert sugar syrup is sweeter than sugar, and its ability to resist crystallization resulting in smooth, melt-in-the-mouth candies is popular with professional confectioners and bakers. The strong hygroscopic nature helps bakery items stay moist over longer periods of time and promotes rapid crust coloration and better spread for batters.

Invert Sugar Production

Commercially manufacturing invert sugar occurs by dissolving sucrose in water, heating the solution, and adding either an acid such as cream of tartar or an invertase enzyme such as sucrase. The acid or enzyme hydrolyzes the sucrose into two equal portions of glucose and fructose. This process is called "inversion" (Chemist's Corner 21-4). The amount of hydrolyzing agent added determines the percentage of invert sugar in the finished syrup. Adding cream of tartar or sucrase enzyme inhibits crystallization when invert sugar is used to make candy (see Chapter 25). In addition, the acidity of cream of tartar (tartaric acid) has the added benefit of preventing the natural decomposition of monosaccharides into bitter, brown-colored substances, which occurs when they are exposed to hard water or any other alkaline medium.

CHEMIST'S CORNER 21-4

Inversion

Invert sugar is produced by hydrolyzing sucrose using either enzymes or the combination of heat and acid. Sucrose breaks down to D-glucose and D-fructose. The hydrolyzed mixture is called "invert" sugar because the optical rotation of the molecules reverses (or inverts) from 166 degrees to 222 degrees when sucrose is broken down to fructose and glucose (48).

Invert Sugar in Foods

The confectionary industry uses invert sugar to develop the soft, fluid center of certain chocolates (see Chapter 25).

Sugar Alcohols

Sugar alcohols (also referred to as polyols, polyalcohols, or polyhydric alcohols) are not carbohydrates but the alcohol counterparts of specific carbohydrates. Polyols approved for use in the United States include erythritol, isomalt, lactitol, maltitol, mannitol, polyglycitols (hydrogenated starch hydrolysates), sorbitol, and xylitol (13). Although found naturally in fruits and vegetables, they are also synthesized by hydrogenating certain sugars (Chemist's Corner 21-5). Maltitol appears to be the closest equivalent to sucrose in solubility and functionality (35). Sugar alcohols have low hygroscopicity; erythritol has the lowest, followed by mannitol, isomalt, lactitol, maltitol, sorbitol, and xylitol (48). Although most sugar alcohols are primarily sold as ingredients to food manufacturers, isomalt is available to professional chefs.

Sugar Alcohols in Foods

Reduced Calories

Sugar alcohols provide fewer kcalories than sucrose, which contributes 4

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CHEMIST'S CORNER 21-5

Sugar Alcohol Production

Sugar alcohols are polyols, which is short for "polyhydric alcohols" (12). These polyols occur naturally in certain foods, but for commercial use, they must be prepared in a laboratory as shown below for several sugars and their alcohol counterparts. These sugar alcohol compounds differ from their saccharide counterparts by a slight rearrangement of their atoms; specifically, the carbohydrate's hydroxyl group (–OH) is replaced with an aldehyde or ketone group (C=O).

Carbohydrate	Alcohol Counterpart	Kcal/gram	Production
Glucose	Sorbitol	2.6	Sorbitol is the most common polyol (50), and made by hydrogenating glucose.
Sucrose	Isomalt	2.0	Sucrose is reduced to isomaltulose that is then hydrogenated to isomalt.
Glucose	Erythritol	0.2	Produced from glucose through fermentation.
Lactose	Lactitol	2.4	Reducing the glucose from lactose (48).
Mannose	Mannitol	1.6	Hydrogenation of mannose, glucose, or fructose (derived from sucrose or starch) (48).
Maltose	Maltitol	2.1	A 1,4-linked molecule of glucose and sorbitol produced by hydrogenation of high-maltose syrups derived from the enzymatic hydrolysis of starch (48).
Xylose	Xylitol	2.4	Hydrogenation of D-xylose found in xylans which are gummy polysaccharides found wood pulp, sugar cane bagasse, wheat straw, oat hulls, corncobs, and birch wood (50).

kcalories per gram (see Chemistry Corner 21-5). The low kcalorie content of sugar alcohols allows foods manufactured with them to be labeled "sugar-free" but not "calorie-free" and yet offer some sweetness (40 to 100% as sweet as sucrose) (13). The low kcalorie content of sugar alcohols make them attractive to food manufacturers as sweetening agents, especially in dietetic candies, jellies, jams, chocolate, hard-boiled candies, chewing gums, and ice cream (48).

Cooling Sensation

Sugar alcohols produce a negative heat of solution when they are dissolved (48). This means they produce a characteristic cooling sensation when they dissolve in the mouth, making them useful for such products as sugarless gums, dietetic candies, sugar-free cough drops, throat lozenges, breath mints, and tablet coatings. Not all sugar alcohols are equal in their cooling effects: xylitol has a strong cooling effect, whereas maltitol and isomalt do not.

Cariostatic

Even bacteria cannot digest sugar alcohols, so they help prevent dental caries (cavities).

Humectant

Polyols also function as **humectants** and emulsifiers, extending the shelf life of processed foods. Sorbitol, the most widely used sugar alcohol, is frequently used as a humectant to maintain moistness in marshmallows and shredded coconut.

Problems with Sugar Alcohols

The lower caloric content of polyols is partially due to resisting digestion by intestinal enzymes. This lack of complete digestion means that they are more slowly absorbed from the small intestine than other sugars (or not at all), which can lead to diarrhea, abdominal pain, and gas (13). For this reason, consumption of more than 50 grams of sorbitol per day is not recommended (13), and only limited quantities of xylitol are allowed in foods marketed for special diets (16).

NONNUTRITIVE SWEETENERS

Nonnutritive sweeteners (also known as *intense sweeteners, artificial sweeteners,* or *sugar substitutes) are* defined as substantially sweeter than sucrose by weight (range from thirty to several thousand times as sweet as sucrose) but provide minimal to no calories. The eight nonnutritive sweeteners currently approved by the FDA for use in the United States are Acesulfame-K, advantame, aspartame, luo han guo fruit extract, neotame, saccharin, stevia glycosides, and sucralose (Table 21-5) (13). Advantame and neotame are derivatives of aspartame.

Use in Foods and Beverages

These low- to zero-kcalorie sweeteners are popular among people with diabetes, those watching their weight, and people trying to avoid tooth decay (51). Some of the most common dietary items containing nonnutritive sweeteners are diet soft drinks, plain or flavored waters, sport/energy drinks, yogurts, sugar-free gum, tabletop sweeteners, and frozen desserts (31). Other examples include pudding, gelatin, powdered drinks, cakes, cookies, jams, jellies, and candy.

Safety

Nonnutritive sweeteners have a history of controversy regarding their safety. Because the safety of a substance is often related to the amount consumed, the FDA has established **Acceptable Daily Intake (ADI)** values for each of the nonnutritive sweeteners currently in use.

Humectant A substance that attracts water to itself. If added to food, it increases the water-holding capacity of the food and helps to prevent it from drying out by lowering the water activity.

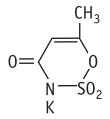
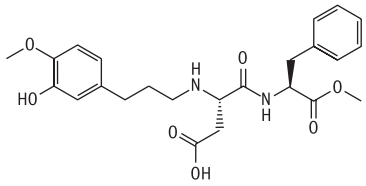
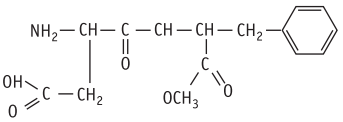
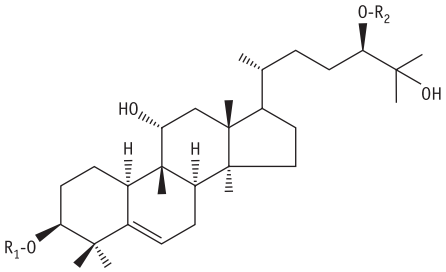
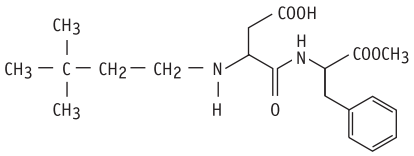
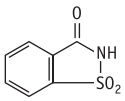
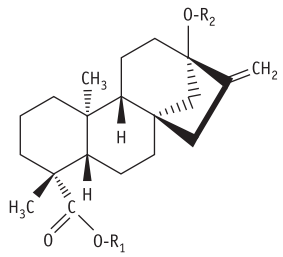
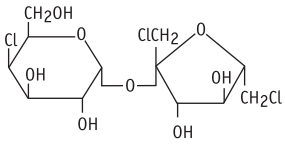
Acceptable Daily Intake (ADI) The amount of a food additive that can be safely ingested daily over a person's lifetime.

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TABLE 21-5 Approved Nonnutritive Sweeteners

Sweetener	Chemical Structure	Sweetness (sucrose = 1)	Taste Characteristics	Uses	ADI* (mg/kg of body weight) OR equivalent
Acesulfame Potassium (Ace-K) (Sunette™, Sweet One®)		200	Rapid onset, persistent, side-tastes at high concentrations	General use (except meat and poultry)	15 25 diet soda cans
Advantame		20,000	Clean, sugar-like taste	General use (GRAS) (except meat and poultry)	32.8 4,920 packets
Aspartame (Nutrasweet™, Equal, Sugar Twin®)		200	Clean, similar to sucrose, no bitter aftertaste	General use (except meat and poultry)	50 75 packets 15 diet soda cans
Luo han guo extract† (Monk Fruit Extract, PureFruit™, Nectresse®)		250–300	Pure form has clean taste, but high concentrations may cause an aftertaste	GRAS use as tabletop sweetener, as food ingredient, and in sweetener blends	None determined
Neotame (Newtame®)		8,000	Clean, sweet, sugar-like taste; enhances flavors of other ingredients	General use (except meat and poultry)	18
Saccharin (Sweet 'N Low™, Sweet Twin®, Necta Sweet®)		200–700	Slow onset, persistent aftertaste, bitter at high concentrations	Used in soft drinks, assorted foods, and tabletop sweeteners	5 8 packets‡
Steviol glycosides purified from the leaves of *Stevia rebaudiana* (Truvia®, PureVia®, Enliten®, A Sweet Leaf®, Sun Crystals®, PureVia™)		200–300	Some types may have bitter aftertaste	GRAS use in beverages, cereals, energy bars, and tabletop sweeteners	4 (steviol glycosides) 9 packets
Sucralose (Splenda™, Equal in "yellow packet")		600	Can withstand high temperatures without losing flavor	General use (except meat and poultry) and in tabletop sweeteners	5 23 packets 5 diet soda cans

GRAS = Generally Recognized As Safe.

*Acceptable Daily Intake (ADI) values for aspartame and acesulfame-K are FDA established. Values for saccharin and sucralose are set by the United Nations Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives (JECFA).

†Cucurbitane glycosides, mogroside II, II, IV, V, VI.

‡One Sweet'N Low™ packet contains 30 mg; one soft drink averages 125 mg.

§Steviol glycosides, rebaudioside A, stevioside.

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How & Why?

How is the ADI determined?

This value is defined as the amount of a specific food additive that can be safely consumed each day on a long-term basis. The ADI of a substance is determined by animal and, sometimes, human toxicological studies. The **no-observed-effect level (NOEL)** is also used to determine safety (39). After finding a safe level based on animal studies, a conservative safety factor, usually about a hundred-fold, is applied. For instance, a substance that was considered safe at 100 mg/kg will have an ADI of 1 mg/kg.

The Food and Agriculture Organization/World Health Organization's Joint Expert Committee on Food Additives (JECFA) is a volunteer group of international experts that provides recommendations on technical and scientific matters, establishes specifications for identification and purification of food additives, evaluates toxicological data, and, in some cases, provides recommendations for ADI values (14). JECFA also provides advisory services for the Codex Committee on Food Additives (CCFA). CCFA establishes maximum or guideline levels for food additives and is currently creating a comprehensive General Standard for Food Additives (GSFA).

Food Functions

Another potential problem with nonnutritive sweeteners is that they lack the important functional characteristics of sugars: bulking, binding, texturing, and fermenting. Their lack of bulking power can be compensated for by the addition of certain compounds, including cellulose (2), maltodextrin (also used for its binding property), the sugar alcohols, and polydextrose. Polydextrose is a synthetic glucose polymer that is classified as a soluble fiber and provides a texture similar to that of sugars with only 1 kcalorie per gram. It is currently approved for use in frozen dairy desserts, baked goods and mixes, confections and frostings, hard and soft candies, chewing gum, gelatins, puddings and fillings, and salad dressings (16).

Saccharin

Saccharin was discovered as a sweetener in 1879 by Constantin Fahlberg (32). The researcher noticed that his dinner roll tasted strangely sweet and traced it back to a substance he had accidentally spilled on his hands while working in his university research lab (29). Saccharin is known by the brand name Sweet'N Low™ (38). It can be used in a variety of products, including baked or processed foods. Saccharin's major drawback, at least for some people, is its bitter aftertaste, which can be masked only partially by blending it with other sweeteners (9).

Concerns about Saccharin

The controversy over saccharin's safety peaked when researchers in a Canadian study reported an increased incidence of bladder cancer in rats fed very high amounts of saccharin (5% to 7.5% of the diet)—the human equivalent of drinking at least 800 diet sodas a day (23). Responding to that study, the FDA proposed a ban on saccharin in 1977. When letters of protest poured into Congress, a congressional moratorium was placed on the FDA ban, along with the requirement that all saccharin-containing products carry a public health warning. In 2000, Congress relieved manufacturers of the requirement to include a warning label on products containing saccharin (39).

The Office of Technology Assessment, a research arm of Congress that attempts to review scientific matters objectively, concluded that saccharin is a potential cause of cancer in humans, although it is among the weakest carcinogens ever detected.

Aspartame

Like saccharin, aspartame was discovered by accident in 1965 by James Schlatter researching ulcer drugs at G.D. Searle Company. He licked his finger to pick up a piece of weighing paper, noticed that the finger tasted sweet, and traced the sweetness back to an earlier spill in the laboratory (38).

What Is Aspartame?

Aspartame is a synthetic combination of two amino acids, aspartic acid and phenylalanine. These amino acids provide 4 kcalories per gram, but the energy value is insignificant because so little is needed to produce intense sweetness. Approved by the FDA in 1981, aspartame is now sold as NutraSweet™, Equal™, and Equal Next™. Equal is a blend of dextrose, maltodextrin, and aspartame; Equal Next combines these ingredients with saccharin (3). Soft/pop drinks account for over 70% of the aspartame consumed (13).

Aspartame Side Effects

As with saccharin, several research studies have questioned the safety of aspartame, and there does appear to be a small subgroup in the population that is sensitive to one or more of its breakdown products (aspartic acid, phenylalanine, and methanol) (26). Common symptoms among this subpopulation include headaches, dizziness, mood changes, and nausea. In addition, research suggests a possible increased risk of brain cancer in rats (26). Although these side effects are controversial, there is no question that aspartame should not be consumed by individuals with phenylketonuria (PKU), a rare genetic disease afflicting 1 out of every 15,000 infants. For this reason, food products containing aspartame as an additive must carry the following warning: "Phenylketonurics: Contains Phenylalanine."

Although aspartame does not have the bitter aftertaste of saccharin, it loses its sweetness when exposed to heat or acids. It can be used in baked goods if encapsulated in a hydrogenated fat coating that melts at the end of baking.

Acesulfame-K

Acesulfame-K was discovered in 1967 by accident. Sold as Sunette® and Sweet One® (38), acesulfame-K was FDA approved in 1988 for use in tabletop sweeteners, dry beverage mixes, and chewing gum (13). It is stable to heating and cooling but has a bitter aftertaste.

Sucralose

Sucralose, marketed as Splenda™ in the United States and Canada (50), was discovered in 1976, and approved by the FDA in 1998 (13). It is known by

No-observed-effect level (NOEL) The level or dose at which an additive is fed to laboratory animals without any negative side effects.

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its E number (E955) within the European Union. Shashikant Phadnis was the student who discovered this nonnutritive sweetener in London's King's College lab where he mistook the word *testing* for *tasting*. Sucralose is produced by replacing three hydrogen–oxygen groups on the sucrose molecule with three chlorine atoms.

This nonnutritive sweetener is stable at high temperatures, making it suitable for use in baked products. Sucralose is used in more than 100 products, such as carbonated soft drinks, cakes, muffins, juices, and gums, and as a tabletop sweetener (35). At one point, Splenda became so popular that demand started to surpass supply. Scientific conclusions regarding the safety of nonnutritive sweeteners continue to be controversial (20), but Splenda currently appears to be less questionable than aspartame.

Neotame

In 2002, the FDA approved the newest nonnutritive sweetener on the scene, neotame (13). The sweetener is 8,000 times sweeter than sugar and kcalorie free. Like aspartame, neotame is made from the amino acids aspartic acid and phenylalanine. However, neotame is not significantly metabolized to phenylalanine, so no warning label is required for people with phenylketonuria. Only about 6 milligrams of neotame are needed to sweeten a 12-ounce can of soda.

Stevia and Its Derivatives

The leaves of the South American plant *Stevia rebaudiana* contain components (steviol glycosides) that are 250 to 300 times sweeter than sucrose (44). However, a sometimes bitter, astringent aftertaste may follow depending on the specific steviol glycoside extracted and/or modified. Confusion results when the generic term *stevia* is used interchangeably with the whole plant or its leaves and the names of the extracted and/or modified steviol glycosides responsible for the sweet taste, such as stevioside and rebaudioside A (Chemist's Corner 21-6). In addition, the sweetener is sold under various brand names.

Though the introduction of stevia products to the U.S. market is a recent development, the leaves have been used in Paraguay, Venezuela, Brazil, and Colombia as a sweetener for more than 1,500 years (36). Guarani native inhabitants of Paraguay used stevia to sweeten a bitter drink called "mate." Sweeteners made with stevia were introduced to the Japanese market in the early 1970s (36).

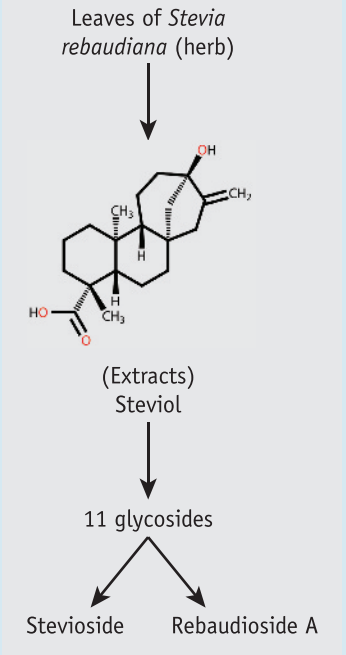
CHEMIST'S CORNER 21-6

Stevia's Sweet Substances

In 1931, French researchers extracted steviol from the leaves of the stevia plant. Approximately eleven glycosides, which are responsible for stevia's sweet taste, were derived from steviol. Among these, stevioside and rebaudioside A are the most common (Figure 21-4) (6).

FIGURE 21-4 *Stevia rebaudiana* plant leaves yield various sweet extracts.





Dario Sabljak/Shutterstock.com

Although certain country agencies approve stevia as a sweetener, others, including the European Commission, do not. Stevia was banned in the United States until 1995, when the 1994 Dietary Supplement Health and Education Act led the FDA to permit stevia as a dietary supplement but not as a food additive. This is why whole-leaf stevia or its crude extracts can be purchased at health food stores or in the nutritional supplement section of stores instead of next to other sweeteners.

Large U.S. corporations began to develop and use their own stevia derivatives in their soft drinks, and, in 2008, the FDA granted Generally Recognized as Safe (GRAS) status to one of stevia's extracted components, rebaudioside A (33). This compound is 200 times sweeter than sugar and has a clean taste useful in many foods and beverages. It is marketed as the kcalorie-free sweeteners Truvia™ and Pure Via™. Truvia is made from Rebiana™, a 97% pure extract of rebaudioside A that is commercially synthesized into larger amounts for sale. Rebiana is made by drying stevia leaves and then steeping them in fresh water. The sweet components of the leaves are then purified from the water. More commonly, these substances are synthesized in a laboratory. Whether extracted or synthesized, this extract has a purer taste and lacks the licorice flavor found in cruder stevia mixtures. Truvia is available as a tabletop sweetener that contains erythritol and other flavoring agents. EverSweet™ is made with the same sweeteners found in stevia leaves—Reb M and Reb D—but through the use of specialized yeast (*Saccharomyces cerevisiae*) fermentation.

Safety of Stevia

The majority of studies suggest that stevia is safe, and many government agencies consider it safe (44). The European Food Safety Authority concluded that steviol glycosides do not cause gene mutations, cancer, or reproductive problems (33). Some researchers, however, express concerns that steviol, a product of the breakdown of stevia by human intestinal bacteria, may be absorbed into the body and disrupt endocrine (hormone) function (42).

Luo Han Guo

Luo han guo (*Siraitia grosvenorii*), or monk fruit, is a natural sweetener and GRAS additive derived from plants (33).

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Its name is derived from Buddhist monks who cultivated the fruit on the steep mountains of China where it has a long history of being used as a sweetener. The fruit's extract is 150 to 300 times sweeter than sucrose.

Other Nonnutritive Sweeteners

Alitame, neohesperidine, thaumatin, and cyclamate are some of the nonnutritive sweeteners approved in other countries but not the United States (13). Cyclamates were discovered in 1937 by a university graduate student, Michael Sevda. This substance is thirty times sweeter than sucrose and stable to heat, but in 1970, cyclamates were banned in the United States because studies indicated they might be carcinogenic. Manufacturers in the United States have been trying to regain approval for cyclamates, which are permitted for use in low-kcalorie foods in more than forty countries and for tabletop sweeteners and pharmaceuticals in Canada (32). In 1980, the FDA rejected a petition for cyclamate approval, but the nonnutritive sweetener continues to be under review.

Around the world, the search continues for kcalorie-free sweetening substances. Several sweeteners from a variety of sources are being investigated or are awaiting approval. Chemical structures vary tremendously and include peptides, amino acids, carbohydrates, inorganic salts, and synthetic compounds. Several proteins with sweet tastes, including thaumatin, talin, brazzein, monellin, mabinlin, and pentadin, have also been identified (38). A few of these are described in the following list:

- **Glycyrrhizin.** This extract from the licorice root is fifty to one hundred times sweeter than sucrose and is used only in confections.
- **Dihydrochalcones.** Obtained from citrus peel, these compounds are several hundred times sweeter than sucrose, with a slow taste onset and a lingering aftertaste.
- **L-sugars.** The chemical mirror image of natural sugars, these are not metabolized by body enzymes and are noncarcinogenic.
- **Miraculin.** This protein was identified more than 40 years ago from a West African plant (*Richardella dulcifica*). It was often called "miracle fruit" because of its unique ability to make sour or acidic materials taste sweet (33).
- **Neohesperidin.** This licorice-flavored substance can enhance the taste and mouthfeel of beverages and is actually listed as a flavor ingredient but not a sweetener.
- **Thaumatin.** An extract of the fruit of a West African plant, *Thaumatococcus danielli* (32), it is one of the sweetest substances known—1,600 times sweeter than sucrose. It has a licorice-like taste when used in high concentrations, is very stable to heat and acid, and is used in chewing gums.
- **Tagatose.** This natural substance is found in dairy products (1.5 kcalories per gram). It offers the bulk of sucrose and is almost as sweet. It is considered GRAS and may be used in the U.S. food supply (13).
- **Trehalose.** Also on the GRAS list is trehalose, which is naturally found in honey, mushrooms, and lobster but is commercially made from starch. It benefits frozen foods by protecting their cell structure to improve texture (7).
- **Isomaltulose.** Used as a sugar substitute in Japan since 1985, this alternative sweetener provides 4 kcalories per gram and is about as sweet as table sugar (13). Also known as Palatinose, NRGylose, or Xtend Isomaltulose, this disaccharide is manufactured enzymatically from sucrose via bacterial fermentation.
- **Brazzein.** Cweet™ uses this protein, derived from the West African fruit *Pentadiplandra brazzeana Baillon*, to provide sweetness (36). The taste of brazzein is similar to that of sucrose, with no significant aftertastes. Because it is a protein, diabetics need not include it when counting carbohydrates.
- **Mabinlin.** This relatively new sweetener is a protein molecule found in the seeds of the *Capparis masaikai* plant (38).

FUNCTIONS OF SUGARS IN FOODS

Table 21-2 shows numerous other functions of sugars in foods besides making them sweeter. Even when it comes to sweetening ability, various sugars differ in their ability due to their unique chemical structures. These structural differences also influence how each dissolves, crystallizes, browns, melts, absorbs water, contributes to texture, ferments, and preserves food.

Sweetness

Sugars are not equal in their ability to sweeten foods or minimize sour and bitter tastes. Table 21-6 compares the relative sweetness of sugars, sugar alcohols, and nonnutritive sweeteners to sucrose, which is scored as 1. Even the taste of sweeteners differs among table sugar (sucrose), honey, molasses, and corn syrup. Temperatures influence sweetness because foods and drinks usually taste sweeter cold rather than hot.

TABLE 21-6 The Relative Sweetness of Sweeteners as Compared to Sucrose

Sweetness	Sweetener (Sucrose = 1)
Less Sweet than Sucrose	
Lactose	0.4
Maltose	0.5
Sorbitol	0.6
Galactose	0.6
Glucose	0.7
Mannitol	0.7
Xylose	0.7
Invert sugar	0.7
Xylitol	0.8
Sucrose	***1.0***
Sweeter than Sucrose	
Invert sugar syrup	1.6
Fructose	1.7
Cyclamate	30
Glycyrrhizin	50
Acesulfame-K	130
Aspartame	180
Stevioside	300
Saccharin	500
Sucralose	600
Thaumatin	1,600
Alitame	2,000
Talin	2,500
Monellin	3,000
Neotame	8,000

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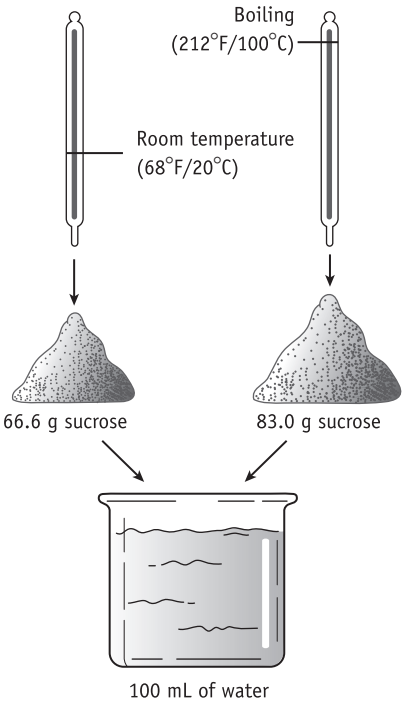
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Other variables are pH, other food ingredients, and the taster's sensitivity to sweetness (11). The dominant determinants of sweetness, however, are the type of sugar used and its concentration.

Solubility

Syrups owe their existence to sugars' ability to dissolve in water. Solubility, which varies from sugar to sugar, is determined by measuring how many grams of a sugar will dissolve in 100 mL of water (24). The solubility of a sweetener influences the perceived mouthfeel and texture of a food or beverage. For example, the least soluble sugar, lactose, is responsible for the gritty texture of ice cream that has partially thawed and been refrozen. Increasing the temperature of a sugar solution allows more sugar to dissolve, resulting in a supersaturated solution when it cools (Figure 21-5). In turn, increasing the sugar concentration raises the boiling point of water (Table 21-7). (See Chapter 3 for more discussion of saturation and solutions.)

FIGURE 21-5 Effect of temperature on the solubility of sucrose.



Reducing sugars Sugars such as glucose, fructose, maltose, and others that have a reactive aldehyde or ketone group. (Sucrose is *not* a reducing sugar.)

Crystallization

Crystallization is vital for manufacturing confectionaries. The development or inhibition of crystal formation determines the finished product's quality (21). (See Chapter 25 for more on candy and crystallization.) The goal in preparing noncrystalline candies is to prevent the sugars in solution from precipitating out in the form of crystals, causing an undesirable grainy texture. The formation of one crystal can start a domino effect, triggering the entire mixture to crystallize. Small foreign particles, changes in temperature, or nicks or cracks on the container's surface may also serve as the starting point for crystal formation. In baked goods, the high oven temperature causes the surface of the dough to dehydrate, inducing sugar crystallization (27). This results in the crunchy, sweet coating of brownies, pound cake, cookies, and muffins.

How & Why?

How is the solubility of a solution expressed?

Solubility may be expressed as the number of grams of sucrose that will dissolve in 100 mL of water or as a percentage (grams of sucrose per 100 grams of solution [sucrose plus water]). It is important to distinguish between the two measurements. For example, at 68°F (20°C), the solubility of sucrose is 199.4 g/100 mL of water, whereas at 212°F (100°C), it is 488.2 g/100 mL of water. Clearly, more than twice the amount of sucrose can be dissolved in 100 mL of water at the higher temperature. Expressed as percentages, these solubilities are 66.6% and 83.0%, respectively. The difference in solubility appears smaller when expressed as a percentage, unless it is recognized that a 66.6% solution contains 33.4 grams of water, whereas an 83% solution contains only 17 grams of water.

TABLE 21-7 Adding Sucrose to a Solution Increases Its Boiling Temperature*

		Boiling Point	
% Sucrose	% Water	°F	°C
0	100	212	100
40	60	215	101
60	40	217	103
80	20	234	112
90	10	253	123
99.6	0.4	340	170

*The boiling point corresponding to each sugar concentration differs for different sugars.

Source: Food Technology

Browning Reactions

Browning reactions involving sugars **(reducing sugars)** and proteins (usually from milk) are due to the Maillard reaction (see Chapter 3). Food products relying on browning from the Maillard reaction include microwaved baked products that have incorporated fructose or dextrose sugars. These reducing sugars should not be added to powdered beverage mixes because they may cause browning during storage; sucrose is used instead.

How & Why?

Why doesn't sucrose cause browning of baked goods?

Sucrose does not take part in the Maillard reaction because, unlike glucose and fructose, it is not a reducing sugar. All monosaccharides and some disaccharides such as maltose and lactose are reducing sugars because they contain a free carbonyl (aldehyde or ketone) group. This group is able to react with a free amino group on a protein, resulting in a browning reaction such as occurs in baked goods. Although glucose and fructose are both reducing sugars, when they react to form sucrose, both free carbonyl groups are involved in formation of the bond between the two molecules; therefore, neither group is available to take part in the Maillard reaction.

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Caramelization

Caramelization results from heating sugars. Sucrose placed in a dry pan will start to melt into a clear, viscous mass when heated to about 320°F (160°C). If heating continues to 338°F (170°C), the melted sugar mass will become smooth and glossy and start to caramelize and brown (1). Sugars differ in the temperatures at which they melt. Fructose, for example, caramelizes at a slightly lower temperature, about 230°F (110°C).

Caramelization is the result of chemical reactions that break the sugar molecules into smaller pieces, which develop a darker color and complex flavor (27). Caramelized sugars are less sweet but more flavorful than the original sugars and may even be slightly bitter. The darker the caramel, the less sweet it becomes. The food industry relies on caramelized sugars to give a distinct flavor and color to food products such as puddings (flan), frostings, ice cream toppings, and dessert sauces. Candies made using the principles of caramelization include, as the name suggests, caramels, as well as peanut brittle.

Moisture Absorption (Hygroscopicity)

The hygroscopic nature of sugars influences the moistness and texture of foods. The degree to which particular sugars draw moisture from the air differs, with fructose having the most moisture absorption capability. For this reason, foods made with high-fructose syrups such as honey and molasses are noted for their moisture retention. In fact, cookies and other baked goods made with honey stay moist even to the point of losing their desired texture. These and other baked products, when made with sucrose, will retain freshness longer. The moisture-absorbing property of sugars makes it imperative that baking mixes be stored in airtight containers; otherwise, moisture drawn to the mixture will lower the quality of the baked product. Unfortunately, sucrose itself gets lumpy if it absorbs too much moisture from the air, so additives are incorporated into commercial baking mixes to prevent ingredients from lumping or caking.

Texture

The textures of many processed or prepared foods rely on sweeteners, especially sucrose. Without sugars, soft drinks feel flat in the mouth, so bulking agents are often added. Sometimes other carbohydrates such as inulin (a polysaccharide) are added to increase viscosity and add a creamy, fat-like consistency to a liquid. Inulin occurs naturally in plants and is used primarily as a texturizer to give body to beverages, improve the texture of low-fat ice creams, make creamier sauces, and help aerate nonfat icings (40). Sugars attract water, causing baked goods to retain a soft, moist texture and preventing drying (27). Moist cakes can be dusted with confectioners' sugar just before serving to further attract moisture and create a sticky, sweet coating. Sugar also acts to prevent overdevelopment of protein and starch structures in baked goods, which would make the dough tough (27). In meringues, sugar forms a supportive coating around the air bubbles within the batter, which prevents their collapse to keep the meringues light and fluffy.

Fermentation

Many alcoholic beverages and quite a few foods rely on the ability of carbohydrates to be fermented. Fermentation plays a role in producing beers, wines, cheeses, yogurts, and certain breads. The following conditions are desirable for fermentation:

- The presence of a yeast, mold, or bacterial culture. Even natural yeasts in the air can cause foods to ferment, and, in some cases, spoil, by metabolizing their available sugars. Perhaps this led to the discovery of baking yeast breads.
- A food source, usually a carbohydrate, to feed the microorganisms. Yeast bread rises because of the carbon dioxide gases produced by the yeasts feeding off the carbohydrates in flour. Any sugar except lactose can be fermented to carbon dioxide and alcohol by yeast organisms.
- Sufficiently warm temperatures to stimulate microbial growth.
- Correct salt and acid concentrations.

Preservation

High concentrations of sugar act as a preservative by inhibiting the growth of microorganisms. Sugar was used to preserve jams, jellies, and other fruit spreads long before either canning or freezing methods were developed. The osmotic pressure created by the high concentration of sugar dehydrates the bacteria or yeast cells to the point of inactivation or death (28). That is why honey can remain opened and unspoiled on the shelf for years.

Leavening

Sugars promote the leavening of baked goods (27). When sugar is added to a bread batter, its particles break up the dough, creating pockets of air. During baking, these air pockets expand upward causing the batter to rise.

Other Uses

Food products benefit from sugars contributing to crust formation, coating, creaming, and surface cracking.

Caramelization A process in which a dry sugar, or a sugar solution with most of its water evaporated, first melts into a clear, viscous liquid and then turns into a smooth, brown mixture as it is heated.

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PICTORIAL SUMMARY / 21: Sweeteners

From the earliest times, sweet tastes have attracted people and led them to search for new ways to obtain sweeteners from the world around them. Today, sugars represent the number-one food additive, by weight, in the United States.

NATURAL SWEETENERS

As people sought to sweeten foods, they discovered that the only sweetener of animal origin is lactose, found in milk. Plants, however, produce abundant natural sugars through photosynthesis. Once extracted from their source, sugars become refined carbohydrates delivering 4 kcalories per gram.

Sweeteners can be grouped into three categories:

1. Granulated sugars

- **Sucrose** (table sugar) is derived from either sugar cane or sugar beets. The sucrose obtained from either plant is then refined into these commercial products:

White sugar **Powdered sugar** **Turbinado sugar**
Baker's Special **Sanding sugar** **Brown sugar**
Liquid sugar **Muscovado sugar** **Raw sugar**
Fruit sugar **Invert sugar**



- **Glucose** (dextrose) is the building block of most carbohydrates and the major sugar in our blood. Sources are fruits, vegetables, honey, and corn syrup. It is one-half as sweet as sucrose.
- **Fructose** is found naturally in fruits and honey and is the sweetest and most hygroscopic of all the granulated sugars.
- **Lactose,** found in milk, is the least sweet of all sugars.
- **Maltose,** also called "malt sugar," provides the characteristic "malt" flavor of milkshakes but is mostly used to make beer.

2. Syrups
(sugars in solution)

- Corn syrup
- High-fructose corn syrup
- Honey
- Molasses
- Maple syrup
- Invert sugar

3. Sugar alcohols
(found naturally in fruits and vegetables or synthesized from certain sugars)

- Sorbitol
- Mannitol
- Xylitol
- Maltitol
- Isomalt
- Lactitol
- Erythritol

NONNUTRITIVE SWEETENERS



FDA-Approved Nonnutritive Sweeteners

- Acesulfame-K
- Advantame
- Aspartame
- Luo han guo extracts
- Neotame
- Saccharin
- Sucralose
- Stevia glycosides

FUNCTIONS OF SUGARS IN FOODS

Sugars in foods function in many ways besides merely providing sweetness, and various sugars differ in their sweetening ability. The unique chemical arrangements of the various sugars influence how they are used in food preparation:

Sweetness: The type of sugar and its concentration determine sweetness. Fructose is the sweetest.

Solubility: Solubility is determined by measuring either how many grams of a sugar will dissolve in 100 mL of water or the percentage of a saturated solution that consists of sugars (grams of sugar per 100 grams of solution). Fructose is the most soluble sugar.

Crystallization: Sugars with low solubility, such as lactose, have a greater tendency to crystallize, while fructose, with its high solubility, does not crystallize readily. Invert sugar and corn syrup resist crystallization and inhibit crystallization of sucrose, and thus are often used in confectionary production.

Browning reactions: Two major types of browning involving sugars are the Maillard reaction, dependent on protein (amino acids) and reducing sugars, and caramelization, dependent on dry heat.

Moisture absorption (hygroscopicity): The hygroscopic nature of sugars influences the moistness and texture of food to which they are added. Fructose has the best ability to absorb moisture from the air and impart it to food.

Texture: Many foods rely on sucrose for body and texture. In baked goods, sugar produces a finer texture, enhances flavor, generates browning of the crust, promotes fermentation of yeast breads, and extends shelf life by virtue of its ability to retain moisture. Sugar gives body to soft drinks and helps offset the bitter, acidic, or salty taste of certain foods, such as tomato sauces, chocolate, and sodium-processed meats (ham, bacon, etc.).

Fermentation: Sugars (except lactose) serve as fuel for yeast during fermentation, especially in certain baked products and alcoholic beverages.

Preservation: High concentrations of sugars act as a preservative.

Leavening: Sugars promote leavening of baked goods.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Raw sugar is made from _____.
   a. beets
   b. sugar cane
   c. sugar beets
   d. molasses

2. Which of the following is the sweetest of all granulated sugars?
   a. Fructose
   b. Powdered sugar
   c. Turbinado sugar
   d. White sugar

3. Children under 1 year of age should not be fed honey because it may contain _____.
   a. *C. botulinum* spores
   b. *E. coli*
   c. *Salmonella*
   d. *G. lamblia*

4. The nonnutritive sweetener aspartame is made from which two amino acids?
   a. Glutamic acid and glutamine
   b. Glycine and phenylalanine
   c. Lysine and aspartic acid
   d. Aspartic acid and phenylalanine

5. What is the name of the process by which dry sucrose is melted to form a brown, viscous mixture?
   a. Fermentation
   b. Caramelization
   c. Maillard reaction
   d. Crystallization

6. An important function of sugars is solubility, which is defined as:
   a. the degree to which a sugar draws moisture from the air.
   b. a heated sugar solution that turns brown.
   c. the amount of a sugar that dissolves in 100 mL of water.
   d. precipitation out of the solution in the form of crystals.

7. High concentrations of sugars in jams act as a preservative due to _____.
   a. fermentation
   b. hygroscopicity and osmotic pressure
   c. caramelization
   d. crystallization

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Discuss the individual functions of sucrose, glucose, fructose, lactose, and maltose in food preparation.
2. Discuss the differences among the following forms of sucrose: raw, turbinado, white, powdered, fruit, Baker's Special, sanding, liquid, and brown.
3. Discuss the differences among the following syrups: corn syrup, high-fructose corn syrup, honey, molasses, maple syrup, and invert sugar.
4. What is a dextrose equivalent (DE), and how is the DE value of a substance determined?
5. How are sugar alcohols different from other sweeteners? How are they used in food products?
6. What nonnutritive sweeteners are currently available in the marketplace? Discuss their basic chemical structures and their sweetness relative to sucrose.
7. Define *solubility,* and list the sugars according to their solubilities, from lowest to highest.
8. Which foods are dependent on the crystallization of sugars and why?
9. Describe the two types of browning reactions involving sugars and how these processes are used by the food industry.
10. Define *hygroscopicity,* and describe the role this characteristic of sugars plays in food preparation.

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22



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Fats and Oils

Functions of Fats in Food 429
Types of Fats 434
Fat Replacers 441
Food Preparation with Fats 443
Storage of Fats 446

Fats and oils (referred to collectively in this chapter as *fats*) are very important in the diet because they contribute to the flavor, color, texture, and mouthfeel of numerous foods. The first dietary fat that was used by humans probably came from animal carcasses. Humans quickly learned that melted fat improved food flavor. The domestication of animals provided another major source of fat—butter. The heavy cream-colored liquid rising to the top of milk was soon separated, churned, and used. As populations grew, a more abundant source of fat was used by extracting the oils from plant seeds. The seed type determined what kind of vegetable oil was produced—safflower, sunflower, sesame, cottonseed, olive, corn, and others. People also learned that many kinds of nuts—almonds, walnuts, peanuts, and macadamia nuts, to name a few—provided a variety of oils. A few fruits high in fat such as coconut and avocado were also used to generate oils.

As time passed, technology allowed the development of new fats. Wartime food shortages triggered the demand for a butter replacement, and margarine was created by the thickening of vegetable oil, a process first introduced in the 1860s. The continued thickening of vegetable oils past the "soft margarine stage" resulted in the thick, white paste of vegetable shortenings used for frying.

Soon fats were being used not only for preparing foods but also as an ingredient. Food manufacturers added fats to their food products to ease production and handling and improve storage stability (2). Today, fats are often added to various processed food products because of their unique shortening powers, melting points, plasticities (ability to be shaped), and solubilities. Fat is added as an ingredient to a wide variety of food products, including breads, dairy foods, numerous processed foods such as potato and tortilla chips, and desserts such as cakes, icings, cookies, pies, pastries, and some frozen desserts.

Fats are used not only in the preparation and formulation of many foods but are also added directly to finished foods. For example, butter or margarine is spread on breads or vegetables;

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mayonnaise is mixed into salads (potato, tuna, and chicken); and salad dressings are served on greens. As a result, so many foods contain fats and oils through preparation, formulation, and addition that it is sometimes difficult to find foods without fat. The health risks associated with excessive kcalorie intakes and dietary fat led to the development of fat replacers.

This chapter focuses on the preceding topics and covers the various functions of fat in foods, different types of fat, fat replacers, the use of fat in food preparation, and storage requirements. This and the preceding chapter on sweeteners come before the chapters concerning various desserts because so many of these desserts incorporate both sweeteners and fats. Chapter 3 covers the chemical composition and classification of fats.

FUNCTIONS OF FATS IN FOOD

Nothing else can mimic the unique properties that fats impart to foods (Table 22-1). As a result, it is difficult to achieve the functional characteristics of food fats through substitution of other ingredients. The unique chemical configuration of the fat molecule (specifically, the length and saturation of the three fatty acids on the glycerol molecule of a triglyceride; see Figures 3-18 and 3-19 in Chapter 3) is key to the uses of fats in foods. As explained in this section, it contributes to the functions of fat in heat transfer, shortening (tenderizing) power, and emulsions, as well as influences the fat's melting point, plasticity, solubility, flavor, texture, appearance, satiety, and nutrient content.

Heat Transfer

A major function of fats is their ability to act as a medium for heat transfer. Numerous meals use fat to transfer heat to foods without burning them—butter in the frying pan, oil in the deep fryer, and peanut oil in the wok. The amount of fat used can range from the minimal quantities used in sautéing, to the moderate levels used in pan-frying, to enough to completely submerge a food, as in deep-frying.

TABLE 22-1 Functions of Fats in Foods

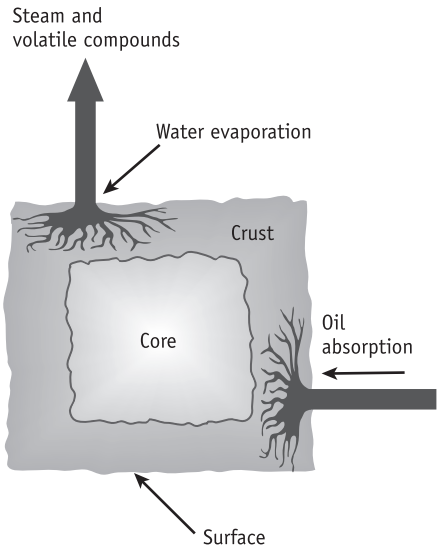
Function	Examples
Heat transfer	Sautéing, pan-frying, deep-frying
Shortening power	Biscuits, pastries, cakes, cookies
Emulsions	Mayonnaise, salad dressings, sauces, gravies, puddings, cream soups
Varying melting points	Candies
Plasticity	Confections, icings, pastries, other baked goods
Solubility	Fats do not dissolve in water, yielding unique food flavors/textures and foods such as salad dressings
Flavor/mouthfeel	Flavor (butter, bacon, fried foods), lubricity, thickness, cooling
Textures	Creaminess, flakiness, tenderness, elasticity, ease of cutting, viscosity
Appearance	Sheen, oiliness, color
Satiety	Fats contribute to "feeling full"
Nutrients	Provide energy: 9 kcal/g; carry fat-soluble vitamins

How & Why?

How is food heated in deep-frying?

In deep-frying, food is quickly cooked in several stages involving moisture transfer, fat transfer, crust formation, and interior cooking (35). As soon as the food is submerged in fat, the water on the food's surface vaporizes into the surrounding oil, which draws the moisture within the food toward its surface (Figure 22-1). A layer of steam forms around the food, protecting it from the high temperatures of frying and preventing it from becoming saturated with oil, although some amount of oil is transferred into the food through the pores from which the water escaped. In the next stage, the crust browns, in part because of the Maillard reaction, and becomes somewhat larger and more porous from the water being driven out of the food by the frying heat. Most of the oil that has been absorbed remains in the crust and outer layer of the fried food. Finally, the inner core of the food cooks through heat penetration rather than by direct contact with the heated fat. Specifically, waves of liquid heat circulate around the food (convection), and then the hot oil passes through the food (conduction) to heat the water within so that the food is also steamed.

FIGURE 22-1 In fried food, oil is absorbed and water leaves as steam, contributing to a crisp, moist surface.



Source: Reprinted with permission from *Food & Nutrition Encyclopedia*.

Shortening Power

The **shortening** power of certain fats makes them essential in the preparation of pastries, piecrusts, biscuits, and cakes. The more highly saturated

Shortening A fat that tenderizes, or shortens, the texture of baked products by impeding gluten development, making them softer and easier to chew.

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fats, which are solid at room temperature, tend to be more useful as shortenings in baked goods. Shortening power depends on the consistency of the fat and the method of its incorporation into the dough. For example, solid shortenings are necessary to make flaky pastry, whereas oils will produce a tender pastry that tends to be crumbly rather than flaky. Mixed into a flour mixture, fat separates the flour's starch and protein and, when heated, melts into the dough. This creates air spaces that give the finished baked product its characteristic delicate texture. A fine grain is created from certain cake and cookie batters with the use of shortenings that gently encase the numerous air bubbles, serving as a starting point for the air to expand and increase overall volume. Baked goods become more tender, up to a point, as fat concentration increases. The exact role of fat in the formation of various baked products and their lower-fat alternatives is discussed in more detail in Chapters 19, 20, and 23.

Emulsions

All foods contain some amount of liquid, and if fats or oils are present, then the combination results in some type of **emulsion** (6) (Chapter 3). There are two types of lipid emulsions:

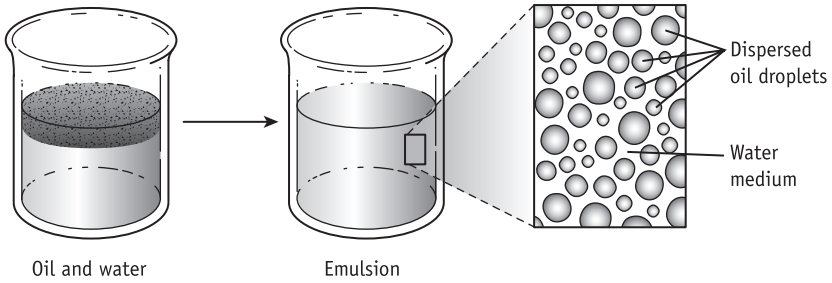
- Oil-in-water (Figure 22-2), in which oil droplets are dispersed throughout the water
- Water-in-oil, in which water droplets are dispersed throughout the oil

Most food emulsions are of the first type—oil-in-water. Examples of such natural emulsions include milk, cream, and egg yolks. Emulsions can be quite viscous and thick, or more fluid and less stable. Examples of prepared foods that are emulsions (oil-in-water) include mayonnaise, salad dressings, cheese sauces, gravies, puddings, and cream soups. The less common water-in-oil emulsion, in which the smaller amount of water is dispersed in the fat, is found in foods such as butter and margarine.

Emulsion A liquid dispersed in another liquid with which it is usually immiscible (incapable of being mixed).

Surfactant A surface-active agent that reduces a liquid's surface tension to increase its wetting and blending ability.

FIGURE 22-2 Oil-in-water emulsion; the oil is dispersed in water.



Emulsions have three parts:

- The dispersed or discontinuous phase, which is usually oil
- The dispersion medium or continuous phase, which is most likely water based
- An emulsifier, a compound that helps keep one phase dispersed in the other

Emulsifiers

The two phases of emulsions are kept apart by surface tension, and the boundary between them is called the *interface*. The emulsifier migrates to this interface and acts as a **surfactant,** lowering the surface tension between the dispersed and continuous phases so that the two phases mix more readily (51).

How & Why?

How are surfactants and emulsifiers different?

In the food industry, the terms *surfactant* and *emulsifier* tend to be used interchangeably. However, strictly speaking, there is a difference: emulsifiers are a special type of surfactant. The term *surfactant* is an abbreviation of "surface active." All surfactants contain both hydrophilic and hydrophobic groups and thus prefer to exist at the boundary between oil and water rather than dissolving in either phase. Their presence at the interface reduces surface tension and makes it easier to disperse one liquid in the other. This makes surfactants such as lecithin good wetting agents that help disperse many food ingredients, from fats in baked goods and sauces to the cocoa powder in chocolate milk. The lipoproteins of egg yolk are an excellent example of a good food emulsifier. All emulsifiers are surfactants, but not all surfactants make good emulsifiers. A good emulsifier must do more than make it easier to form an emulsion; it must also stabilize the emulsion, or, in other words, prevent separation of the phases on standing. The best emulsifiers are able to form a stable film around the emulsion droplets (oil droplets if it is an oil-in-water emulsion) that prevents their coalescence.

An emulsifying agent can act as a bridge between oil and water because it contains two distinct types of molecular groups, one *hydrophilic* ("water loving") and the other *hydrophobic* ("water fearing") (Figure 22-3). It has been suggested that this balance of water-loving and water-fearing (or lipid-loving) portions allows emulsifiers to act like a "zipper" in drawing the water and oil phases together. In addition to migrating to the interface, the best emulsifiers are able to form bonds with other emulsifier molecules, thus creating a stable interfacial film that resists coalescence (see Figure 3-4 in Chapter 3). Without such a film, when the emulsion droplets (e.g., oil droplets in an oil-in-water emulsion) collide, they are likely to combine to form one larger droplet, and as this continues, the phases separate. When surrounded by a stable film, the droplets can collide without coalescing.

Emulsifiers work not only with liquids but also with gaseous phases. Figure 22-4 shows how an emulsifier added

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FIGURE 22-3 Mechanism of emulsifiers in oil-in-water and water-in-oil emulsions.

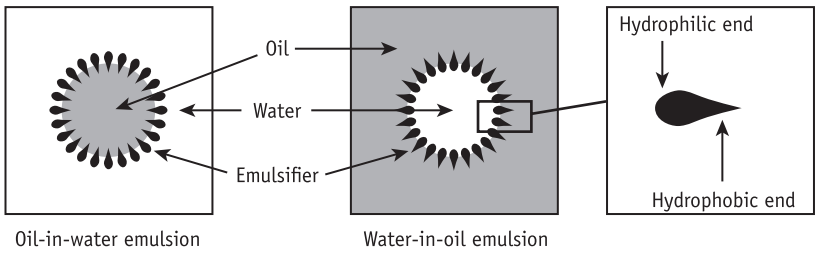
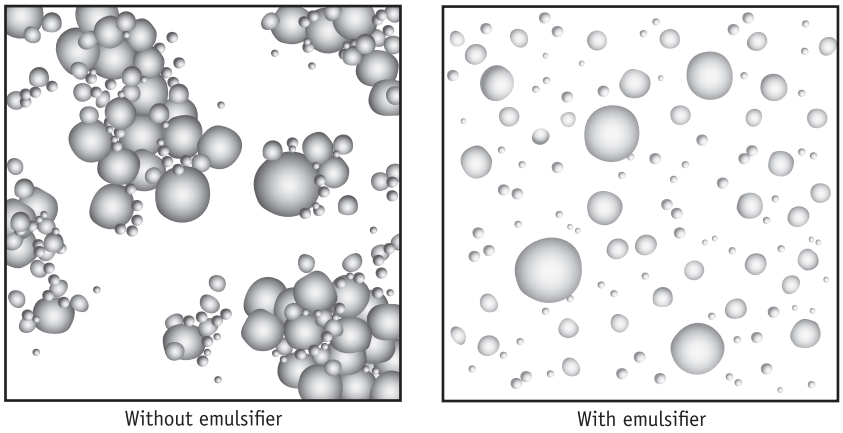


FIGURE 22-4 Emulsifier added to cake batter.



to cake batter disperses the air bubbles, resulting in a cake with a finer crumb.

Monoglycerides and diglycerides are the most frequently used emulsifiers in the food industry (Chemist's Corner 22-1). They are added to foods to increase or improve emulsion stability, dough strength, volume, texture, and tolerance of ingredients to processing (18). Other emulsifiers include phospholipids (lipoproteins from egg yolks), milk proteins, soy proteins, gelatin, gluten, vegetable gums such as carrageenan, and starches. Ground paprika, dried mustard, and other finely ground herbs or spices, which are often included in salad dressings, can act as surfactants. Emulsifiers synthesized by the food industry include polysorbate 60 and propylene glycol monoesters.

Stability of Emulsions

Emulsions differ in their degree of stability—temporary, semipermanent, or permanent—and viscosity. Stability is defined by an emulsion's capacity to resist separation when subjected to gravity, agitation, long storage times, extreme temperatures, surface drying, or added salt.

CHEMIST'S CORNER 22-1

Monoglyceride and Diglyceride Emulsions

Monoglyceride and diglyceride emulsifiers are able to mix lipid-based and water-based ingredients because of the unique configuration of their molecules. Half the molecule (the glycerol molecule and hydroxyl groups) is drawn toward the aqueous phase, whereas the other half (one [monoglyceride] or two [diglyceride] fatty acids) is drawn toward the lipid phases. This same principle works in a micelle, an aggregate of surfactant molecules arranged into a "ball." The hydrophobic portions point toward the middle, whereas the hydrophilic heads are oriented toward the outside or surface of the "ball" (23).

Temporary Emulsions

Temporary emulsions are the least viscous and stable; they separate on standing when left alone. An example of a temporary emulsion is oil and vinegar salad dressing, in which the oil rises to the top of the vinegar. These emulsions must be shaken each time they are used in order to reform the emulsion. They are unstable because they rely on surfactants that are unable to form a stable interfacial film to temporarily disperse one phase in another (see previous How and Why? feature).

Semipermanent Emulsions

The tendency of the emulsion to separate is decreased by adding stabilizers, which create a viscosity similar to that of soft yogurt. Examples of semipermanent emulsions include commercial French and Italian salad dressings.

Permanent Emulsions

Permanent emulsions are very viscous and stable, to the point that they do not separate. Mayonnaise is a permanent emulsion in which the major ingredient is vegetable oil (dispersed phase), which remains dispersed in the liquid, usually vinegar or lemon juice (continuous phase). The added egg yolk in mayonnaise contains lipoproteins with lecithin and protein components. These lipoproteins migrate to the interface and form a strong, stable interfacial film that prevents coalescence. The high oil content of mayonnaise contributes about 100 kcalories and 11 grams of fat in every tablespoon. However, lower-fat alternatives are available.

Melting Point

Not all fats melt at the same temperature. Each food fat has a unique melting temperature range that depends on the mixture of fatty acids contained in its triglycerides. These fatty acids are single molecules that each have a distinct melting point (Chemist's Corner 22-2). Ultimately, a fat's melting point is determined by the following four characteristics of its predominant fatty acids:

- Degree of saturation
- Length
- Cis–trans configuration
- Crystalline structure

Degree of Saturation

Most plant oils contain more polyunsaturated fatty acids than saturated fatty acids, which causes them to be liquid at room temperature. Animal fats tend to have more saturated fatty acids, causing them

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CHEMIST'S CORNER 22-2

Fatty Acid Melting Points

Melting points increase with chain length, saturation (less double bonds), cis-configuration, and larger crystal size. The extent to which the molecules attract each other and are able to align and bond with each other increases the melting point. The greater the attraction, and/or the easier it is to fit the molecules together, the more energy is required to break the bonds between them and melt the fat. This principle applies to all four characteristics that affect the melting point:

- Longer fatty acid chain = higher melting point. Short chain = lower melting points. More attraction points between the fatty acid molecules require more energy to separate them.
- Saturated fatty acids = higher melting point. Unsaturated fatty acids = lower melting points. Double bond creates a kink in the molecule, making it harder for the fatty acids to fit together. As unsaturation increases, melting point decreases. This explains why unsaturated oils tend to be liquid, whereas saturated fats tend to be solid.
- Cis configuration of the double bonds creates a bigger kink in the molecule as compared with trans double bonds, which again results in a lower melting point (Figure 3-20 in Chapter 3).
- Larger crystals require more energy to melt, resulting in higher melting points.

to be solid at room temperature. Plant oils may be subjected to hydrogenation, a commercial process that adds hydrogen to the double bonds of the unsaturated fatty acids. The number of double bonds decreases and saturation increases; as a result, hydrogenated fats are normally solid, instead of liquid, at room temperature. Hydrogenation makes the fat more spreadable and increases its shelf life. The degree of saturation and length of selected fatty acids is shown in Figure 22-5.

FIGURE 22-5 Fatty acids differ in saturation and length.

Common Name	Carbon Atoms: Double Bonds		Chemical Structure
Saturated Fatty Acids			
butyric acid	4:0		$CH_3(CH_2)_2COOH$
caproic acid	6:0		$CH_3(CH_2)_4COOH$
carprylic acid	8:0		$CH_3(CH_2)_6COOH$
capric acid	10:0		$CH_3(CH_2)_8COOH$
lauric acid	12:0		$CH_3(CH_2)_{10}COOH$
myristic acid	14:0		$CH_3(CH_2)_{12}COOH$
palmitic acid	16:0		$CH_3(CH_2)_{14}COOH$
stearic acid	18:0		$CH_3(CH_2)_{16}COOH$
arachidic acid	20:0		$CH_3(CH_2)_{18}COOH$
behenic acid	22:0		$CH_3(CH_2)_{20}COOH$
Unsaturated Fatty Acid			
Common Name	**Carbon Atoms: Double Bonds**		**Chemical Structure**
ω-3 Fatty Acids			
α-linolenic acid	18:3 (9,12,15)	CIS	$CH_3CH_2—(CH{=}CH—CH_2)_3—(CH_2)_6COOH$
ω-6 Fatty Acids			
linoleic acid	18:2 (9,12)	CIS	$CH_3(CH_2)_4—(CH{=}CH—CH_2)_2—(CH_2)_6COOH$
γ-linolenic acid	18:3 (6,9,12)	CIS	$CH_3(CH_2)_4—(CH{=}CH—CH_2)_3—(CH_2)_3COOH$
arachidonic acid	20:4 (5,8,11,14)	CIS	$CH_3(CH_2)_4—(CH{=}CH—CH_2)_4—(CH_2)_2COOH$
ω-9 Fatty Acids			
oleic acid	18:1 (9)	CIS	$CH_3(CH_2)_7—CH{=}CH—CH_2—(CH_2)_6COOH$
erucic acid	22:1 (13)	CIS	$CH_3(CH_2)_7—CH{=}CH—CH_2—(CH_2)_{10}COOH$
nervonic acid	24:1 (15)	CIS	$CH_3(CH_2)_7—CH{=}CH—CH_2—(CH_2)_{12}COOH$
elaidic acid	18:1 (tr9)	TRANS	$CH_3(CH_2)_7—CH\overset{tr}{=}CH—CH_2—(CH_2)_7COOH$
linolelaidic acid	18:2 (tr9, tr12)	TRANS	$CH_3(CH_2)_7—CH\overset{tr}{=}CH—CH_2—CH\overset{tr}{=}CH—(CH_2)_7COOH$

Length of the Fatty Acids

The length of the fatty acids can alter these general rules, as even saturated fats with shorter carbon chains can have lower melting points than fatty acids with longer ones. Butyric acid and stearic acid are saturated fatty acids found in butter. However, butyric acid has only 4 carbons and thus melts before stearic acid, which is 18 carbons long. Coconut oil is a saturated oil containing short fatty acids, which causes it to remain solid at room temperature. However, it will quickly liquefy if the bottle is held in a person's warm hand. In general, increasing the chain length of the fatty acids in a fat increases its melting point.

Cis–Trans Configuration

Another significant structural difference that affects the melting point of a fatty acid is the predominance of cis or trans double bonds (Chapter 3). A fatty acid with a trans configuration has a higher melting point than an identical fatty acid with a cis form at the double bond. For example, oleic acid, an 18-carbon fatty acid with one double bond in the cis form, has a melting point of 57°F (14°C), whereas the same fatty acid in the trans form, called elaidic acid, has a melting point of 111°F (44°C). The "bends" created by cis double bonds reduce interactions, which decreases the fat's melting point.

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Crystalline Structure

The fourth influence on the melting point of fats is its crystalline structure, the arrangement of the fatty acids on the triglyceride molecule. How they are packed, or crystallized, in the solid phase of the fat determines at what point the fat will melt. This principle is very important to chocolate manufacturers: the larger the fat's crystals, the higher the melting point will be, which allows chocolate to be held in the hand without melting.

Types of Crystals Affect Food Quality

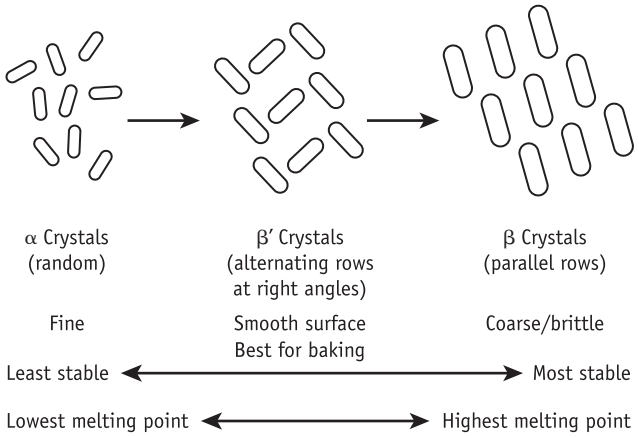
Most fats appear to be uniform in shape but are really a mixture of crystals. This is called **polymorphism**, which is the ability to exist in more than one crystalline form. Fat crystals are classified as alpha (α), beta prime (β′), intermediate, or beta (β). Crystal type determines their usefulness in food preparation.

For instance, the melting point of fats rises as the crystal size increases from α to β′, and eventually to β (Figure 22-6). The rate of cooling after a fat is heated dictates the type of crystals formed. Rapid cooling results in unstable α crystals with a waxy, transparent consistency. α crystals are extremely fine and very unstable, melting readily and recrystallizing into the larger, more stable β′ form. These β′ crystals can be obtained by agitating the fat during cooling, which should be conducted at an intermediate rate. β′ crystals are best for food preparation because they yield fine-textured baked goods and smooth-surfaced hydrogenated vegetable shortenings and margarines (26). Slightly coarse intermediate crystals result from β′ crystals melting and recrystalizing. Extremely slow cooling times or long storage times form the most stable, or β, crystals, which have an opaque look but produce a sandy, brittle texture.

Plasticity

Plasticity describes the ability of a solid fat to hold its shape but still be molded or shaped under light pressure. A plastic fat may be molded into various shapes. Plasticity also determines a fat's spreadability. It is an important characteristic in the preparation of confections, icings, pastries, and other baked products. Although many fats look solid at room temperature, they are actually composed of liquid oil with a network of solid fat crystals holding it in place. The ratio of liquid oil to solid fat crystals, which depends on the specific fatty acids present and the temperature, determines whether a fat is liquid, plastic, or solid. The more unsaturated a fat is, and the warmer its temperature, the more plastic it will be. Chilled butter has very little plasticity as compared with hydrogenated vegetable oil (shortening). However, hard fats such as butter become soft and more spreadable when warmed.

FIGURE 22-6 Fat forms. The crystalline form of fat (α, β′, or β) influences its melting point and texture.



Solubility

Fats are generally insoluble in water. That is why oil floats above the vinegar in a salad dressing. Fats are actually defined as fats because they do not dissolve in water, but they will dissolve (become soluble) in organic compounds such as benzene, chloroform, and ether.

Flavor

The taste of fried foods such as breaded poultry or fish, French fries, potato chips, and doughnuts is one of the most obvious contributions of fat to flavor in foods. The flavor developed in certain foods by fats is very difficult to duplicate. For example, fats give butter, bacon, and olive oil their own distinctive tastes. Fats not only contribute their own flavor to foods but also absorb fat-soluble flavor compounds from other foods. Sautéing garlic, onions, and herbs in oil releases their flavorful and aromatic compounds, while also lending them a smooth, rich mouthfeel.

Texture

Fats also contribute texture to foods. Consider how fat gives textures to flaky pastries, smooth chocolates, half-melted ice cream, whipped cream topping, and crispy fried foods. The texture of baked products would not be the same without fat's positive influence on tenderness, volume, structure, and freshness (see Chapter 17).

The higher the fat content in ice cream, the smoother and creamier is the mouthfeel. The tenderizing effect of fats makes foods easier to chew and causes foods to feel more moist in the mouth (43). The lubricating action of fat aids saliva in moistening certain foods, such as crackers and chips. These dry foods are processed in the mouth much more easily if they are coated with an oil or served with a high-fat dip or spread.

Appearance

Foods are made more appealing by pigments located in their natural fats. Milk, for instance, would be chalky white or bluish without its natural fat-based

Polymorphism The capability of solid fats to change into several crystalline forms, each with its own melting point, crystal structure, and solubility.

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pigments. The soft yellow hue of butter was found to be so important to consumers that attempts were made to duplicate it in margarine. Fat also coats food with a sheen of delicate oil that improves the appeal of chicken, pastries, chocolate, and many other foods.

Satiety or Feeling Full

Fats induce a sense of fullness, or satiety. Foods and beverages containing fat help to delay the onset of hunger pangs by two methods: (1) fats take longer to digest than carbohydrates and proteins, and (2) fats delay the emptying of the stomach contents, which makes a person feel full longer.

TYPES OF FATS

Through the years, fat's desirability in foods and multiple roles in food preparation have led to many different types of fats being obtained from both animal and plant sources. The most abundant sources of fats and oils in the diet are those of animal origin such as meats, poultry, and dairy products. Plants also contribute to dietary fat, and the richest sources include nuts, seeds, avocados, olives, and coconut. This section describes the different types of fats such as butter, margarine, shortenings, oils, lard, and cocoa butter; a later section discusses fat replacers.

Butter

Undisturbed, unhomogenized milk will separate into its watery and fatty portions. The cream that floats to the top is used to make butter. In short, butter is made from the cream of milk. A full 10 cups (2½ quarts) of milk are used to generate one stick (¼ pound) of butter. The U.S. Department of Agriculture (USDA) defines butter as 80% milk fat, no more than 16% water, and 4% milk solids. Salt and coloring additives such as extract of annatto seed or carotene may or may not be added.

Clarified butter Butter that will not burn because its milk solids and water have been removed.

Butter is responsible for the desirable mouthfeel of baked goods and the flakiness and tenderness of pastries; it increases shelf life by decreasing moisture loss and slowing staling of starches (8). Other properties of butter include aeration of dough, emulsification, and flavor extension.

How & Why?

How is butter made?

Dramatic changes occur when the cream of milk is converted to butter: milk, an oil-in-water emulsion, reverses to a water-in-oil emulsion, butter. For this to occur, the membranes (phospholipid) around the fat globules have to be mechanically broken down to release the milk fat so it can lump together (Figure 22-7). Methods of doing this include stirring cooled cream or, in commercial operations, centrifuging the cream to expel the water. The fatty portion of the cream separates out as a soft, yellowish solid; these are granules of butter the size of corn kernels. Liquid drained from the process is collected and sold as buttermilk, a tangy-tasting, opaque, reduced-fat milk by-product. The butter granules are washed and then churned at a slower speed until they are mixed into a smooth, homogeneous paste. Any remaining water is drained, and salt is sometimes added at this point for flavor and to act as a preservative.

In commercial dairies, the process of making butter begins with a cream that is concentrated up to 80% fat and then further concentrated to 98%. It is first pasteurized to destroy pathogenic bacteria, cooled, and then recombined with the milk solids and water. In India, ghee (**clarified butter**) is created by heating and concentrating the butter or cream to over 99% milk fat and less than 0.2% moisture. This lower-lactose, nutty-tasting butter has a shelf life of 6 to 8 months even at ambient or tropical temperatures (19).

After it is formed, commercial butter is divided into blocks that are individually wrapped. Waxed paper is usually used to prevent absorption of odors from other foods. Butter bought at the market has usually been cut into quarter-pound segments and rewrapped. It is sold in half-pound or 1-pound packages. Grading is voluntary on the part of the processor. The quality of butter is evaluated based on its texture, flavor, color, and salt content (Figure 22-8). Butter can be purchased in several forms that differ in taste, consistency, and color (Table 22-2).

Margarine

During the Napoleonic Wars, the short supply and rationing of butter led Napoleon III to organize a contest to find a suitable butter replacement. And so, in 1869, a French pharmacist and chemist, Hippolyte Mege Mouries, won the contest by developing oleomargarine. During World War II, when a law prevented the coloring of food products, margarine was introduced to U.S. consumers in a form unappetizingly lard-like and flat white in color. Eventually the law was repealed, and yellow margarine is now a staple in the North American market.

How & Why?

How did margarine get its name?

The original product, oleomargarine, contained mixed glycerol esters of oleic ("oleo") and margaric ("margarine") acids (19). Today, different blends of fatty acids are used and vary by global region.

Composition of Margarine

Standard stick margarine must contain at least 80% fat, about 16% water, and 4% milk solids, which is very similar to butter's general composition. Contrary to popular belief, regular margarine contains as many kcalories as butter. However, the fat sources differ, and lower-fat versions are available. Margarine may be made from soybean, corn, safflower, canola, or other partially hydrogenated vegetable oils. Some soft margarines are made without the hydrogenation of oils. In addition, margarines usually contain the following:

- Cultured skim milk
- Emulsifiers/surfactants such as lecithin

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FIGURE 22-7 Butter production.

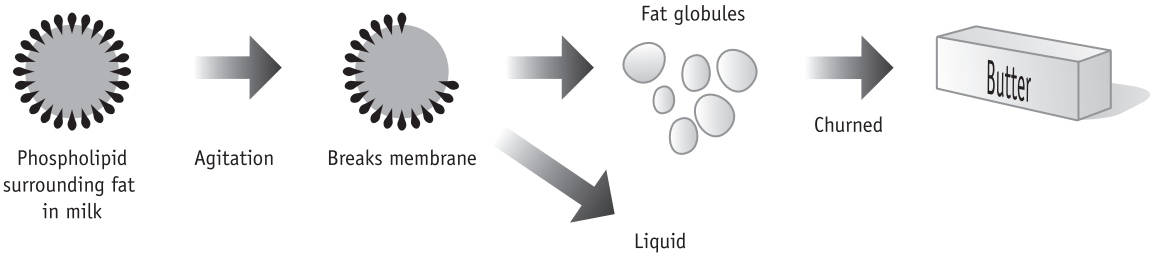


FIGURE 22-8 USDA grades for butter.



- Monoglycerides and diglycerides
- Preservatives such as sodium benzoate, potassium sorbate, calcium disodium ethylenediaminetetraacetic acid (EDTA), isopropyl citrate, and citric acid
- Vitamins A and D
- Flavorings, usually diacetyl
- Food colorings, usually annatto and/or carotene

Diacetyl is added to margarine for flavoring because it is largely responsible, in addition to short-chain fatty acids, for butter's characteristic flavor (Figure 22-9).

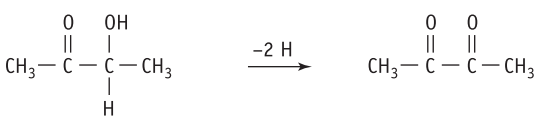
Types of Margarine

Some types of margarines include whipped margarine; light blends of margarine and butter containing about 60% fat; diet or reduced-kcalorie margarine, which has a higher water content; and imitation margarine, identified as "vegetable oil spread." Imitation margarines generally average half the fat of regular margarines. Plant stanol/sterol-fortified margarines are also available to consumers.

TABLE 22-2 Types of Butter

Sweet cream	Cultured by being acidified by lactic bacteria, this butter is made with or without added salt.
Whipped	A popular variant in texture is whipped butter, which is lighter in weight than regular butter and easier to spread because it has been aerated with air or nitrogen gas. The lower density results in half the kcalories (50 vs. 100 per tablespoon). However, more of the whipped butter may be needed to achieve the same flavor as imparted by sweet cream butter. Its lighter density makes it unsuitable as a substitute for regular butter in recipes.
Compound (flavored or composed)	A softened butter mixed with one or more flavors, such as garlic, lemon, honey, wine, herbs, or nuts.
Powdered	One of the newer forms of butter, powdered butter is made by removing the fats from natural butter and chemically treating, drying, and combining it with various ingredients such as whey solids, maltodextrins, guar gum, corn syrup solids, and color additives. It can be reconstituted with hot water and used in food-service establishments to add flavor to vegetables, sauces, soups, and baked products. It is lower in kcalories and cholesterol than natural butter.
Clarified	High temperatures will burn regular butter because its milk solids burn very easily. It must be specially treated before it can be used in certain types of food preparation involving high heats. The milk solids are removed by melting butter over low heat and allowing it to cool until the heavier, cloudy milk solids have settled out. The clear liquid portion is then gently poured off. Butter so treated, called "clarified butter "(ghee in Indian cuisine), is almost 100% fat. Ghee is a major fat used in Indian cooking. Clarified butter has a higher smoke point than regular butter, so it can be heated to a higher temperature (see Table 22-7).
Brown or black	The tendency of butter's milk solids to burn can also have a positive effect. It allows the nuttier-flavored brown butter (beurre noisette) and black butter (beurre noir) to be made by heating butter over low heat until it turns the desired color.
European-style	This butter's more intense, buttery flavor results because it is often churned from cultured cream. It also contains more milk fat than regular butter.

FIGURE 22-9 Diacetyl and other short-chain fatty acids contribute to the "buttery" flavor in butter.



Diacetyl formation

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Shortenings

Shortenings are plant oils that have been hydrogenated to make them more solid and pliable. Soybean oil is the major source of hydrogenated shortening and serves as a common frying oil. In the manufacture of shortenings, the soybean oil is hydrogenated until it reaches a solid consistency and then whipped or pumped with air to improve plasticity and give it a white color. Many shortenings are also **superglycerinated**, making them ideal for baking applications needing solid fat, especially for flaky pastries and cakes containing more sugar than flour (30).

How & Why?

Why are some fats called "shortening"?

A dough with lots of gluten cross-linkages can be stretched into *long* strands; however, adding fat interferes with gluten development and results in a nonelastic dough that creates more crumbly baked products. "Short" is an old term for "crumbly texture"—hence the name "shortbread." Originally, the term *shortening* was synonymous with lard, but now it is used almost exclusively to describe hydrogenated vegetable oil (i.e., Crisco®). Both are suitable for making pastries.

Oils

Vegetable oils are derived from a variety of seeds, fruits, and nuts (19). The most common vegetable oils used in food preparation come primarily from

Superglycerinated Describes a shortening that has had monoglycerides and diglycerides added for increased plasticity.

Omega-3 fatty acids Polyunsaturated fatty acids in which the first double bond is three carbons from the methyl (CH_3) end; examples are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

NUTRIENT CONTENT

Excess Dietary Fat and Health. Pure fats, such as certain vegetable oils, contain **no carbohydrates, proteins, vitamins, or minerals**—just fat. They also contain **very little water**. In contrast, foods such as **butter contain about 16% water** and small amounts of protein and other nutrients. Diet margarines can contain up to 50% water, which causes them to spatter when placed in a hot pan.

The important functions and attributes of fat have led to its incorporation into many foods, perhaps more so than needed. Researchers generally agree that the average American diet contains too much total fat, even though the percentage of total kcalories from fat has been decreasing. The health concern is fat's probable relationship to obesity (20).

Recommended Fat Intake. Both the amount and types of fat consumed are important. The 2015–2020 *Dietary Guidelines for Americans* recommends that adults keep dietary fat intake between **20% and 35% of kcalories**, with less than **10% derived from saturated fat** (46). Obtaining less than 7% of kcalories from saturated fat is recommended for disease prevention by the American Heart Association, which is about 16 grams of saturated fat for someone eating 2,000 kcalories a day (4).

Trans-Fatty Acids. Though consumers' awareness about the need to reduce trans-fatty acids has increased, their knowledge about food sources of different fats has remained low (13). Small amounts of trans-fatty acids are found naturally in some foods (beef, butter, etc.), but the largest dietary sources are products of hydrogenation. Vegetable oils are hydrogenated to increase their stability, solidity, and shelf life. An estimated 75% of dietary trans-fatty acids come from partially hydrogenated oil and/or the foods made with this ingredient—vegetable shortenings, frying oils, margarines, baked products, confectionary products, deep-fried products, and many processed snack foods (12). These trans-fatty acids appear to have adverse effects on blood lipids and are associated with **elevated risks of coronary heart disease** (12). In 2015, the Food and Drug Administration (FDA) determined that partially hydrogenated oils are not Generally Recognized as Safe (GRAS) and that food manufacturers must remove them from their products by 2018 unless they obtain permission for their use through an FDA petition (47). The 2015–2020 *Dietary Guidelines* recommend keeping trans-fatty acid intake as low as possible (46).

Omega-3 Fatty Acids. On a positive note, **omega-3 fatty acids** from fish or algae are increasingly found in many food products, such as breads, pasta, and yogurt (44). Examples include **eicosapentaenoic acid (EPA, 20:5), docosahexaenoic acid (DHA, 22:6), and α-linolenic acid (ALA, 18:3)**. These fatty acids may benefit health by helping to prevent hypertension, thrombosis (coagulation of the blood in the heart or veins), and sudden death due to cardiovascular disease, as well as by acting against autoimmune diseases such as lupus and arthritis (22). They are also thought to be possibly beneficial for brain health (reduced risk of Alzheimer's disease, improved memory) (49); inflammatory conditions (arthritis, psoriasis); and cancer (22). The many double bonds in omega-3 fatty acids contribute to their health benefits but also make them very susceptible to damage by oxygen, so antioxidants are often added to foods that contain them.

Fats Are Essential Nutrients. Completely eliminating all sources of dietary fat is not recommended. A total lack of fat can cause a **deficiency of essential fatty acids (α-linoleic acid and α-linolenic acid)**, resulting in **failure to thrive (stunted growth) in children and eczema (red, itchy, scaly skin) in both children and adults**. Dietary fat should **never be restricted in healthy children under 2 years** of age (3), and **at least 3 to 5 grams of essential fatty acids (especially linoleic acid) equivalent to 15 to 25 grams of total fat are recommended daily for adults**. Keeping a certain amount of fat in the diet, including balanced vegetarian diets (10), is also important because it serves as a **carrier for the fat-soluble vitamins: A, D, E, and K** (39). Particular types of fat such as the omega-3 fatty acids are thought to benefit health, as just discussed and in Chapter 9.

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CALORIE CONTROL
Sensible Fat Choices

Major Sources of Dietary Fat. Fat delivers more than twice as many kcalories per gram as carbohydrate or protein, so it's important to know dietary sources when planning a kcalorie-balanced diet. North Americans typically get most of their fat from the following:

- Meats
- Dairy products (whole milk, butter, cheese, cream, ice cream, and whipped cream)
- Commercial fats and oils

Steps to Lower Fat Kilocalories

- **Monitor portion sizes.** A small amount, the size of your thumb, delivers approximately 100 kcalories and 10 grams of fat, for example:
  - *1 tablespoon butter, margarine, or mayonnaise.* Fat is filling and delicious, but use it sparingly.
  - *1 tablespoon vegetable oil or salad dressing.* This amount poured over low-kcalorie greens adds 126 kcalories and 14 grams of fat. Low-kcalorie dressings are an option, or limit regular dressings to one tablespoon.
  - *1 ounce cheese.* Most people like cheese, but it takes a cup of milk and all its kcalories to make an ounce.
- **Watch for invisible fats.** Some fats—such as the fat in poultry skin, steak trim, vegetable oil, butter, margarine, shortening, lard, and tallow—are clearly visible. Fat becomes invisible, however, when it acts as an ingredient in candies, cakes, sauces, snack foods, and other food products or is concealed as the marbling within high-fat meats.
- **Watch for plants high in fat.** A few plant foods are high in fat, including nuts, seeds, avocados, coconuts, and olives.
- **Exercise portion control for nuts.** Nuts average 10 kcalories each, depending on the type, so about 10 nuts deliver 100 kcalories. A tablespoon provides about 50 kcalories, and ¼ cup can yield approximately 200 kcalories. See Table 22-3 for more precise measurements. However, some researchers suggest that the true kcalorie values of nuts may be lower than previously thought when determined based on the actual energy content used by human beings rather than chemical analysis of the nuts (5).
- **Exercise portion control for peanut butter and other nut butters.** Spread these thin because 1 tablespoon yields almost 100 kcalories and 10 grams of fat.

TABLE 22-3 Kilocalories in Nuts: Per Single Nut, Tablespoon, and ¼ Cup

Nut	Each	Tablespoon	¼ Cup
Almond	8	52	206
Brazil	31	55	218
Cashew	9	50	197
Macadamia	19	60	241
Peanuts	6	53	214
Pecans (half)	14	44	176
Pistachio	3	44	176
Pumpkin Seeds	2	18	71
Sunflower Seeds	Negligible	54	207
Walnuts (half)	13	48	163

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soybeans, rapeseed (canola oil), sunflower seed, corn, cottonseed, and safflower seeds. Fruit oil sources include the avocado, coconut, palm kernel, palm, and olive. A few examples of nut sources include almonds, peanuts, and walnuts. Oils differ dramatically in their taste, color, and texture, depending not only on their source but also on their method of extraction.

Oil Production

Oils are obtained from plant sources through the process of extraction and are often refined further thereafter.

Extraction

The first step in producing any oil is to extract it from its original food source—seeds, fruit, or nuts. Oils are removed from their plant sources by one of the following three extraction methods:

- **Cold-pressing.** Mechanically pressing the seeds. Cold-pressed oils are sometimes sold as "specialty" oils and are usually not refined. Unrefined, cold-pressed oils such as peanut and olive oils have the full flavor of the plants from which they were pressed.

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TABLE 22-4 Selecting a Refined Cooking Oil

Name	Description/Uses for Refined Oils	Fat Type*	Smoke Point
Almond	Nut oils are best used in cold dishes; heat destroys their delicate flavor.	Mono	495°F (257°C)
Avocado	This rather unusual light, slightly nutty-tasting oil is considered primarily to be a novelty.	Mono	520°F (271°C)
Canola	Of all oils, canola is second highest in monounsaturated fatty acid content. (Olive oil has more, but its flavor is not as mild.) Refined canola oil's mild flavor and relatively high smoke point make it a good all-purpose oil.	Mono	400°F (204°C)
Corn	Made from the germ of the corn kernel, this oil's abundance makes it one of the most common vegetable oils in the United States. Many chefs like its mild, almost buttery flavor that becomes slightly toasty when used in pan-frying. It is high in polyunsaturated fat and used to make margarine, salad dressings, and mayonnaise.	Poly	440°F (227°C)
Grape seed	This light, medium-yellow, aromatic oil is a by-product of wine making. It is used in salads and some cooking and in the manufacture of margarine.	Poly	400°F (204°C)
Olive	Olive oil is extracted from tree-ripened olives. Olive oils range from light amber to green in color and from bland to extremely strong in flavor. Olive oil is graded according to its degree of acidity and the process used to extract the oil (Table 22-5).	Mono	Unrefined 320°F (160°C); extra virgin 406°F (208°C); virgin 420°F (216°C); extra light 468°F (242°C)
Peanut	Peanut oil is made from pressed, steam-cooked peanuts. Peanut oil has a bland flavor and is good for cooking because it doesn't absorb or transfer flavors.	Mono	450°F (232°C)
Safflower	Sunflower oil is an excellent all-purpose oil made from the seeds of safflowers. Safflower oil is a favorite for salads because it doesn't solidify when chilled and has a pale yellow color and a bland flavor. The refined version has a high resistance to rancidity.	Mono	450°F (232°C)
Sesame	There are two types of sesame oil made from pressed sesame seeds: light (made with untoasted sesame seeds) and dark (made with toasted sesame seeds). Light sesame oil has a nutty flavor and is especially good for frying. Dark sesame oil (Asian) has a stronger flavor and should only be used in small quantities for flavoring foods—stir-fries, baking, sauces, and spreads. It has a rich, smoky, sesame aroma; nutty taste; dark brown color; thick consistency; and cloudy appearance. It is used a great deal in Chinese and Indian cooking. Just a few drops enhance the flavor of many foods.	Poly	410°F (210°C)
Soybean	This oil is an all-purpose oil because it has very little flavor. Highly refined soybean oil is reasonably priced, very mild, and versatile, accounting for over 80% of all oil used in commercial food production in the United States. Almost any product that lists vegetable oil as an ingredient probably contains refined soybean oil.	Poly	492°F (256°C)
Sunflower	Sunflower oil is an all-purpose oil made from sunflower seeds. A pale, bland-tasting oil very similar to safflower oil but not as widely available.	Mono	450°F (232°C)
Vegetable	An inexpensive and all-purpose blend of oils made from plant sources such as vegetables, nuts, and seeds. Read the label to see the predominant oil(s) used in vegetable oil; most are made from soybeans.	Varies	Varies

*Type refers here to the predominant fatty acid in the oil. All vegetable oils contain a combination of saturated, monounsaturated, and polyunsaturated fatty acids. The proportional differences determine how vegetable oils differ in their cooking properties and health effects.

Source: Adapted from *Fine Cooking* (April/May):78, 2001.

- **Expeller-pressing.** Squeezing the seeds at very high pressures, which may generate some heat. These oils still retain most of their flavor, color, aroma, and nutrients.
- **Chemical solvents.** Chemically removing the oil from the seeds with solvents (27). The majority of commercial vegetable oils sold in bottles have been extracted using chemical solvents. They are not required to be labeled as solvent extracted.

After an oil is extracted, it is either left unrefined or purified (refined) to produce a neutral, clean-flavored oil. Extracted oils contain natural impurities such as water, resins, gums, color compounds, soil, and free fatty acids. If these substances are not removed, they adversely affect the oil's flavor, color, clarity, smoke point, and shelf life.

The aroma from the original source often lingers with unrefined oils, so they are used for salad dressings and as a result are frequently called salad oils. Sometimes their intense flavors dominate the food, which may or may not be desirable. They cannot be exposed to high temperatures due to the risk of smoking (their smoke point is 320°F/160°C or less), so they are limited to sautéing or low-heat baking uses. They are usually slightly higher in nutritional value than refined oils, but their free fatty acids can detract from their flavor and make them prone to rancidity.

Refining

Refining produces a neutral, low-aroma, bland-flavored oil. Many refined oils lack any distinguishing characteristics, a factor desired by chefs who do not want the oil influencing the flavor of the food being prepared (Table 22-4).

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FIGURE 22-10 Steps to refining edible vegetable oils.

Degumming
When combined with water, certain impurities in oil form gums. These gums are removed by adding hot water to the oil and spinning it at high speeds to separate the oil from the gums.

Neutralizing
Free fatty acids are removed by adding an alkaline medium to convert the fatty acid to an insoluble soap, which settles to the bottom of the neutralizing tank. Newer methods use a centrifuge to separate the major layers according to specific gravity.

Washing/Drying
Traces of soap created by the neutralizing process are removed by washing the oil with water. The water is drained, and the oil is dried under a vacuum.

Bleaching
Colored matter in the oil is removed by adding absorbent materials, such as fuller's earth or activated carbon. The absorbed colored matter is then filtered out.

Deodorizing
Passing steam through the heated oil removes volatile compounds that cause off-odors—aldehydes, free fatty acids, hydrocarbons, ketones, and peroxides.

These oils have higher smoke points, making them more suitable for frying. As a result of these two advantages, most commercially produced oils are extracted by the use of heat and solvents and then refined. Refining, which results in oil that is 99.5% triglycerides, consists of five steps: degumming, neutralizing, washing and drying, bleaching, and deodorizing (Figure 22-10). Once refined, these oils can be used as medium-heat cooking oils (225 to 350°F [107 to 177°C]), high-heat cooking oils (350 to 450°F [177 to 232°C]), and deep-frying oils (≥450°F/≥232°C).

Types of Oils

Many different types of oils are available for food preparation purposes. Their individual characteristics determine their applications and vary depending on whether they are refined (Table 22-4) or unrefined (Table 22-5). The first factor to consider when selecting an oil is its flavor or lack thereof (15). Frying oils are mild flavored, bland, and stable to heat. Oils ideal for frying include soybean, corn, and safflower. Cottonseed oil, however, is the leading choice in food-service operations for frying potato chips and for producing baked goods and snacks. This oil is preferred because it is relatively inexpensive and presents a low risk of developing and imparting off-flavors due to its heat stability.

Another bland-flavored oil is canola, so named because it was developed in *Can*ada; "canola" is a contraction of "*Can*adian *o*il, *l*ow *a*cid." This oil is derived from rapeseed, which has a high monounsaturated fatty acid content. Rapeseeds originally contained high levels of erucic acid and glucosinolates, which, in large amounts, were found to cause cancer in laboratory animals. However, new genetic varieties contain minimal amounts of these substances, and the FDA permits the sale of canola oil.

Strong-flavored oils such as peanut oil or olive oil vary widely in quality and character. Because their flavors are distinctive, these oils must be used carefully in foods. Peanut and sesame seed oils are more costly than many others, but their unique flavors make them the oils most commonly used in Chinese stir-fry dishes. Refined peanut oil is less expensive and is very heat stable, making it ideal for high-heat sautéing and frying. Peanut oil's flavor is preferred by some snack food manufacturers for their products (19).

Olive Oil

Olive oil, which is considered a specialty oil, is more expensive than most other vegetable oils. Despite its higher price, olive oil appeals to health-conscious consumers because of its high monounsaturated fatty acid content (77%) (38). A qualified health claim for olive oil regarding reducing the risk for coronary heart disease has been approved by the FDA (48). Part of this claim states, "Limited and not conclusive scientific evidence suggests that eating about 2 tablespoons (23 grams) of olive oil daily may reduce the risk of coronary heart disease due to the monounsaturated fat in olive oil." Recent research suggests that substituting dietary monounsaturated fat for saturated fat may reduce cardiovascular disease risk, but not more than substituting polyunsaturated fat for saturated fat (21).

When it comes to quality, the FDA has no grades for olive oils, but following Italian law, olive oils are classified according to acidity: the lower the acid content, the better the grade (Table 22-5) (7). The International Olive Council (IOC) sets standards for most olive-producing countries, but the United States recognizes the stricter rules established by the Olive Oil Commission of California (24). Price does not always reflect quality; olive oils are best judged by whether or not they have a clear, deep color (usually, but not always, green) and a distinct olive aroma and flavor. Some of the compounds contributing to the flavor and aroma of extra virgin olive oil are volatile and are lost when heated, so it is best used in cold salad dressings and as a final flavoring added to a dish. The term "virgin" means that the oil was extracted by mechanical means only, and not with chemicals (24). Milder olive oils are preferred for sautéing. Unrefined olive oils are also popular in Italian dishes and salad dressings because of their full flavor.

Tropical Oils

Food products using tropical oils such as coconut, palm, and palm kernel oils have longer shelf lives. The higher saturated fat content of these oils has made them popular with the food industry in the past. Foods commonly made with tropical oils include cereals, candy, baked items, chocolate coatings for ice cream bars, pressurized whipped toppings, and dog and cat food. Because saturated fats contain no double bonds, they break down less easily than unsaturated fats. Therefore, they do not become rancid as quickly when subjected to oxygen, heat, and light. Tropical oils received negative publicity, however, when the consumption of saturated fats was linked to an increased risk of heart disease (25). As a result, many food manufacturers and even some fast-food enterprises have switched from tropical oils to vegetable oils for frying. Tropical oils are still used

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TABLE 22-5 Olive Oil* Variations According to Acidity (Based on International Olive Council)

Extra virgin**	The highest-quality and best-tasting (strongest) olive oil derived from the olives' first pressing. This olive oil is the least acidic (no more than 0.8% acidity) and produced solely from mechanical presses (no chemicals or heat are used). The olives are ground to a paste before the oil is cold-extracted through either a centrifuge or a hydraulic press. The result is a high-quality oil with a strong olive flavor and a greenish tint from the presence of chlorophyll pigments.
Virgin	This oil is also produced by cold pressing (not more than 2% acidity).
Olive oil or pure olive oil	This is a blend of virgin olive oil and refined olive oil. This combination creates a lower acidity (1%) than refined olive oil but also a less intense flavor and color than either virgin or extra virgin olive oil.
Light or extra-light	Refers to color, fragrance, and taste, but not fat or kcalorie content. This refined oil is lighter in color than corn or safflower oil and almost as mild, so it is better for sautéing, baking, and salad dressings.
Olive-pomace	This oil may not be called olive oil. It is produced less expensively by extracting the oil from olives through both cold pressing and the use of solvents. The resulting oil is refined and then blended with virgin olive oil to improve its taste, odor, and color.

*Olive oils deteriorate with time and are best in the first year after bottling, but they are still fine to use through the next year. Check the olive oil's "sell by" date.

for some confections, such as chocolate coatings for ice cream bars, because they become firm but melt quickly in the heat of the mouth.

Oils as Functional Foods

Some oils are marketed as functional foods because of their favorable fatty acid profile or other purported benefits (32). Flaxseed oil is rich in α-linolenic acid, which has been shown to decrease blood pressure. Rice bran oil is hypoallergenic and rich in antioxidants such as tocopherols, tocotrienols, gamma oryzanol, phytosterols, polyphenols, and squalene. Olive oil and canola oil are valued for their high monounsaturated fatty acid content (21). Other functional oils include borage oil for its γ-linolenic acid content, sunflower oil for its high vitamin E level, and fish oil for its high content of omega-3 fatty acids (32).

Winterized Oils

Some vegetable oils do not remain completely liquid when stored in the refrigerator. The cooler temperatures may result in cloudiness from the crystallization of certain fatty acids that have a higher melting point than their neighboring fatty acids. This cloudiness may be eliminated by **winterizing** the oil. Commercial salad dressings and so-called salad oils are usually made with winterized oil (17). Unwinterized vegetable oils that have crystallized in the refrigerator are perfectly edible and will revert to their clear character if allowed to come to room temperature.

Hydrogenated Oils

Hydrogenation makes fats and oils more solid, allows them to be heated to higher temperatures without smoking, and increases their shelf life or that of the foods coated with them (Chemist's Corner 22-3). Through this process, vegetable oils may be converted to spreadable hydrogenated shortenings or margarines. Too much hydrogenation, however, will cause the product to become brittle and hard. In addition to affecting plasticity, hydrogenation contributes to making piecrusts flaky and puddings creamy. Shortening keeps dough particles separate from each other, so that after the fat melts during baking, the resulting pastry is flakey.

Side Effects of Hydrogenation

One of the side effects of hydrogenation is that more trans than cis configurations are created at the double bonds between carbon atoms. The benefits of a higher concentration of trans-fatty acids are a rise in the fat's melting point, increased solidity, and lengthened shelf life. Among other health risks, trans-fatty acids have been reported to increase the risk for heart disease (12), and the *Dietary Guidelines*

Winterizing A commercial process for vegetable oils that removes the high-melting point triglycerides that would otherwise crystallize during low-temperature (refrigerator) storage and make the oil appear cloudy.

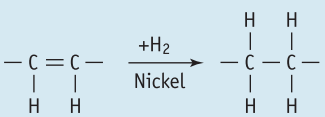
Hydrogenation A commercial process in which hydrogen atoms are added to the double bonds in monounsaturated or polyunsaturated fatty acids to make them more saturated.

CHEMIST'S CORNER 22-3

Hydrogenation

The process of hydrogenation is facilitated with the aid of a metal catalyst (nickel, copper, platinum, or palladium) and the presence of pressure and heat (Figure 22-11). The catalysts are removed after the process is completed. The degree of hydrogenation, or the number of hydrogen atoms added, determines the firmness of the final product.

FIGURE 22-11 Hydrogenation: Hydrogen atoms can be added to double bonds in unsaturated fatty acids in the presence of a catalyst, pressure, and heat.



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recommend keeping intakes as low as possible. This heart-health concern led the FDA to mandate that food products list the amount of trans fat per serving on Nutrition Facts labels beginning in 2006 (29).

Lard/Tallow/Suet

Lard, which is the fat from swine, was the major shortening in use in the early 1900s. Tallow is also an animal fat, but it is derived from beef cattle or sheep. Suet is the solid fat found around the kidneys and loin of beef and sheep. These animal sources of fat are primarily saturated. They cannot be used for their shortening power in food preparation without first being rendered (melted down); for commercial use, the rendered fat is then deodorized. Antioxidants are often added to lard to increase shelf life. Lard produces poor textures in cakes and icings; however, it makes excellent piecrusts. It is also used in commercial frying and in regional cooking.

Interesterification

Lard was largely replaced by the shortenings that appeared on the market in the 1950s. Its usage increased again in the 1960s when the process of **interesterification** was introduced. Certain fats, such as cocoa butter substitutes and lard, have unacceptable textures until they are modified by interesterification. Lard is naturally too grainy and soft at room temperatures, but it becomes extremely hard when refrigerated. Interesterification creates smaller crystals in the lard, resulting in a smoother texture with a slightly higher melting point. This change allows the lard to retain its shape at room temperature. Interesterification is also used to manufacture certain emulsifiers, which are incorporated into numerous processed foods to improve fat functionality.

Cocoa Butter

Cocoa butter originates from the seeds of the *Theobroma cacao* tree. Its melting point is just below body temperature, making it perfect for "melt-in-the-mouth" chocolate confections and candies. Cocoa butter is also used in the manufacture of nonfood products such as soaps and cosmetics.

FAT REPLACERS

One of the biggest challenges facing the food industry is reducing the fat content of foods without losing the important functions of fat. Fat reduction affects important functional properties such as flavor, appearance, texture, mouthfeel, handling, preparation, and storage stability (33). Although consumers consistently report dietary fat to be among their top nutrition concerns, they simultaneously value taste above nutrition (40).

The number of fat replacers and their use continue to increase as the food industry tries to meet the consumer demand for better-tasting, low-fat food items (33). Some common fat-modified foods include dairy products such as cheese, yogurt, sour cream, cream cheese, butter, and margarine; meat products such as sausages and hamburgers; frozen desserts, including ice cream and yogurt; baked goods such as cakes, biscuits, and muffins; and frostings, salad dressings, snack foods, mayonnaise, sauces, and gravies (11).

Types of Fat Replacers

There is no official classification of fat replacers or any standard method of naming them. The term *fat substitute* is often used interchangeably with *fat replacer*. However, *replacer* is a more general term describing any ingredient used to replace fat, which can include substitutes, mimetics (imitators), analogs, and extenders (33):

- **Fat substitutes.** Have physical and sensory properties identical to those of fats without the kcalories. They are often lipid-based, are stable at frying and cooking temperatures, and replace the fat in foods on a weight-to-weight basis (11).
- **Fat mimetics.** "Mimic" the effects of fat. These water-soluble, often protein- or carbohydrate-based ingredients replicate fat's creaminess and smoothness (11). They do not replace fat by weight, as do the fat-soluble substitutes and extenders (45).
- **Fat analogs.** Have the characteristics of fat but with fewer kcalories because of their altered digestibility.
- **Fat extenders.** Optimize fat functionality so that less fat is required.

Composition of Fat Replacers

Fat replacers are made from a variety of ingredients such as synthetic fats, microparticulated proteins, starch, fiber (cellulose, gums, etc.), and even dried fruit puree; research continues on others. The synthetic fat replacers approved by the FDA are Simplesse® and olestra. Some synthetic fats awaiting approval are esterified propoxylated glycerol (EPG) and trialkyl tricarballylate (TATCA).

Fat replacers, regardless of the name, are commonly grouped according to their chemical structure—carbohydrate-, protein-, or fat-based (Table 22-6).

Carbohydrate-Based Fat Replacers

Most of the fat replacers used by the food industry are based on carbohydrates (11). Fibers, gums, pectin, cellulose, and starches bind with water, swell, and impart some of the texture, mouthfeel, and opacity of fat (11).

Protein-Based Fat Replacers

Milk (whey) or egg proteins usually serve as the source for protein-based fat replacers. These are often used in meats and other food products that have to be refrigerated or frozen.

An example of a protein-based fat replacer is Simplesse®, which provides only one-seventh the number of kcalories found in fat (11). It is made from the whey of milk or from egg-white proteins that have been reduced to tiny particles through a process called microparticulation (Figure 22-12). These protein droplets break down when heated, so Simplesse cannot be used in baking or frying (11).

Lipid-Based Fat Replacers

Chemically modifying the molecular structure of fats can result in fat replacers that have fewer kcalories than

Interesterification A commercial process that rearranges fatty acids on the glycerol molecule within triglycerides so that they are more heterogeneous, resulting in smaller fat crystals and producing a smoother-consistency fat.

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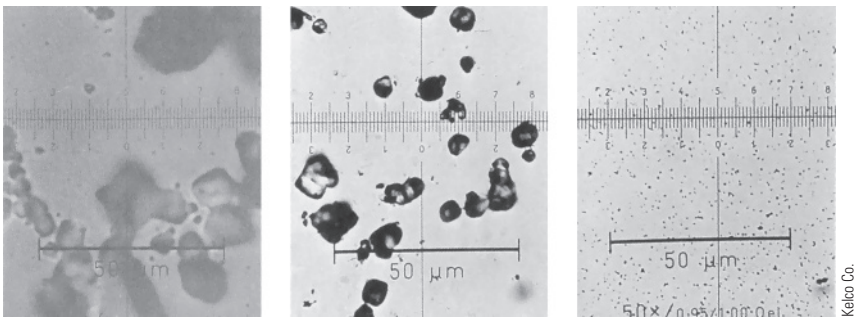
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TABLE 22-6 Fat Replacers Classified as Carbohydrate-, Protein-, or Fat-Based

Class	Examples	Composition	Functional Properties
Carbohydrate-Based			
Cellulose	Avicel® cellulose gel, Methocel™, Solka-Floc®, JustFiber®	Cellulose ground to microparticles	Water retention, texturizer, thickener, mouthfeel, stabilizer
Dextrins	Amylum, N-OIL®	Sources include tapioca	Gelling, thickening, stabilizing, texturizing
Fiber, grain	Opta™, Oat Fiber, Snowite, UltraCel™, Z-Trim®	Sources include oat, soybean, pea, and rice hulls or corn or wheat bran	Moisturizer, mouthfeel
Fiber, fruit	Prune paste, dried plum paste, Lighter Bake, WonderSlim, fruit powder	Sources include fruits (prunes and plums)	Gelling, thickening, stabilizing, texturizing
Gums (xanthan, guar, locust bean, carrageenan, alginates)	Kelcogel®, Keltrol®, Slendid™	Hydrophilic colloids or hydrocolloids	Water retention, texturizer, thickener, mouthfeel, stabilizer
Maltodextrins	CrystaLean®, Lorelite, Lycadex®, Maltrin®, Paselli® D-LITE, Paselli EXCEL, Paselli SA2, Star-Dri®	Sources include corn, potato, wheat, tapioca	Gelling, thickening, stabilizing, texturizing
Polydextrose	Litesse®, Sta-Lite™	Water-soluble polymer of dextrose containing minor amounts of sorbitol and citric acid	Moisture retention, bulking agent, texturizer
Starch (modified food starch)	Amalean® I & II, Fairnex™ VA15 & VA20, Instant Stellar™, N-Lite, OptaGrade®, Perfectamyl™ AC, AX-1 & AX-2, PURE-GEL, STA-SLIM™	Sources include potato, corn, oat, rice, wheat, tapioca starches	Gelling, thickening, stabilizing, texturizing
Protein-Based			
Microparticulated protein	Simplesse®	Whey, milk, or egg protein	Mouthfeel
Modified whey protein concentrate	Dairy-Lo®	Whey protein	Mouthfeel
Other	K-Blazer, ULTRA-BAKE®, ULTRA-FREEZE™, Lita®	Egg white, milk, and corn protein	Mouthfeel
Fat-Based			
Emulsifiers	Dur-Lo®, EC™-25	Vegetable oil monoglycerides and diglycerides	Mouthfeel
Fat extender	Caprenin®, Salatrim/Benefat®	Triglyceride molecules with specific fatty acids	Mouthfeel
Lipid analogs	Olean	Sucrose and edible fats and oils	Mouthfeel

Source: Adapted from Damodaran S, KL Parkin, and OR Fennema (Eds.). *Fennema's Food Chemistry.* CRC Press, New York, 2007; Omayma ES and MM Youssef. Fat replacers and their applications in food products: A review. *Alexandria Journal of Food Science and Technology* 4(1):29–44, 2007; and Calorie Control Council. Glossary of fat replacers. http://caloriecontrol.org/glossary-of-fat-replacers. Accessed 8/2/16.

FIGURE 22-12 Microparticulation. The process of reducing the original size of a substance to numerous tiny particles.



Powdered sugar (10–30 microns) | Nonfat chocolate (5–10 microns) | Simplesse fat substitute (0.1–3.0 microns)

fat (11). Often the chemical changes involve inhibiting absorption or shortening the length of the fat's fatty acids. For example, short- and medium-chain fatty acids provide fewer kcalories than larger ones, which is why butyric acid (4 carbon atoms) yields fewer kcalories than palmitic acid (16 carbons) (11).

Olestra

Olestra is a heat-stable, fat-based fat replacer used in snack foods (crackers, potato chips, and tortilla chips), fried and baked goods, and dairy products. Procter & Gamble researchers were

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trying to locate an easily digested fat for premature infants but instead found a substance not broken down by the body at all (50). Previously known as sucrose polyester, olestra gained FDA approval in 1996 and is marketed under the brand name Olean®. It is made from sugar and vegetable oil in a process in which the 3-carbon glycerol molecule in the oil is replaced by sucrose, which can bond with 6, 7, or 8 fatty acids. This molecule is so large that it moves through the digestive tract before enzymes have time to digest the fatty acids (33). Side effects of too much olestra consumption may include diarrhea, cramps, and gas (28).

FOOD PREPARATION WITH FATS

Very few fat replacers transfer heat during food preparation the way fat can. Fats allow the transfer of heat during frying, sautéing, stir-frying, pan-frying, and deep-frying (see Chapter 5). Oils used in deep-frying influence the food's flavor, texture, appearance, nutrient value, and shelf life (16). This section focuses on proper care of frying fats and describes techniques to reduce the amount of fat transferred to the food. Other recent considerations may include oil availability, price, and a preferred fatty acid balance without allergens or GMO (16).

Selection and Care of Frying Fats

Foods fry better if the preparer knows which fats are best for frying, understands optimal frying temperatures, uses recommended equipment, and maintains the fat's frying ability with optimal care.

Fats Suitable for Frying

Not every fat is suited for the very high temperatures of deep-frying, which average 350 to 450°F (177 to 232°C). The high temperatures of deep-frying allow foods to be heated more quickly than if they are boiled. The fats commonly used for frying must be 100% fat and heat stable, so that they do not smoke or develop rancid off-flavors; these include vegetable oils (except for olive or sesame oil) and hydrogenated shortenings (without additives such as emulsifiers). The vegetable oils most frequently used include cottonseed, corn, canola, peanut, and safflower. Soybean and canola oils are not used because their omega-3 fatty acid content (7% and 10% linolenic acid, respectively) makes them susceptible to oxidative rancidity at the high temperatures of frying.

Many vegetable oils are chosen for frying because they have little flavor of their own and will not overpower the flavor of very lightly seasoned or bland foods. Conversely, some foods call for butter as a sautéing fat to enhance flavor, but the heat must be carefully controlled because the water and milk solids in butter cause it to spatter and burn more easily. Margarine is not recommended for frying because, in addition to containing water, it has a low **smoke point**. The water will splatter, and foods fried in fats with low smoke points develop unpleasant flavors.

Smoke Point

Select fats with a high smoke point—above 420°F (216°C) or higher—for frying. This temperature is much higher than the boiling point of water (212°F/100°C) and even higher than frying temperatures, which range from 350 to 450°F (177 to 232°C). Fat boils at a much higher temperature than water, and fat that starts to bubble is very dangerous because it has reached its boiling point. It should be immediately removed from the heat source. Selecting a fat with a smoke point above the frying temperature is also important, or it may overheat and break down—that is, decompose into glycerol and its individual fatty acids. The glycerol is further broken down (hydrolyzed) to a steel-blue smoke called acrolein (Figure 22-13). Acrolein's sharp, offensive odor warns people of its presence. The smoke is not only extremely irritating, but it is even harmful to the mucous membranes of the mouth and nasal passages.

Table 22-7 lists the smoke points of various fats. Selecting fats with smoke points above 420°F (216°C) for commercial frying automatically excludes olive oil, lard, and vegetable shortenings. Hydrogenated shortenings with added monoglycerides and diglycerides are not recommended for frying. Their fatty acids are easily removed from the glycerol molecule, which is then free to form acrolein.

FIGURE 22-13 Acrolein formation.

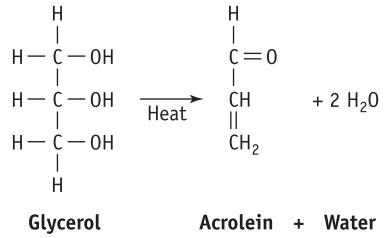


TABLE 22-7 Smoke Points of Selected Frying Fats and Oils*

Fat/Oil	Smoke Point
Butter (regular)	250–300°F (121–149°C)
Vegetable shortening + emulsifier	356–370°F (180–188°C)
Lard	361–401°F (183–205°C)
Most olive, virgin oils	391°F (199°C)
Vegetable oils	441–450°F (227–232°C)
Corn oil, Sesame oil	440°F (227°C)
Ghee (clarified butter)	485°F (252°C)
Soybean oil	492°F (256°C)
Avocado oil	520°F (270°C)

*Refined oils (unrefined oils have lower smoke points)

Flash Point and Fire Point

A more serious problem than smoking occurs when an oil is heated to its **flash point**, or to about 600°F (316°C). Increasing the heat even higher to 700°F (371°C) will result in the fat reaching its **fire point**. If this occurs, water should not be used to put out the fire.

Smoke point The temperature at which fat or oil begins to smoke, due to the release of free glycerol, followed by the breakdown of glycerol to acrolein.

Flash point The temperature at which tiny wisps of fire streak to the surface of a heated substance (such as oil).

Fire point The temperature at which a heated substance (such as oil) bursts into flames and burns for at least 5 seconds.

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Fire extinguishers with a *C* designation should be used to extinguish a fire caused by fat. If an extinguisher is not available, it may be possible to smother the fat-fueled fire with a pan lid or large amounts of baking soda.

Controlling the Temperature of Frying Fats

It is difficult to detect overheating visually. Compounding this problem, heated oil is always hotter than it appears. These two problems can cause overheating, which contributes to the rapid deterioration of fat through **polymerization**. Any egg yolks used in the coating of battered foods also contribute to the darkening effect on the fat. Further, the increased viscosity of overheated fat results in higher fat absorption rates in the fried foods, making them greasy (41). One way to control the temperature of cooking fats and prevent excess absorption is to use thermostatically controlled deep fryers, but it is recommended that their thermostats be routinely checked for accuracy.

Avoid Too-Low Temperatures

Although it is important not to overheat frying fats, it is equally important not to let temperatures drop too low because this may lead to excessive fat absorption, resulting in soggy, greasy fried food. Temperatures quickly drop when large quantities of frozen food are added to hot oil. To combat this problem and help stabilize the temperature, the food should be added in batches so that the oil has sufficient time to reheat to the correct temperature. It is also important that the food pieces in a batch be the same size, so they finish cooking at the same time.

Perfect Browning of Fried Foods

If temperatures are correctly controlled, the result will be a food that has a crisp, golden crust surrounding a tender, perfectly cooked interior. The key in deep-frying is to ensure that the food's inside is sufficiently cooked without overdoing its outside. Fried foods cook on the principle that frying temperatures convert the food's water to steam, which then escapes, keeping the food cool and preventing it from burning and/or absorbing fat. Eventually, however, the amount of steam decreases, allowing the outside to brown. Foods left too long in the fryer after all the steam has escaped will have burned crusts and excess fat absorption.

High-moisture foods such as French fries need to be cooked at lower temperatures, or the outside will turn crispy before the inside has had a chance to cook. Steam trapped by the hard crust will cause the food to become limp as it cools. Conversely, low-moisture foods need higher temperatures so they will cook quickly, leaving no time for the oil to enter the food. Other determinants in temperature selection to obtain the best crust color are the amount of food, the length of time it is submerged in oil, the temperature of the food, the oil quality, and the food's shape and size, porosity, and type of coating (36).

Optimal Frying Temperatures

The optimal frying temperature is 375°F (191°C), with higher temperatures (375 to 390°F/191 to 199°C) required for smaller pieces of food and lower temperatures (350 to 365°F/177 to 185°C) for larger pieces of food (35).

Recommended Equipment

Frying temperature is not the only factor influencing the fried food product's quality. It is important to use stainless-steel equipment; iron, and especially copper or copper alloys such as brass, may increase rancidity. Hoods or exhaust systems above the fryer should be cleaned frequently so that accumulated particles do not drip back down into the fat. Deep, narrow containers are recommended for deep-frying, because shallow, wide pans increase the surface area, lowering the smoke point through greater exposure to air. The fryer should be filled no more than one-half to three-fourths full of oil. As fat is absorbed by the foods, it should be replaced with fresh fat. However, fresh fat should never be added to fat that is rancid, foaming, or dark because it will not overcome these defects and will deteriorate very quickly.

Optimal Frying Conditions

The fats in a fryer go through stages that influence the quality of the fried product. At the new and break-in stages, foods absorb too little oil; just the right amount is absorbed at the fresh and optimal levels that follow; and then too much soaks in at the degraded and runaway phases (31). Many professional chefs claim that foods fry best in oil that has been used at least once. Desirable browned crusts occur when oils pick up proteins and carbohydrates from the foods that have been fried in them. Eventually, however, the browning becomes too dark, and the fat must be replaced. In addition, as the fat deteriorates, the surface tension of the frying oil decreases, making foods more likely to soak up the fat. Repeated use of a frying fat will also lower its smoke point because each heating hydrolyzes some of the triglycerides into smaller molecules.

Avoid Water

Foods should be as free of surface moisture as possible before being submerged in the heated fat. Water causes spattering of hot oil, which can cause burns; it requires more energy to maintain temperatures; it may result in longer frying times; and it promotes hydrolytic rancidity, which causes the fat to break down chemically, reducing its frying life.

Remove Food Particles

Inevitably, particles of food or breading break off or fall through the basket and build up in a deep fryer over time. These food particles should be filtered out daily (or every 8 hours of use), or they will darken the oil's color, lower its smoke point, and reduce its keeping time. On the other hand, excessive filtering introduces oxygen into the oil, resulting in rancidity, gum development, and foaming; the latter is observed as a persistent layer of bubbles on the surface.

Cool the Frying Fat

A frying fat should theoretically stay fresh for several months if it is cooled immediately after use and stored in an airtight container in a dark, cool place. Refrigeration will also increase its shelf life. Large commercial fryers contain too much fat to be cooled completely and then efficiently reheated, so they are turned down to approximately

Polymerization A process in which free fatty acids link together, especially when overheated, resulting in a gummy, dark residue and an oil that is more viscous and prone to foaming.

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225°F (107°C). Decreasing the temperature during downtime prevents the fat's breakdown and extends its usefulness.

When to Discard the Used Frying Fat

There is no easy method for determining when oil that has been used repeatedly should be discarded. Generally, the oil becomes darker and more viscous, smokes easily, begins to have a rancid odor, and starts to impart off-flavors to the foods fried in it. The first indication that an oil needs to be replaced is usually that its color and the color of the food fried in it start to darken. This transformation takes place right before the flavor and odor of the oil start to deteriorate. An experienced person can tell by looking at it whether the oil needs changing, but food-service establishments may purchase a commercial kit that allows anyone to determine an oil's freshness by checking its color against the kit's standard. A further indication that the oil is too old is that the food fried in it is greasier than normal due to increased oil absorption. Other factors to consider in the decision to discard oil include the type of oil used, the type of foods being fried, the number of times the oil has been used, the presence of many particles, excessive foaming or smoking, and the quality of the foods cooked in the oil (35). Guidelines for preserving frying oils are summarized in Figure 22-14, and Table 22-8 provides a list of problems that may arise and what causes them.

FIGURE 22-14 Preserving frying oils.

Equipment
- Stainless steel
- Deep, narrow containers for deep frying
- Fill no more than one-half to three-fourths full
- Clean commercial fryers at least once a week
- Keep hood/exhaust system above fryer clean

Heating
- Most frying occurs in oil heated to 350–450°F (177–232°C)
- Avoid high temperatures (undercooked inside, overly crispy/brown outside)
- Avoid low temperatures (soggy fried food)
- Heat no longer than necessary
- Allow sufficient time for oil to reheat between batches
- Avoid large quantities of frozen foods
- Do not overheat to flashpoint, about 600°F (316°C)
- Check thermostat for accuracy

During Frying
- Use oils with smoke points above 420°F (216°C)
- Avoid exposure to oxygen/air, light, salt (season after frying), certain metals (iron, copper, nickel)
- Only completely dry food should be submerged
- Filter particles of batter/flour and/or food
- Limit egg yolks used in the batter or flour (darkening effect on the fat)
- Monitor freshness of frying oils by checking their color against a standard
- Add fresh oil daily to commercial fryers in order to replace entire amount every 3 to 5 days

Storage
- Store unopened containers in cool, dry place
- Store opened containers airtight in refrigerator
- Commercial fryers: reduce temperatures to about 225°F (107°C)
- Discard dark, gummy, or repeatedly used oil

Lower-Fat Preparation Techniques

Dietary fat consumption may be reduced by following the ChooseMyPlate.gov guidelines, which recommend limiting "empty" kcalories from solid fats; following a meal pattern that is lower in fat, especially the saturated and trans types; relying on lower-fat or nonfat cooking methods; reducing the fat in recipes; and pretreatment of foods prior to deep-fat frying (16).

Fats Preferred for Health

After overall fat intake is reduced following these guidelines, the next step is to modify the types of fat that are ingested. Consumers are advised to replace dietary solid (saturated or trans) fats with monounsaturated and polyunsaturated fats. Trans fats are the least desirable. Table 22-9 shows that, compared to other cooking oils and fats, canola oil contains one of the highest levels of monounsaturated fatty acids (58%) (42). In the same category, olive, avocado, almond, and apricot oils tend to impart more flavor but are more expensive. Safflower oil scores highest in the polyunsaturated oil category. Saturated fats such as coconut, palm, and palm kernel oils and butter should be avoided according to certain dietary guides. Butter is often chosen, however, for its unique flavor or by those concerned about the trans-fatty acids found in margarines and other partially hydrogenated fats. Although butter and margarine contain approximately the same number of kcalories and grams of fat, the fat in butter is primarily saturated, whereas that from margarine is more unsaturated. Lard, the saturated fat from swine, is best replaced by vegetable shortening, but even the latter is partially saturated.

Reducing Fat by Healthy Methods

Dietary fat intake may also be lowered by selecting a cooking method that does not rely on fat. All of the moist- and dry-heat cooking methods, with the exception of frying, lend themselves to fat-free preparation of foods. Even frying, specifically sautéing and stir-frying, is acceptable if the right type of fat is chosen and a minimal amount is used. Pan-frying and deep-frying are the only two methods for which it is essentially impossible to lower the amount of fat used.

Modifying Recipes to Reduce Fat

Another way to reduce fat in food preparation is to focus on the recipes. The following foods are the main contributors to fat in recipes: meats, dairy

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TABLE 22-8 Problems in Deep-Frying Oils and Their Causes

Problem	Possible Cause
Fat darkens excessively	• Overheating of fat • Defective equipment • Inadequate filtering • Inadequate cleaning of equipment • Use of inferior fat • Foreign material entering the fat
Fat smokes excessively	• Overheating of fat • Defective equipment • Inadequate filtering • Use of inferior fat • Poor ventilation • Inadequate cleaning of equipment
Life apparently gone from fat: fat won't brown the food; fat won't hold the heat	• Too low a frying temperature (including faulty thermostat) • Lack of proper kettle recovery • Not cooking long enough • Excessive foam development • Overloading kettle • Improper preparation of food
Fat foams excessively and prematurely	• Overheating of fat or failure to reduce heat when not in use • Insufficient filtering • Failure to clean and rinse equipment adequately • Brass or copper being used in kettle • Use of inferior fat • Salt or food particles getting into the fat
Food greasy; too much absorption	• Frying at too low a temperature • Slow temperature recovery due to poor equipment • Overloading kettle • Frying fat has broken down • Improper preparation of food • Keeping food in fat after it is done, or insufficient draining after removal
Fat has "objectionable" odor or flavor	• Excessive crumb or foreign material in kettle • Use of poor-quality food • Detergent film due to insufficient rinsing • Use of inferior or broken-down fat • Excessive fat absorption • Holding cooked food too long

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products (including whole milk, cheese, cream, ice cream, whipped cream, and butter), commercial fats and oils, avocado, coconut, olives, nuts, and seeds.

Processed foods such as cakes, cookies, pies, snacks, and others that are made with these ingredients are also high in fat. Many recipes could simply have their fat content reduced or another ingredient substituted without affecting overall quality (Table 22-10). Sometimes the fat can be removed altogether. Following ChooseMyPlate.gov recommendations will automatically eliminate recipes that are too high in fat and that cannot be adequately modified. A good rule of thumb is that any recipe exceeding 20 grams of fat per serving is probably too high in dietary fat for people consuming three meals a day. Other ways to reduce the amount or modify the type of fat in the diet include the following:

- Fruit preserves and honey can replace butter on breads.
- Mustard, ketchup, or low-fat salad dressing or mayonnaise may substitute for regular mayonnaise in sandwiches or salads.
- Purees of fruits such as plums, dates, apples, and figs may replace some, but not all, of the fat in recipes for baked products.
- Crumb crusts can replace standard piecrusts.
- Double-crust pies can be converted to one-crust pies, automatically cutting fat by close to 50%.
- A nonfat condiment such as salsa, relish, or chutney can replace some of the butter or sour cream toppings on baked potatoes.

Pretreatments to Reduce Absorbed Oil

Reducing the moisture content of foods prior to deep-fat frying will decrease the amount of absorbed oil during the frying process. A number of methods can be used, including air or vacuum frying, which is a new technology that fries foods at well below atmospheric pressure (13). Vacuum frying also reduces acrylamide content while preserving nutrients, color, and flavor. Other methods are blanching, osmotic dehydration, predrying (158–167°F/70–75°C) (16). The use of hydrocolloids as part of a commercial food's ingredients will also retard moisture loss. Examples include modified starch, pectin, powdered cellulose, carboxymethylcellulose, and sodium alginate.

STORAGE OF FATS

The proper storage method for fat depends on its type. Fats such as butter and margarine are best stored in the refrigerator. Butter will keep for months in the freezer, but margarines do not freeze as well because their emulsions may separate under such conditions. Shortenings and most oils are usually stored at room temperature and should be kept tightly covered in a dark spot on the cupboard shelf; however, they are best refrigerated because they will keep longer. Olive oil has a shorter shelf life than most vegetable oils and should be refrigerated fairly soon after opening. Monounsaturated fats such as olive oil usually keep for about 1 year. The storage and use of frying fats depends on their stability and whether or not they are prone to rancidity (1).

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TABLE 22-9 Comparison of Dietary Fats*

DIETARY FAT	Cholesterol mg/Tbsp	% Monounsaturated Fat	% Polyunsaturated Fat	% Saturated Fat
Highest in monounsaturated				
Olive oil	0	77	9	14
Canola oil	0	58	36	6
Peanut oil	0	49	38	13
Highest in polyunsaturated				
Safflower oil	0	12	79	9
Sunflower oil	0	20	69	11
Corn oil	0	25	62	13
Soybean oil	0	24	61	15
Cottonseed oil	0	19	54	27
Hydrogenated				
Margarine	0	48	34	18
Vegetable shortening (Crisco)	0	43	31	26
Highest in saturated				
Coconut oil	0	6	2	92
Butter (fat)	33	30	4	66
Palm oil	0	39	10	51
Lard	12	47	12	41

*Fatty acid content normalized to 100%.

Source: Adapted from chart found on www.todaysdietitian.com/newarchives/021115p24.shtml; Thalheimer JC. Heart-healthy oils. They're not all created equal. *Today's Dietitian* 17(1):24–27, 2015.

TABLE 22-10 Replacing Fatty Ingredients in Recipes

Higher-Fat Item		Replaced by Lower-Fat Item	
1 oz (1 square)	Baking chocolate	3 Tbsp	Powdered cocoa + 1 Tbsp margarine
1 C	Butter	1 C	Margarine (lowers saturated fat)
1 oz	Cheese	1 oz	Lower-fat cheese
1 C	Cream (heavy)	1 C ⅔ C	Evaporated skim milk Nonfat milk + ⅓ C vegetable oil
1 C	Cream cheese	1 C	Reduced-fat cottage cheese + 4 Tbsp margarine + salt to taste + milk for blending
1	Egg (large)	1 2 ¼ C	Egg white + 1 tsp vegetable oil Egg whites Egg substitute
1 C	Fat	⅓ C	Applesauce + ⅔ C fat
1 C	Milk (whole)	1 C	Nonfat or reduced fat milk
1 Tbsp	Salad dressing	1 Tbsp	Low-kcalorie salad dressing
½ C	Shortening	⅓ C	Vegetable oil
1 C	Sour cream	1 C 1 C	Plain yogurt Reduced-fat cottage cheese (blended)

Rancidity

Rancidity is the chemical deterioration of fats, which occurs when the triglyceride molecule and/or the fatty acids attached to the glycerol molecule are broken down into smaller units that yield off-flavors and rancid odors. The longer a fat is stored, the greater the possibility of its becoming rancid. Fats and oils used in cooking tend to become rancid because they are exposed to oxygen, heat, and light. For this reason, they should be checked frequently for rancidity. Rancid fats should be discarded because they will adversely affect flavor if used to make cakes, cookies, or other baked goods. Rancid fat will also ruin the flavor of sautéed or fried foods and cause problems during heating because of its lower smoke point.

Types of Rancidity

There are two basic types of rancidity: hydrolytic rancidity, which occurs when *water* breaks larger compounds into smaller ones, and oxidative rancidity, in which the double bond of an unsaturated fatty acid reacts chemically with *oxygen* to result in two or more shorter molecules (9).

Hydrolytic Rancidity

Fats become rancid when exposed to water, usually the water found frozen on food to be fried. The addition of water hydrolyzes the bonds in the triglyceride, causing it to break down into smaller compounds (Chemist's Corner 22-4). The released fatty acids have an unpleasant aroma and taste. Catalyzing this reaction are lipase enzymes and heat. This hydrolytic rancidity has implications for deep-frying. Placing cold, wet food in heated frying oil introduces water, making the oil prone to hydrolytic rancidity. Conversely, fats that have not been heated are more prone to hydrolytic rancidity because the lipase enzymes have not yet been destroyed by heat. Butter left out at room temperature, which is ideal for the lipase enzyme, quickly decomposes; therefore, butter is often refrigerated or frozen. Butter has a tendency to go rancid because it contains some water. The volatile short-chain fatty acids of butter, such as butyric and caproic acids, create a rancid odor and off-flavor when released into the air. The long-chain fatty acids are also freed, but they do not contribute to rancid butter odor because they are not volatile.

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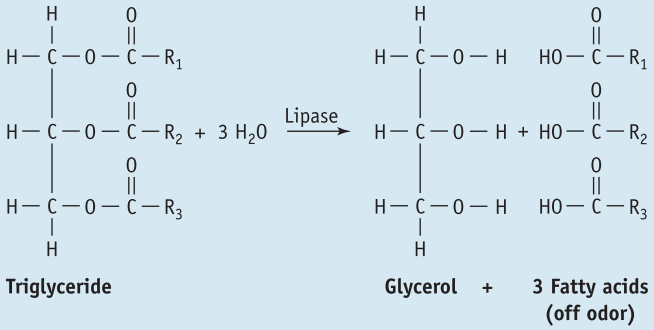
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CHEMIST'S CORNER 22-4

Hydrolytic Rancidity

Water breaks down a triglyceride through the process of lipolysis, removing the fatty acids from the glycerol molecule (Figure 22-15).

FIGURE 22-15 Hydrolytic rancidity.



Oxidative Rancidity

Fats can also become rancid when they are exposed to the oxygen in air because oxygen is taken up at the double bonds of an unsaturated fatty acid. The higher the degree of unsaturation, the more likely it is that the fat will be subject to oxidative rancidity. This is why saturated and hydrogenated fats that last longer than unsaturated fats were popular in the past with some food manufacturers and food-service establishments. Fats containing omega-3 fatty acids are particularly susceptible, and the problem is magnified at high temperatures, such as those used in frying.

Unlike hydrolytic rancidity, the rancidity due to oxygen occurs in a series of steps (Chemist's Corner 22-5). The initiation period is slow and triggered by light, high temperatures, table salt, food particles in the frying oil, and certain metals such as iron, copper, and nickel. This initial stage is followed by a quicker, irreversible, and self-perpetuating chain reaction. Oxygen atoms attach to the carbons next to the double bond of the fatty acid, creating very reactive and unstable molecules called free radicals (Chemist's Corner 22-5). These free radicals contribute to the further breakdown of fats into smaller compounds, resulting in unpleasant odors and off-flavors. After this process starts, it is difficult to stop because the free radicals generated by the reaction create more free radicals, and this domino effect continues until all the double bonds have been used in the process. Antioxidants, found naturally in the fat or commercially added, inhibit oxidative rancidity and extend shelf life.

Flavor reversion The breakdown (oxidation) of α-linolenic acid, an essential fatty acid found in certain vegetable oils, leading to an undesirable flavor change prior to the start of actual rancidity.

Flavor Reversion

Food manufacturers must also deal with **flavor reversion**, a type of characteristic flavor change that occurs even before actual rancidity begins. The odor and flavor of oils, particularly those having high α-linolenic acid (18:3) levels, can be altered by light and heat, which convert the fatty acids to volatile compounds, causing off-odors. Only a small amount of oxygen needs to be present to oxidize α-linolenic acid. The odors and flavors produced by flavor reversion depend on the type of oil. Fish oils have a tendency to become "fishy," while soybean oils become "beany" and then "fishy." The two most commonly used oils, cottonseed and corn, are very resistant to flavor reversion.

Preventing Rancidity

Rancid products have reduced shelf lives and must be discarded. In the past, cereal manufacturers incorporated predominantly saturated fatty acids such as coconut and palm oils into their products to reduce the risk of rancidity. More recently, public concern over saturated fat and its relationship to blood cholesterol levels contributed to the increasing use of unsaturated oils and new ways of deterring rancidity.

Avoid Oxygen and Heat

One method of inhibiting rancidity is to pack food items high in unsaturated fatty acids, such as potato or tortilla chips, in vacuum packs or nitrogen to prevent contact with oxygen.

Several protective measures can also be taken to prevent rancidity: recapping vegetable bottles immediately after use to minimize exposure to oxygen; storing them in cool, dry places away from air, light, high temperatures (away from the range; and possibly keeping them in the refrigerator in warmer climates); and minimizing exposure to metals such as iron and copper.

Antioxidants

The USDA's Code of Federal Regulations defines antioxidants as substances used to preserve food by retarding deterioration, rancidity, or discoloration due to oxidation. Antioxidants, natural and commercial, are added to foods containing large amounts of unsaturated fats in order to prevent rancidity (Chemist's Corner 22-6). Foods to which antioxidants are commonly added include dry cereals, crackers, nuts, chips, and flour mixes.

Naturally occurring antioxidants include vitamins E and C, lecithin, flavonoids, and gum guaiac (Chemist's Corner 22-7). Many vegetable oils naturally contain vitamin E. Commercial antioxidants permitted by the FDA include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate, and tertiary butyl hydroquinone (TBHQ) (Figure 22-17).

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CHEMIST'S CORNER 22-5

Oxidative Rancidity

The three stages of oxidative rancidity, also known as oxidation, are initiation, propagation, and termination (Figure 22-16) (6). The process is self-perpetuating because it is an autocatalytic reaction where the products of one reaction become the catalysts for the next reaction.

- **Initiation.** Initiation occurs when the loosely held hydrogen atom at the double bond of an unsaturated fatty acid is lost, forming a free radical (R•), which is very reactive.
- **Propagation.** In the propagation stage, oxygen combines with the free radical, forming a compound (peroxide free radical) that can remove another hydrogen near a double bond and yield another free radical. This reaction can be repeated several thousand times until most double bonds on the fatty acids have been removed. Further breakdown of the hydroperoxide molecules into smaller units such as acids, alcohols, aldehydes, and ketones results in rancid off-odors and flavors.
- **Termination.** The chain reaction is terminated when all the free radicals have reacted with other free radicals or antioxidants, and/or there are no more hydrogens at the unsaturated fatty acids' double bonds to react with oxygen.

FIGURE 22-16 Stages of oxidative rancidity.

INITIATION:

$$RH \xrightarrow[\text{metal}]{\text{heat, light}} R\bullet + H\bullet$$

Free radical

PROPAGATION:

$$R\bullet + O_2 \longrightarrow ROO\bullet$$

$$ROO\bullet + RH \xrightarrow{\text{slow}} ROOH + R\bullet$$

TERMINATION:

$$R\bullet + R\bullet \longrightarrow 2R$$

$$R\bullet + ROO\bullet \longrightarrow ROOR$$

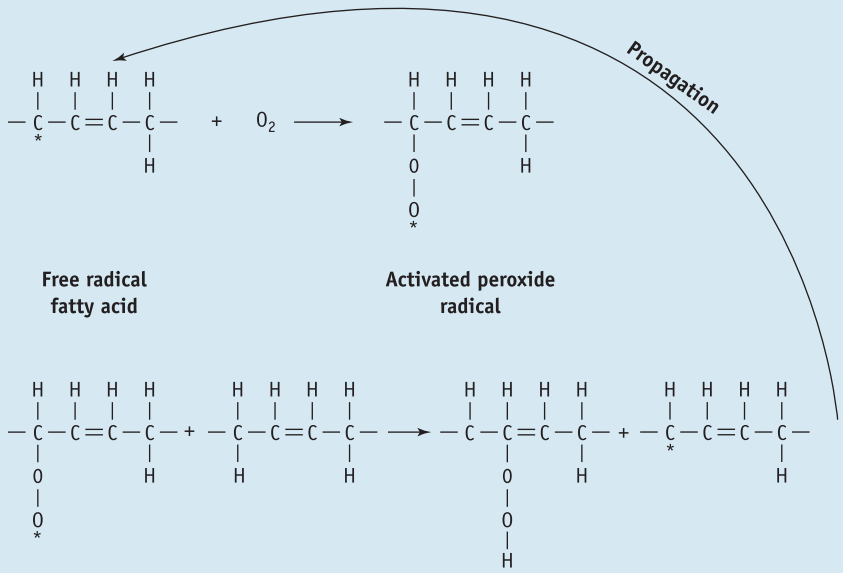
$$ROO\bullet + ROO\bullet \longrightarrow ROOR + O_2$$

1. Initiation stage - formation of a free radical. Reaction catalyzed by light, heat, metals (copper & iron) & enzymes (lipoxygenases).



Unsaturated fatty acid — **Free radical fatty acid** — **Released hydrogen**

2. Propagation stage - oxidation of free radical to yield activated peroxide.



Free radical fatty acid — **Activated peroxide radical**

Activated peroxide radical — **New unsaturated fatty acid** — **Hydroperoxide** — **Free radical fatty acid**

3. Termination stage - elimination of all the free radicals.

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CHEMIST'S CORNER 22-6

Measuring Oxidation

The most popular techniques for measuring oxidation are the thiobarbituric acid (TBA) test and the peroxide value (PV) (34). The TBA test detects and quantifies lipid peroxidation. TBA is a molecule that reacts with malondialdehyde (MDA), one of several end products formed from the oxidatively damaged fatty acids. The reaction results in a red, fluorescent color that can be measured to reflect oxidative damage. The PV is the milliequivalent of iodine released from the reaction of lipid hydroperoxides with hydrogen iodide.

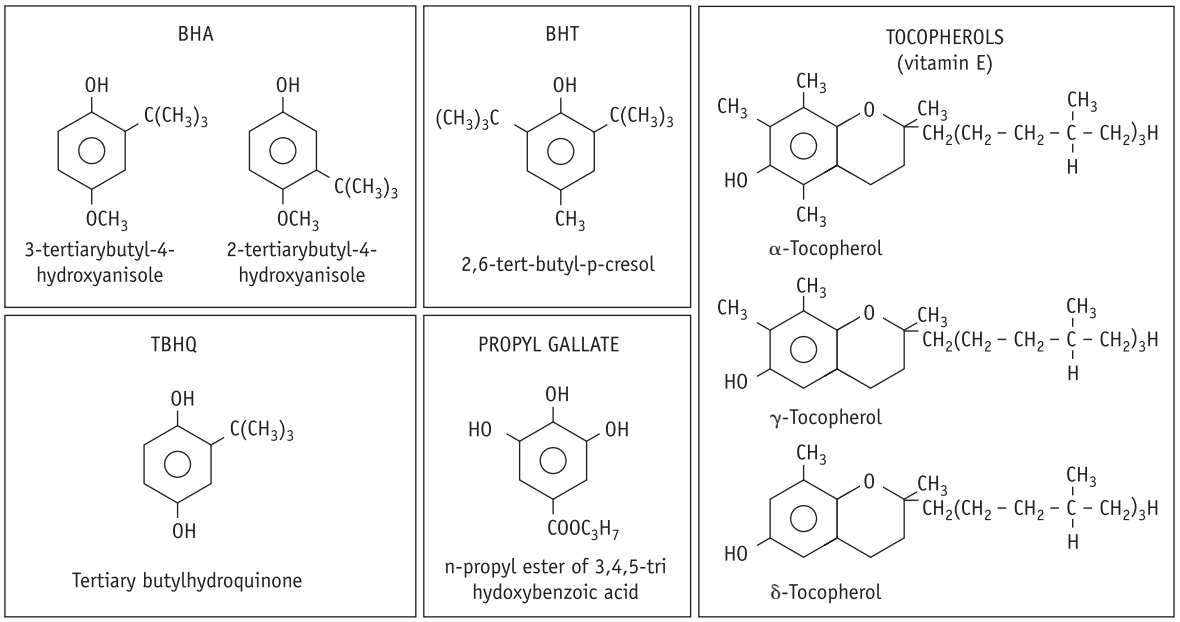
CHEMIST'S CORNER 22-7

Antioxidants in Action

Antioxidants prevent oxidation of fats by (1) being oxidized themselves, (2) donating their hydrogen to a fatty acid as a reducing agent, and/or (3) sequestering metals by acting as a chelating agent. Substances that assist with the second mechanism of action by transferring hydrogen are called "reducing agents." Examples include vitamin C, vitamin E (tocopherols), β-carotene, flavonoids, erythorbic acid, ascorbyl palmitate, and sulfites.

The third method involving chelating agents works when they "attach" to metal ions such as copper or iron and prevent them from catalyzing oxidation. The word *chelate*, from chela or *claw*, refers to the claw-like manner in which the agent binds to the metal through coordinate covalent bonds. Examples of chelating agents, also known as metal sequesterers, include EDTA, citric acid, and phosphates (6).

FIGURE 22-17 Commonly used commercial antioxidants.



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PICTORIAL SUMMARY / 22: Fats and Oils

Fats and oils are important components in well-prepared and good-tasting food. Their unique properties not only contribute to taste, texture, and nutrition, but they also greatly influence food preparation.

FUNCTIONS OF FATS IN FOOD

Properties of fat that affect food preparation:

Heat transfer: Fats act as a medium to transfer heat and prevent food from burning.

Shortening power: Fats are essential in the preparation of pastries, piecrusts, biscuits, and cakes. The more highly saturated the fat is, the greater the shortening power.

Emulsions: All foods contain some liquid, and if fats or oils are present, the combination is an emulsion, such as mayonnaise.

Melting point: Fats have a range of melting points. Most plant oils are liquid at room temperature, whereas animal fats are solid.

Plasticity: The plasticity of fat is its ability to hold its shape but still be molded and spread; this influences its use in icings and the like.

Solubility: Fats are generally insoluble in water.

Flavor/Satiety: Fats contribute their own flavor as well as release the flavors and aromas of other foods when cooked with them. Fats also provide a creamy texture to foods, and because they take longer to digest than carbohydrates and proteins, they induce a sense of fullness or satiety.

Nutrition: Fats and oils contribute essential fatty acids and kcalories to the diet. According to the current dietary goals, 20 to 35% of kcalorie intake in adults should be derived from fat; however, children under 2 years of age should not be restricted in their fat intake.

TYPES OF FATS

Fats are derived from both plant and animal sources.



Butter is made by churning the cream from milk.

Margarines are vegetable oil spreads.

Shortenings are hydrogenated oils.

Vegetable oils are derived from plants, primarily the seeds of soybeans, corn, cottonseed, rapeseed, sunflower, and safflower.

Lard is derived from the fat of swine, and **tallow** from beef or sheep fat.

Cocoa butter, which is used in the manufacture of chocolate candies, is made from the seeds of the cacao tree.

FAT REPLACERS

Fat replacers used in the food industry include synthetic fats (olestra), proteins, starch, fiber, and even dried fruit puree.

FOOD PREPARATION WITH FATS

In food preparation, fats and oils are primarily used for frying (sautéing, pan-frying, deep-frying) and as shortening agents in pastries and other baked goods.



Vegetable oils with high smoke points are used for deep-frying, and their care consists of several steps that must be taken to ensure their preservation. A frying temperature that is too high or too low can lead to excessive fat absorption by the food.



Fat content can be reduced during food preparation by carefully regulating the amount of fat and by making substitutions.

STORAGE OF FATS

Fats are best stored in the refrigerator, and butter will keep for months in the freezer. Oils, except olive oil and cold-pressed oils such as walnut oil, can be stored tightly covered for long periods of time at room temperature.



The longer a fat is stored, the greater the possibility of its becoming rancid (oxidative or hydrolytic) and producing undesirable off-odors and unpleasant flavors.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Emulsifying agents act as a bridge between _____ and _____.
   a. water and water
   b. water and oil
   c. oil and oil
   d. water and vinegar

2. Increasing the chain length of a saturated fatty acid will _____ its melting point.
   a. increase
   b. decrease
   c. not influence
   d. saturate

3. Shortenings are solid at room temperature because they have gone through the process of _____.
   a. interesterification
   b. clarification
   c. emulsification
   d. hydrogenation

4. The fat replacer olestra is composed of sucrose and 6 to 8 _____.
   a. amino acids
   b. fatty acids
   c. phospholipids
   d. triglycerides

5. Which type of rancidity results from the exposure of fat to oxygen?
   a. Regular rancidity
   b. Oxidative rancidity
   c. Hydrolytic rancidity
   d. Flavor rancidity

6. Most refined vegetable oils have a smoke point:
   a. Within the temperature danger zone of 40 to 140°F (4 to 60°C)
   b. Below boiling at 212°F (100°C)
   c. At frying temperatures of 350 to 450°F (177 to 232°C)
   d. Above 420°F (216°C)

7. Frying oil needs to be replaced when:
   a. It starts to show excessive foaming or smoking
   b. Too much fat is being absorbed by the fried foods
   c. It starts to show a darker, more viscous quality
   d. Any of the above is observed

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. List and briefly describe some of the functions of fats in food preparation.
2. What types of foods rely on the shortening power of fats?
3. Define *emulsion*. Discuss the three parts of an emulsion and the different types of emulsions. What is the difference between an oil-in-water emulsion and a water-in-oil emulsion?
4. Discuss the four factors that determine a fatty acid's melting point and that affect solidity at room temperature.
5. What is the importance of a fat's plasticity in food preparation?
6. Define the following: *clarified butter (ghee), smoke point, fire point, winterizing, hydrogenation, interesterification,* and *flavor reversion*.
7. Describe the source, production, and general use of the following fats in food preparation: butter, vegetable oil, shortening, margarine, and lard.
8. Describe the differences among the terms *fat replacer, fat substitute, mimetics,* and *extenders*. Describe the structural differences among carbohydrate-, protein-, and lipid-based fat replacers.
9. Describe factors to consider when selecting a frying fat, as well as optimal frying temperatures and conditions.
10. Define *rancidity*. What is the difference between hydrolytic and oxidative rancidity?

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23



Cakes and Cookies

Types of Cakes? 453
Preparation of Cakes? 456
Frostings/Icings? 463
Storage of Cakes? 464
Types of Cookies? 464
Preparation of Cookies?. 467
Storage of Cookies?. . . . 468

A basic flour mixture serves as the foundation for quick and yeast breads, but it is also the basis for their sweeter cousins, cakes and cookies. Cakes, which are believed to have originated in Egypt as round, flat, unleavened breads, are essentially sweetened breads, whereas cookies can be considered to be little cakes. Ingredients can be combined in several different ways and styles, creating confections ranging from simple sugar cookies to elegantly decorated, many-tiered wedding cakes. In the not-too-distant past, such items were created "from scratch," but now the vast majority of cakes and cookies are made from packaged mixes that come ready to be combined with liquid ingredients. Making the process even easier are refrigerated doughs sold ready to bake. This chapter discusses the different types, the nutrient content, and the preparation and storage of cakes and cookies. Their ingredients, along with their specific functions, were discussed in Chapter 17 (on flours and flour mixtures).

Shortened cake A cake made with fat.

TYPES OF CAKES

As shown in Figure 23-1, cakes are classified according to whether or not they contain fat. The majority of cakes are either shortened or unshortened; chiffon cakes make up a third category (Figure 23-2). The variety of different cakes that fall into these three basic categories is endless, but some of the more common cakes are briefly described next.

Shortened Cakes

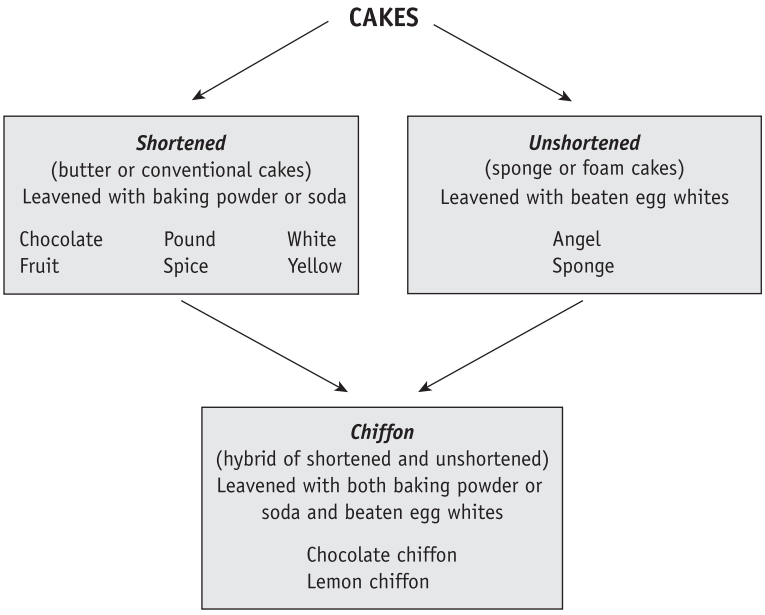
Cakes were not always the delicate creations they are today because at one time they were leavened with yeast. The refined cake grain that is available today therefore was not always possible; the heavy ingredients, such as sugar and fat, were not able to rise easily without the leavening agents baking soda and baking powder. Baking soda did not exist before the 1840s, and baking powder appeared in the 1860s. **Shortened cakes**, also called "butter cakes" or "conventional cakes," are usually leavened with baking powder or baking soda, although steam generated from the liquid ingredients and air incorporated during the mixing process also contribute to leavening.

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FIGURE 23-1 General classification of cakes.



Selected examples of shortened cakes follow in alphabetical order.

Bundt Cake

This dessert is prepared in a Bundt™ pan that did not really sell very well until 1966, when a Bundt cake won second place in a Pillsbury baking contest.

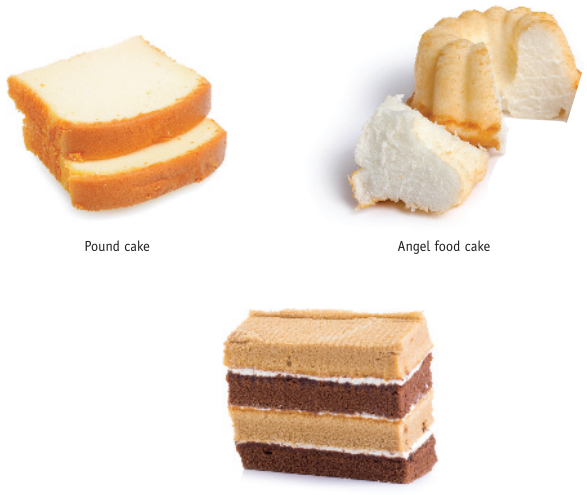
Butter Cake

This is the standard cake commonly used at birthdays, weddings, and graduations. Numerous flavors exist, but the most common are white, yellow, and chocolate.

Carrot Cake

This sweet spice cake closely resembles a quick bread (see Chapter 19 on quick breads). Very moist, dense carrot cakes are prepared either layered, in a loaf pan, or as cupcakes. Basic ingredients include grated carrots, nuts, and cinnamon. Other added ingredients contributing to the cake's moistness and density include oil, applesauce (or apples), raisins, or well-drained crushed pineapple. Carrot cakes are served plain or topped with cream cheese icing.

FIGURE 23-2 Types of cakes: pound cake, angel food cake, chiffon cake.



Pound cake

Angel food cake

Chiffon cake

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Cheesecake

Cheesecake fillings are made from cream cheese, cottage cheese, or ricotta cheese mixed with eggs, sugar, and flavorings. The crust can be made from graham cracker crumbs, wafer crumbs, gingersnaps, finely ground nuts, or pastry. The ingredients are baked in a springform pan or cheesecake pan and may include a top layer of sour cream. Cheesecake styles vary in texture from light and airy to heavy and dense according to their ingredients, which vary among regions. In North America, it is common to have cream cheese as the cheese of choice. Adding heavy cream and egg yolks creates a richer, denser cheesecake, whereas pot or farmer's cheese yields a more tangy, softer type of cheesecake. Neufchâtel cheese and gelatin are preferred in France, whereas emulsified cornstarch and eggs create a unique smooth-style cheesecake often sold in Japan.

Ciambellone

This ring-shaped cake is lightly sweetened and flavored with dried fruit and lemon zest.

Coffee Cake

Often served with coffee, these sweet, rich cakes and breads are usually served at breakfast, brunch, or afternoon tea. Coffee cakes may contain fruits, nuts, spices, chocolate, fruit, jam, streusel, or cream cheese (see Chapter 19 on quick breads).

Cupcake

This small, individual cake is baked in a cup-shaped mold (typically a muffin pan), usually paper-lined, and can be made from many different cake batters.

Devil's Food Cake

This rich, chocolate-layered cake has a "reddish" hue.

Fruitcake

This traditional British Christmas cake is full of fruit (candied and dried), nuts, and spices. Fruitcake is laced with alcohol (usually brandy) and sometimes covered with marzipan and royal icing.

German Chocolate Cake

The "German" portion of the name originates from the Dallas homemaker who used Baker's German Sweet chocolate (sweeter than baking chocolate) to create this chocolate-buttermilk cake.

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FIGURE 23-3 A selection of unshortened cakes.



Angel food | Dacquoise | Miringue | Petit fours | Roulade | Tiramisu

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Its typical coconut-pecan frosting also differentiates it from other chocolate cakes.

Ice Cream

Ice cream serves as the center of a butter cake, or the "cake" is pure ice cream shaped like a cake.

Mooncake

These square or round-shaped Chinese confections are traditionally consumed each fall during the Harvest Moon Festival. The larger, brighter moon during this time allowed harvesting to continue into the night. About the size of a cupcake, these very dense, rich cakes are cut into small wedges and consumed with Chinese tea.

Muffin

Muffins are miniature versions of short breads (see Chapter 19).

Pound Cake

The name is derived from the original British recipe that used one pound each of butter, sugar, flour, and eggs. Although this is no longer the case, the cake still retains much of its original richness and density. Pound cake is still a compact, shortened cake leavened only by air and steam. Grinding the sugar with a food processor makes the pound cake lighter and smoother.

Upside-Down Cake

After baking, this cake is literally turned upside-down. Chopped or whole fruits such as pineapple or cherries are placed on the bottom of the pan on top of a layer of brown sugar before the batter is poured in. Thus, when the cake is inverted after baking, the bottom layer becomes a decorative, moist topping.

Unshortened Cakes

Unshortened cakes are also known as sponge or foam cakes and include angel food, sponge, meringue, dacquoise, génoise, and roulade (Figure 23-3). The term *sponge* in food preparation is frequently used to denote foods made with beaten egg whites. They contain very little, if any, fat—just flour, sugar, and egg whites. The light, delicate structures of angel food and sponge cakes rely on steam and air from foamed, or beaten, eggs as the major leavening agents. Angel food cakes are made with beaten egg whites, whereas sponge cakes are made with whole eggs, which contribute to the latter's rich, yellow color. They can be eaten plain or topped/filled with frostings, whipped cream, preserves, fruit, nuts, chocolate, or other flavorings.

Angel Food Cake

Whipped egg whites and the lack of fat contribute to the very light, airy texture and taste of this cake. A special angel food cake pan with a tube in the middle creates the hole in the middle of the cake and prevents it from falling on itself.

Boston Cream Pie

This "pie" is really a cake. The "cream" is really vanilla custard spread between two layers of sponge cake. A chocolate glaze is poured over the top. It's called "Boston" cream pie because it was first created by a Boston hotel chef around 1855.

Dacquoise (da-kwoz)

This French cake, named after a town called "Dax," consists of alternating layers of meringue and buttercream. Ground nuts are usually added to the meringue, and sometimes whipped cream may replace the buttercream.

Génoise (zh-eh-nwoz)

Génoise is an Italian cake named after the city of Genoa, Italy. The use of whole eggs and melted butter makes it different from other sponge cakes. It may also be sliced into layers separated by chocolate, fruit, pastry cream, or whipped cream.

Meringue (mer-rang)

Meringue layers form the basis of this cake, which is usually topped with soft spreads such as marzipan and whipped cream.

Petit Four

These small multilayer cakes, averaging only 1-inch square, are usually elaborately decorated with icing.

Roulade (roo-lahd)

This is a rolled sponge cake filled with various ingredients that can include preserves, frostings, nuts, or other flavorings. A roulade is created by placing the cake batter in a sheet pan (the type often used for preparing cookies). The thin baked cake, which is only about ½ inch thick, is rolled while still warm to set its log-like shape, unrolled when cooled, spread with fillings, rerolled, and then either left plain on its outer surface or covered with frosting or powdered sugar.

Tiramisu (teer-a-me-sue)

This Italian dessert takes its name from the Italian words *tira* and *su*, which together mean "pull up"—probably due to its caffeine-laden ingredients, coffee and cocoa. Tiramisu basically consists of layers of sponge cake or ladyfinger cookies soaked in coffee and alcohol (wine, brandy, or liqueur), spread with the unique Italian ingredients of mascarpone (mas-kar-pone-eh) cheese and/or zabaglione (za-bal-yone-ee), and then topped with sprinkles of finely grated chocolate. Mascarpone is a soft Italian cheese that is very high in fat because cream is added to the cow's milk before it is made into cheese. Zabaglione is a custard or sauce made by whipping egg yolks, sugar, and wine (usually Marsala) or liqueur over a boiler.

Unshortened cake A cake made without added fat.

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CAREER CORNER

"Food chemistry," Willie Byrd says, "allows you to understand the 'why.'" Willie graduated with a major in food science and a minor in chemistry from Alabama A&M University. He continued his education and obtained a master of science degree in food science and technology.

His first job was as a research chemist developing new laboratory assays for measuring various food components. He then worked as the product evaluation and stability manager for the Kellogg Company. "Stability testing is necessary for shelf-life determination to guarantee freshness," he says. "For example, we make sure packaging material is properly tested to ensure desired shelf life at various temperatures and adverse conditions. In the product evaluation department, sensory panels evaluate the texture, flavor, and appearance of foods."



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Willie Byrd, Director, Manufacturing Audit Programs, Corporate Quality, Kellogg Company

His next move in the corporation was as quality technologist in new product innovation, a position that entailed writing specific standards for new products—shape, size, flavor, sugar concentration, and texture (crispy, glassy, gummy, or dry). Shortly thereafter, he switched to being senior quality technologist of existing brands. After this position, he became the quality manager of two cereal plants. A few of his duties included ensuring sanitation and food safety, implementing Hazard Analysis and Critical Control Point (HACCP) programs, training people in good manufacturing practices (GMPs), and working with government officials in the Food and Drug Administration (FDA), the U.S. Department of Agriculture (USDA), the Occupational Health and Safety Administration (OSHA), and the Environmental Protection Agency (EPA).

Willie then left the cereal division of quality control and moved to the snacks division as associate director of snacks quality programs and global performance. He ensured that the right quality programs and systems were in place for the manufacture of cookies, crackers, and other baked goods. His global performance role was to work with the quality managers in Kellogg Company facilities around the world to ensure that product evaluation systems were in place to capture appearance, flavor, texture, and packaging attributes.

His current role is Director of Kellogg North America Manufacturing Audit Programs. In this role, he is responsible for auditing manufacturing plants and ingredient suppliers to ensure adherence to food safety and quality standards, policies, and procedures.

"I like quality control," he says, "because I enjoy ensuring products the consumers are going to enjoy will be high quality and safe for consumption. Quality control is not negotiable. This is a company with sales of more than $13 billion, and I have to stand up for quality."

Chiffon Cakes

Chiffon cakes are a hybrid of shortened and unshortened cakes that were not developed until the 1920s. Fat, usually from vegetable oil and egg yolks, is combined with foamed egg whites (a meringue), cake flour, and leavening agents. This yields a cake with a texture that is light and airy, yet richer and denser than angel food. A tube pan and extra baking powder are required to lift the cake during baking. Common examples of these variations of angel food cakes include lemon and chocolate chiffon cakes.

PREPARATION OF CAKES

As discussed earlier, the ingredients used to make shortened and unshortened cakes differ; different mixing methods also result in different cakes. Some of the most common ways of combining the ingredients of a shortened cake are the conventional, conventional sponge, pastry-blend, single-stage (quick-mix), and muffin mix methods. These mixing methods apply to other foods besides cakes, and they are discussed in Chapter 5.

Overall, the flour mixtures that produce cakes and cookies are very similar to those used to make breads. The significant differences are that they are sweeter and often have added flavorings not typically used in breads.

Chiffon cake A cake made with fat and an egg white foam that combines the characteristics found in both shortened and unshortened cakes.

Ingredients

Cakes have a higher proportion of sugar, milk, and fat to flour than do breads, and the flour used is usually cake flour (Chemist's Corner 23-1). Flour, milk, and egg whites contain the proteins that "toughen," or contribute strength and structure, to cakes (7). Fat, sugar, and egg yolks have the opposite effect, softening, or "tenderizing," the cake's structure by providing moisture and tenderness. These tenderizers also interfere with gluten development and shorten the gluten strands, resulting in a tender and soft baked product. Too much fat and sugar may weaken the cake to the point at which it does not set. However, too much flour or egg whites may make the cake tough and/or dry. Ultimately, the goal is to create cakes that have the strength to hold together but are still tender and moist.

Flour

Cake flour establishes a crumb structure in cakes (Chemist's Corner 23-2). The flour's starch gelatinizes, and its proteins form gluten to provide a structural network (12). The structural strengthening effect of cake flour and egg is balanced by the tenderizing effect of the sugar and fat ingredients.

Sugar

Sugar's multiple functions in cake preparation include (1) sweetening, (2) increasing volume, (3) browning the crust, and (4) increasing shelf life. The higher

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CHEMIST'S CORNER 23-1

Cake Batters

Most cake batters are considered oil-(fat)-in-water emulsions. A cake batter consists of two phases: a continuous, aqueous phase, holding the dissolved solutes of sugar, salt, and leavening salts; and the dispersed particles too large to go into solution—the colloidal proteins and the suspended starch granules, fat globules, and gas cells (22). The aqueous phase allows the sugar to dissolve while suspending the flour particles. Air bubbles are usually held in the solid fat rather than the aqueous phase, but as the cake batter heats during baking, the air bubbles transfer from the fat to the aqueous/foam phase, where they expand, contributing to volume. The high water content in cake formulas creates a low-viscosity batter that minimizes the formation of gluten, which contributes to the tenderness of cakes (12).

volume seen in cakes made with sugar is due to sugar's ability to delay gelatinization. With sugar, the cake has more time to rise during baking before the starch gelatinizes and sets the cake's structure.

For many years, the weight of the sugar in cake mixtures could not exceed that of flour because higher proportions of sugar would interfere too much with the gelatinization of starch and the hydration of proteins, causing the cake to collapse. Now, high-sugar (high-ratio) cake mixes with a sugar-to-flour ratio ranging from 1.25:1 to 1.40:1 are common as a result of improvements in cake flour and shortenings. The extra sugar results in cakes with greater moisture content, which also improves their shelf life.

CHEMIST'S CORNER 23-2

Chlorinated Cake Flour

Cake flour is often chlorinated to break the bonds (hydrogen and peptide) within and between flour proteins. This is believed to improve dispersion of ingredients, increase swelling of the starch granules, and improve baking quality (22).

Three Rules for "High-Ratio" Cakes

There are three basic guidelines for preparing the sweeter "high-ratio" cakes that contain more sugar than flour (7). Following these ingredient proportions will ensure a high-ratio cake that is not too dry or too moist:

1. The sugar should weigh the same as or slightly more than the flour. It is the *weight* and not the volume that counts. Remember, 1 cup of sugar (7 ounces by weight) weighs more than 1 cup of flour (4½ ounces by weight).
2. Eggs should weigh almost as much as or slightly more than the fat. Because 1 large egg weighs about 1¾ ounces, a recipe using 4 ounces of butter would call for 2 large eggs (3½ ounces).
3. The liquid ingredients (including eggs) should weigh the same as or more than the sugar.

Fats

Fats such as butter and shortening also contribute to (1) tenderness, (2) volume, (3) moistness, and (4) flavor. These attributes are best achieved by fats other than vegetable oil, which does not entrap air during creaming. The purpose of creaming is to beat tiny air bubbles into the fat. Air bubbles are not as easily incorporated into oil as they are into butter, so oil-shortened cakes rely on chemical leaveners such as baking soda or physical leaveners such as air whipped into the batter, especially the egg whites. However, some people add olive oil, which contains natural emulsifiers, to cakes shortened with more solid fats to make them more tender and moist (25). Oil coats the flour proteins, preventing them from adhering to water; this reduces gluten formation and leaves more moisture in the batter. Vegetable oils are generally not used as the sole fat (except in tea breads such as carrot cake and commercial cake mixes) because they completely engulf and eliminate air bubbles, resulting in a decreased volume and harsh crumb (8). The key when including oil is not to add too much; otherwise, the cake becomes too heavy and compact.

Eggs

Eggs are added to help strengthen the structure, as well as to increase leavening, to act as emulsifiers, and to add color and flavor.

How & Why?

Why add eggs one at a time into a shortened cake batter?

Adding the eggs all at once can cause air pockets to collapse, resulting in a cake with less volume and a denser texture (9).

Milk

Milk is usually the main liquid in cake preparation (the aqueous phase described in Chemist's Corner 23-1). It hydrates the dry ingredients, dissolves the sugar and salt, provides steam for leavening, and allows baking soda or powder to react and produce carbon dioxide gas.

Leavening Agent

Both cakes and cookies are leavened with gas produced by baking soda, baking powder, air, and/or steam. The amount of chemical leavening agent used is dependent on how much flour is used. For every cup of flour, high-ratio cakes use 1 teaspoon of baking powder or ¼ teaspoon of baking soda (7).

Additional Ingredients

Salt is an important ingredient because it is a flavor enhancer. In addition, flavoring agents such as vanilla, chocolate, spices, fruits, and nuts are commonly incorporated into the basic flour mixture.

Food Additives in Cakes

Cakes made from scratch do not contain additives other than standard ingredients—sugar, salt, and possibly chemical leaveners. Other additives are introduced when certain commercial cake mixes, cakes, or toppings are purchased. The assortment of available

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TABLE 23-1 Selected Food Additives in Cakes

Food Additive	Function in Food
Annatto	Natural colorant with orange hue
Artificial color and flavorings	FDA-approved substances providing color and flavor
Calcium propionate	Preservative that inhibits mold growth
Carob bean gum	Stabilizer and thickener
Cellulose gum	Stabilizer and thickener
Citric acid	Preservative, antioxidant, pH control agent, sequestrant
Glycerin	Humectant (draws moisture to itself to decrease staling)
Guar gum	Stabilizer and thickener that improves texture
High-fructose corn syrup	Sweetener
Lactose	Sweetener (disaccharide derived from milk)
Maltodextrin	A carbohydrate produced from cornstarch that enhances stability and flavor
Modified cornstarch	Drying agent, formulation aid, processing aid, surface-finishing agent
Monocalcium phosphate	Leavener
Monoglycerides and diglycerides	Emulsifiers
Potassium chloride	Salt substitute
Potassium sorbate	Preservative
Sodium caseinate	Milk proteins that provide emulsification and dispersion
Sodium propionate	Preserves freshness by inhibiting molds
Sorbitan monostearate	Emulsifier, stabilizer, and thickener
Xanthan gum	Stabilizer and thickener that improves texture

food additives is relatively large, but some of the more common ones are listed in Table 23-1. Surfactants are often added to commercial cake mixes, and these are explained in Chemist's Corner 23-3.

Other Factors

In addition to ingredients and mixing methods, four other factors to consider when baking cakes are as follows:

- The type of pans to use and their treatment
- Timing
- Temperature
- Testing for doneness

These factors vary depending on whether the cake is shortened or unshortened.

Preparing Shortened Cakes

Shortened cakes are the most commonly prepared cakes, especially for birthday and wedding celebrations. They can be made from scratch or purchased as a boxed mix in the supermarket.

Conventional round cake pans are typically used, but large rectangular pans create large surfaces that can be covered with a limitless number of icing decorations or messages.

Selection and Preparation of Pans

Pan characteristics affect cake quality, so it is important to select the best pan for the job and to prepare it properly. Dull, rough-surfaced pans are best for

CHEMIST'S CORNER 23-3

Surfactants in Cake Batters

The shortenings in commercial cake mixes often contain surfactants. These compounds improve texture and flavor and aid in the emulsification of ingredients and the incorporation of air into the batter, which improves volume. Examples of surfactants include monoglycerides, diglycerides, polysorbate 60, sorbitol–fatty acid esters, glycerol–lactic acid esters, and propylene glycol–fatty acid esters. Batter viscosity and stability are improved by adding hydrophilic colloids such as gums and carboxymethylcellulose (22).

NUTRIENT CONTENT

Cakes consist of flour mixtures, extra sugar, and sometimes fat, so they are **often high in carbohydrates, fat, and kcalories.** The flour contributes some protein, but the total protein content is more dependent on other ingredients, such as milk, eggs, and occasionally nuts.

Any nutrient modification of cake mixtures usually focuses on the fat content. Fat is not always easy to replace, but fine-tuning the ingredients can reduce fat content somewhat (27). Fat's function as a moistener can be partially fulfilled by substituting yogurt, nonfat sour cream, or applesauce. The flavor lost by the removal of the fat can be replaced, in part, by adding more vanilla or another flavor extract. When baking from scratch, the fat in chocolate items can be reduced by using unsweetened cocoa powder, which contains only 6 grams of fat per ounce compared to the 15 grams found in the same amount of unsweetened chocolate. Food companies have more flexibility than the consumer in reducing the fat content of cakes because the thicker, richer consistency often provided by fat can be partially replaced by using the commercial fat substitutes available to the food industry that are not, as yet, available to consumers (26). Several commercial cake mixes are now on the market that are 94% fat-free by weight.

Gluten-free cakes produced from a number of gluten-free flours, including rice, buckwheat, and lupin, are now available as well (20). Rice flour, potato starch, and cornstarch are often used in commercial cake mixes.

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CALORIE CONTROL
Cakes

Cakes average 225 kcalories and 10 grams of fat per slice. However, this varies depending on the cake type, with angel food cake being the lowest in fat and kcalories, and fruitcake being the highest, as shown in Table 23-2.

- **Control portion sizes:** To limit the number of kcalories in your dessert, serve reasonable slice sizes (and eat only one slice). The kcalorie counts for each slice in Table 23-2 are usually based on one-eighth of an 8-inch round pan. If the serving size is one-fourth of the cake, it provides double the kcalories found in a standard-sized slice. Half a cake provides about 900 kcalories.
- **Choose plain instead of frosted:** Leaving off the frosting reduces the sugar, fat, and kcalorie content of cake desserts. For example, chocolate **frosting provides about 82 kcalories for each tablespoon.**

TABLE 23-2 Kilocalories in Cakes

<200 Kilocalories	200–300 Kilocalories	300 + Kilocalories
Angel food (73)	Coffee cake (220)	Spice (327)
Pound (116)	Boston cream (231)	Pineapple upside down (367)
Cupcake, iced (131)	Chocolate, iced (234)	Fruitcake, 1 × 3 inch (417)*
Fruitcake, 1 × 1 inch (140)*	Yellow (245)	
Sponge (187)	Coconut (250)	
	Banana (250)	
	Devil's food (250)	
	Cheesecake (256)	
	Gingerbread (263)	
	Carrot, iced (280)	
	German Chocolate (280)	

*Notice that the serving size of fruitcake determines its kcalorie content.

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baking cakes because they absorb heat more readily, resulting in the cake baking more quickly and having a larger volume, a finer grain, and a more velvety texture. Crumb formation is partially dependent on the degree of rising that occurs when the cake batter is first placed in the oven, and rapid heat absorption plays a role in this. On the other hand, shiny surfaces reflect heat, which causes the cake to take longer to bake, resulting in a coarser grain and lower volume. The weight, or gauge, of the pan's metal also affects quality: the heavier the pan, the better. When using glass pans for baking cakes, baking temperatures should be lowered by 25°F (14°C) because glass pans lead to shrunken corners from overcooking and cause the exterior crust to brown readily—a condition desirable for breads but less so for cakes.

The pans are prepared prior to mixing the batter. The bottom is greased, but the sides generally are not; the ungreased sides provide traction, allowing the rising mixture to reach its full volume. Solid shortening is preferred over butter for greasing for the following reasons: shortening contains no water, is less expensive, holds dusted flour better, and is both tasteless and odorless. Dusting the pan's greased surface with cake flour, or cocoa if it is a chocolate cake, makes later removal of the cake from the pan easier. After dusting, turning the pan upside down and tapping to remove excess cake flour will prevent the cake from having a mottled bottom. Waxed or parchment paper may also be placed in the bottom before greasing or spraying to allow for easier cake removal.

Temperature/Timing

Prompt transfer of the batter into pans and placement in a properly heated oven is another important factor in cake quality. If a batter is allowed to stand too long after pouring, carbon dioxide and air will escape. This reduces the volume and increases the coarseness of the cake's cells. Immediately after mixing, the pan should be filled with cake batter between half and two-thirds full and placed immediately in a preheated oven to ensure proper leavening. To avoid uneven baking and burning from hot spots, pans should not be allowed to touch each other or the sides of the oven, nor should they be placed directly above or below each other (Figure 23-4).

Most shortened cakes are baked at 325 to 350°F (163 to 177°C). In general, layered cakes (8-, 9-, or 10-inch round pans) bake in about half an hour, whereas thicker loaf cakes take three quarters of an hour to an hour to bake. Cupcakes normally take only about 20 minutes because of the small quantity of batter in each cup.

Changes during Baking

Heat plays several roles during cake baking. It increases volume by expanding air, steam, and carbon dioxide. It sets the structure by coagulating protein and gelatinizing starch. The heat flows from the edges toward the center of the pan, so cakes become rounded on the top as their interiors continue to rise after the outside portions of the cake have started to set. In addition, heat browns the crust via the Maillard reaction and the caramelization of sugars. If the oven temperature is too low, leavening gas is lost from the batter before there is a chance for coagulation of the proteins and gelatinization of the starch. As a result, the cake produced will have low volume, thickened cells, and possibly an indentation in the center. Excessively high temperatures

FIGURE 23-4 Pan placement. Adequate air circulation is achieved by placing the pans on the middle rack and at least 1 inch from each other and the oven sides.



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create a crust before the cake can rise, resulting in a humped form as the interior of the cake continues to rise (22).

Testing for Doneness

Observing appearance, touching, and performing an insertion test are three methods to determine doneness in baked cakes. When cakes are nearing doneness, their surface appears golden brown, and they start to "wrinkle" at the pan edges. They should be removed from the oven before a gap forms between the cake and the pan. Alternatively, the top of the cake may be touched lightly with a finger; if it springs back, the cake is done (Figure 23-5). Finally, a cake tester or toothpick may be inserted into the center of the cake. If it comes out clean, with no batter clinging to it, the cake is done. If a moister cake is desired, it is best to remove it from the oven while a few crumbs are still sticking to the toothpick. Testing for doneness should be reserved until the last few minutes of heating time, and done as infrequently as possible to keep from making unnecessary holes with the tester and to avoid drafts from the open oven door. Every time the door is opened, the oven temperature drops, and baking time is prolonged. The drafts may even cause the cake to fall.

FIGURE 23-5 Testing a cake for doneness. The cake is done baking if a light touch to the center leaves no imprint or if a wooden toothpick inserted in the center comes out clean.



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Cooling

After the cake is done, it should be removed gently from the oven and allowed to cool on a rack for 5 to 10 minutes. The warmer interior of the cake needs a chance to become firm, so any drastic, sudden movement or lack of adequate cooling jeopardizes its structure.

FIGURE 23-6 Cakes should be cooled on a rack. This allows them to set and prevents sogginess.



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The rack allows even air circulation under the cake, which prevents condensation and sogginess (Figure 23-6). Shortened cakes are usually removed from the pan before they are completely cooled, usually about 10 to 15 minutes after being taken out of the oven. After the cake has cooled, a spatula or knife can be inserted and moved around the edges of the pan before inverting the cake onto a cake plate. Cakes should have a fine crumb, a tender texture, optimal volume, and a lightly browned, delicate crust. Common cake faults and their contributing causes are listed in Table 23-3.

TABLE 23-3 Cake Problems and Their Causes

Problems / Causes	Overmixing	Undermixing	Batter too firm	Too much flour	Too much air	Too much sugar	Too little sugar	Too much fat	Too little fat	Too much egg	Too much liquid	Too little liquid	Too little salt	Overbaking	Underbaking	Too-high temperature	Too-low temperature	Too little or old leavening	Too much leavening	Uneven oven heat	Too much flour	Oven door opened too early
Decreased volume	X	X						X			X						X	X				
Increased volume					X																	
Too brown						X								X		X						
Too pale	X						X								X		X					X
Falls in center		X				X		X			X				X		X	X	X			X
Uneven shape																				X		
Peaked	X			X					X							X		X			X	
Cracks on top	X		X					X		X						X			X			X
Tunnels	X		X					X		X												
Tough	X			X			X		X					X				X			X	
Dry/crumbly		X		X			X		X			X			X	X			X		X	
Soggy		X				X		X			X				X				X			
Heavy	X					X		X			X				X			X				
Shrinks	X															X		X				
Flat taste													X									

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TABLE 23-4 Altitude Adjustments for Shortened Cakes

Ingredient Adjusted		3,000 Feet	5,000 Feet	7,000 Feet
Baking powder	For each teaspoon, decrease	1/8 tsp	1/8–¼ tsp	¼ tsp
Sugar	For each cup, decrease	0–1 Tbsp	0–2 Tbsp	1–3 Tbsp
Liquid	For each cup, add	1–2 Tbsp	2–4 Tbsp	3–4 Tbsp

High-Altitude Adjustments

As in bread preparation, ingredients must be modified for cake preparation at altitudes higher than 3,000 feet. The lower atmospheric pressure at higher elevations reduces the need for baking powder or soda. In addition, water evaporates more quickly at higher altitudes, and thus the concentration of sugar is increased. Structural strength can be improved by adding 1 to 2 tablespoons of cake flour, increasing the amount of water, and reducing the quantities of baking powder and sugar (Table 23-4). Increasing the baking temperature 10 to 15°F (6 to 8°C) increases the rate at which the cake sets by speeding the coagulation of the protein and the gelatinization of the starch. Cake mix boxes provide instructions for altitude adjustments.

Microwave Preparation

All cakes are better prepared in a conventional oven, but it is possible to prepare certain cakes in the microwave oven. Microwavable cake mixes are available, and some of these contain special ingredients, such as xanthan gum, to increase moisture retention (31). Microwaved cakes are usually cooked in about 10 minutes and rise higher than conventional cakes. They lack the characteristic browning and crust formation of conventional cakes, but that can be masked with frosting; however, it is more difficult to hide the soft, uneven tops that may occur without crust formation.

Packaged microwave cake mixes usually include a microwave-safe baking pan. If not, round pans are preferred over square or rectangular ones because the corners of cakes baked in the latter are prone to burning. Two or more pans filled with cake mix can be cooked at the same time as long as the air can circulate; otherwise, they are prepared one at a time or baked in one 16-cup fluted pan. Some cake mixes on the market can be baked in either conventional or microwave ovens.

Preparing Unshortened and Chiffon Cakes

Unshortened cakes rely on foam formation for their structure, making their preparation slightly more involved than that for conventional, shortened cakes. The preparation of angel food, sponge, and chiffon cakes (hybrids of shortened and unshortened cakes) is discussed next.

Angel Food Cake

The three basic ingredients of angel food cake are egg whites, sugar, and cake flour. Small amounts of cream of tartar, salt, and flavoring are also added. The tender texture of an angel food cake is partially the result of the cake flour; the majority of leavening is caused by steam produced by the evaporation of liquid from egg whites (6). All angel food cake ingredients should be at room temperature; however, for food safety reasons, if eggs are too cold, they may be dipped briefly in warm water and used immediately. A stable egg-white foam, for which the eggs must be at room temperature, is necessary to form the cake's basic structure. Sugar contributes further to the stability of the foam through the incorporation of air into the mixture as it is added, which allows the formation of small air bubbles. It has a tenderizing effect on the cake by interfering with gluten development, and it raises the coagulation temperature of the egg proteins and the gelatinization temperature of starch. Too much sugar, however, will cause the cake to collapse.

Mixing Technique

Proper mixing technique is essential when making angel food cake. The sugar is added after the egg whites have begun to foam. It should be added very gradually or it will pull water from the egg whites, creating a syrupy foam and producing a low-volume cake. Salt and flavoring are also added at this time. The cake flour is then sifted gradually over the egg-white foam to prevent its weight from collapsing the air cells. The ingredients must be thoroughly blended, while avoiding overmanipulation, which would reduce tenderness and volume (Figure 23-7).

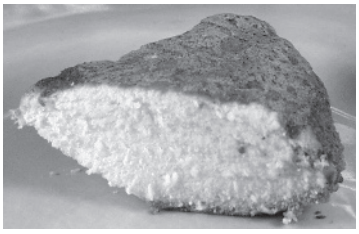
FIGURE 23-7 Undermixing and overmixing angel food cake.



Undermanipulation: uneven grain, course texture, low volume



Optimal folding of ingredients: fine grain, light spongy texture, high volume



Overmanipulation: compact grain, low volume

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FIGURE 23-8 The pan for angel food cake.



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Temperature/Timing

The prepared batter is poured quickly into an ungreased tube pan; a spatula is run through the batter, sealing it to the sides of the pan; and then the pan is placed in the lower third of a preheated moderate (350°F/177°C) oven. An oven that is too cool will cause a low-volume cake because the sugar will absorb liquid from the egg whites, turn syrupy, weep out of the batter, and disrupt the air cells. An oven that is too hot will set the cake's exterior before the cake has been fully expanded and baked through, resulting in a low-volume, dense cake (6). During baking, the light batter rises and relies on the additional support of the central tube (Figure 23-8). As the cake bakes, the proteins coagulate, stabilizing the air cells; water evaporates from the fluid mixture to create a more rigid structure; starch gelatinizes, further contributing to structure; and browning on the surface occurs because of the Maillard reaction (19). Baking time is approximately 45 minutes.

When the cake is done, it is inverted in its pan and allowed to stand for about 1½ hours in this position to stretch and strengthen its structure. For serving, it is best to cut or separate angel food cake into pieces by using the special divider made for that purpose (it looks like a large comb), or by using a sawing motion with a serrated knife (Figure 23-9). Conventional knives will crush the delicate cake.

The few ingredients and minimal number of steps needed for the preparation of angel food cake may make it seem simple, but the delicacy of the egg-white foam can make it a tricky procedure. Chapter 12 on eggs describes how to prepare an egg-white foam and explains the many factors that influence its formation.

FIGURE 23-9 Cutting angel food cake. Unlike other cakes, the delicate structure of angel food cakes requires that they be cut with a comb-like utensil or serrated knife.



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How & Why?

Why is cream of tartar added to angel food cakes?

Cream of tartar is an acid that strengthens the egg-white foam by denaturing the protein, thus stabilizing the air-cell structure. The acidic environment created by the cream of tartar helps increase tenderness and contributes to the white color of angel food cake by whitening the flour's natural yellowish, anthoxanthin pigments.

Sponge Cake

Sponge cake is similar to angel food cake, except there are two foams—an egg-white foam (a meringue) and an egg-yolk foam—and lemon juice often replaces the cream of tartar as the acid ingredient. The acid adds stability to the egg-white foam by lowering its pH (28). (The preparation of egg-white foams is discussed in Chapter 12 on eggs.) There are three possible methods for preparing sponge cake.

Method 1

In the first method, the egg whites and yolks are first separated and then beaten separately to achieve maximum batter volume. Sugar and, possibly, vanilla extract are beaten into the whipped yolks. The cake flour is then gently folded in, followed by the egg-white foam.

Method 2

The syrup or meringue method creates a finer-textured end product. A syrup is made by cooking two parts sugar with one part water and boiling the mixture until it has reached the soft-ball stage (238 to 240°F/109 to 116°C) (see Chapter 25). Egg whites are beaten with cream of tartar until they are stiff but have not yet formed dry peaks. Then, as the egg-white foam is beaten constantly, the hot syrup is poured into it in a fine stream. When this meringue is completed, beaten egg yolks are combined with lemon juice and folded into the mixture. Finally, cake flour is sifted over and lightly folded into the other ingredients.

Method 3

In the third method, whole eggs are beaten until foamy and pale yellow in color, and then a small amount of cream of tartar or lemon juice is added. The mixture is beaten until stiff before the sugar is added in 2-tablespoon increments. A presifted flour-and-salt combination is then sifted into the egg mixture and folded into the batter.

Chiffon Cake

Chiffon cakes are more tender than either angel food or sponge cakes because of added vegetable oil. A chiffon cake is prepared by folding whipped egg whites into a mixture of cake flour, sugar, beaten egg yolks, and oil. The batter is poured into an ungreased tube pan and baked in an oven preheated to 325°F (163°C). When baking is completed, the pan is inverted over a cooling rack and allowed to cool for at least 20 minutes before being turned out onto a cake plate.

Selection and Preparation of Pans

When preparing unshortened cakes, pans are left ungreased in order to provide traction so that the batter can achieve optimal volume; this also prevents angel food cake from falling out of its pan while it is cooling upside down. Tube pans provide structure,

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help set the delicate cake by allowing heat to reach a greater surface area, and allow for easier cake removal.

Temperature/Timing

Unshortened cakes are baked in a moderate (350 to 375°F [177 to 191°C]) oven for approximately 45 minutes to an hour. Excessively high temperatures toughen the cakes' delicate structure, coagulate the top before the air and steam have had sufficient time to accomplish leavening, and may burn the crust.

Testing for Doneness

An unshortened cake is cooked when the surface is lightly brown and springs back when touched. Using a toothpick to test for doneness does not work for unshortened cakes.

FROSTINGS/ ICINGS

Frostings or icings, either uncooked or cooked, are spread on baked products such as cakes, cupcakes, and pastries. In addition to improving the appearance, flavor, and texture of baked dessert goods, frostings retain moisture and increase shelf life. Some of the more popular types of frostings are flat (also known as simple), decorating, buttercream, and whipped cream. More sugary, syrup-like toppings known as ganache and fondant (see Chapter 25 on candies) can serve as both *frostings* and fillings. In this chapter, we refer to these sugary spreads as frostings, which is the common practice in the United States; in other countries, *icings* is the more popular term because confectioners'/powdered sugars are known as icing sugars.

Flat Frostings

Uncooked flat or ornamental frostings are the simplest to prepare. Flat frostings are made by beating powdered sugar (10X) with water, milk or cream, and a flavoring. Powdered sugar is used rather than granulated because it dissolves instantly in unheated liquids. Unfortunately, the presence of cornstarch (about 3%) in powdered sugar gives uncooked frostings a slight raw taste. In addition, unless a fat is added, these frostings have a tendency to become dry and to crack. Flat frostings are most frequently used on coffee cakes and sweet rolls.

Decorating Frosting

Decorating frosting, also called simple buttercream, royal, or ornamental frosting, is traditionally used for decorating wedding cakes. It is similar to flat frosting, but beaten egg whites are added to impart a firmer structure to the icing when it has dried. The hard surface is flat, smooth, and glossy. Decorating frosting is ideal for the delicate work of creating lettering, borders, flowers, and any other structures added to the cake's surface. Although this frosting is useful for its decorative powers, it not only lacks flavor but also sometimes has a "pasty" consistency. It is made by creaming together fats (butter, cream, pasteurized eggs, and or vegetable shortening) and powdered sugar until the desired consistency is attained.

Cooked Frosting

Cooked frostings are often made with granulated sugar that is dissolved in heated water; additional ingredients may include egg whites, cream of tartar, or corn syrup. If confectioners' sugar is used, heating allows the formation of a sugar syrup that will serve as the frosting's foundation. A common cooked frosting, containing either granulated or confectioners' sugar, is buttercream frosting. This frosting is used primarily as a filling and icing for pastries and cakes, and frequently to create rose or leaf decorations.

As the name implies, buttercream frostings have butter (preferably sweet, unsalted) added to make them creamier, easier to spread, more flavorful, and less likely to crack. They are made by combining whipped butter and/or shortening with a boiled sugar syrup and flavorings (vanilla, chocolate, raspberry, lemon, orange, coffee, liqueur such as Grand Marnier, etc.). An additional layer of flavor can be added by spreading the cake with a mixture of jam thinned with liqueur or by adding toppings (29).

Modifications of the basic sugar-based buttercream frostings include those in which soft whipped butter is beaten or folded into a meringue or beaten egg yolks. Pastry chefs use three types of meringue-based buttercream icings for their delicate pastries—Swiss, Italian, and French (4):

- **Swiss buttercream.** The easiest buttercream to prepare. Egg whites and sugar are mixed together over heat (a bowl over a water bath). After the sugar melts, the egg whites are whipped into stiff peaks before adding the butter and flavorings.
- **Italian buttercream.** The lightest and sweetest of all buttercreams. A hot sugar syrup is whipped into the already whipped egg whites.
- **French buttercream.** The rich, heavy consistency of this buttercream is obtained by whipping the hot sugar syrup into whipped egg yolks (or whole eggs).

Whipped Cream Frosting

Whipped cream can be used as a frosting or even a filling. Cocoa or fruit purees can be added to color and flavor the whipped cream.

Ganache

Ganache is the French word for the rich, smooth, and shiny chocolate-cream mixture used as both a frosting and a filling for certain cakes and pastries (Figure 23-10). Prepared from a heated mixture of chopped chocolate and heavy cream, ganache is poured over baked items, where it eventually hardens into a chocolate-based covering. A buttercream consistency can be obtained by whipping soft butter into the basic ingredients, resulting in ganache beurre.

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FIGURE 23-10 Ganache poured over a cake creates a chocolate-based topping.



Scott & Zoe/Getty Images

Garnishes

Numerous garnishes, from figurines to candles, can be added to cakes, limited only by the imagination. Figure 23-11 shows how dragging a skewer (or toothpick, chopstick, table knife, or fork) through two contrasting liquids placed next to each other can create a swirly marbled look (3).

STORAGE OF CAKES

Cakes stale fairly quickly, but this can be prevented to some degree by keeping them covered. Placing half an apple in the cake box also seems to extend the cake's shelf life. Frosting the cake as soon as it cools is another method to slow down moisture loss. The amount and type of sweetener used in the preparation of a cake affect its ability to be stored. As mentioned earlier, high-sugar-content cake mixes have longer shelf lives than lower-sugar-content cakes. Substituting honey for part of the sugar in cake contributes to even more moisture retention; it contains fructose, which is extremely hygroscopic, or water loving. However, the fructose and glucose in honey may result in excess browning due to the Maillard reaction.

Freezing is another method to deter staling. Cakes that have been wrapped airtight can be frozen unfrosted or with one of the types of frostings that freezes well. Cakes with fruit should not be frozen because defrosting will cause the fillings to run, resulting in soggy cakes. Frozen cakes keep up to 3 months if frosted and up to 6 months without frosting.

FIGURE 23-11 How to create the swirly marbled look.



Dave King/Getty Images

TYPES OF COOKIES

The word *cookies* refers to "small cakes." In fact, cookies contain many of the same ingredients as cakes except that the proportion of water is low, whereas those of sugar and fat are high. The word *cookie* is derived from the Dutch word *koekje* or *koekie*. In the United Kingdom, cookies are called "biscuits"; in Spain, they are *galletas*; in Germany, they are *keks*; and in Italy, they are *biscotti*. The joyofbaking.com website says that every country has its favorite cookie: in North America, it's chocolate chip; in the United Kingdom, it's shortbread; in France, it's sablés and macaroons; and in Italy, it's biscotti di Prato.

Cookies and small cakes were popularized by the English ritual of afternoon tea, a practice that did not exist before the 19th century. Until then, lunch was eaten quite early in the day, whereas dinner was served at 8 or 9 p.m. Then, about 1830, Anna, the Duchess of Bedford, asked for tea and light refreshments (now cookies and small cakes) in her room one afternoon. She started inviting friends and soon elegant tea parties were fashionable and serving afternoon tea became a common custom.

There are hundreds of different cookie recipes, and this enormous variety is possible because a wide range of flavoring agents may be added. Chocolate chips, nuts, coconut, fruit, marshmallows, peanut butter, and many other ingredients find their way into cookies. The seemingly endless assortment of cookies (see Figure 23-12) makes it difficult to categorize them, and not all fit neatly into one classification. In general, however, the

FIGURE 23-12 A selection of cookies.



Danny Smythe/Shutterstock.com; Richard M Lee/Shutterstock.com; Hong Vo/Shutterstock.com; Diana Taliun/Shutterstock.com; Al Mueller /Shutterstock.com; unpict/Shutterstock.com; Pattakorn Uttarasak/Shutterstock.com; oksana2010/Shutterstock.com; endeavor/Shutterstock.com

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fluidity of the batter or dough determines which of the following six categories—bar, dropped, pressed, molded, rolled, or icebox/refrigerator—cookies fall into.

How & Why?

Why are cookies crispier than cakes?

Cookies are crisp and tender because very little to no starch gelatinization or gluten formation occurs. Sugar, starch, and flour proteins all compete for the small amount of available water, which limits both processes. Gluten development is also hindered by the cookies' high fat concentrations. If the recipe does call for more water than usual, a more cake-like cookie is produced. However, many commercial cookies are baked with very little water (3 to 4%) to create a crisp cookie in which the sucrose will not dissolve but rather contribute to the cookie's shiny, glassy appearance (22). As sucrose concentration decreases, gluten development increases, and using sugars other than sucrose diminishes the chances of reaching target texture, height/diameter, moisture content, and shelf life (17).

Bar Cookies

The most fluid of cookie batters is used to make bar cookies such as brownies. The batter is baked in a pan instead of on a baking sheet and cut into individual pieces, or bars, with a knife or spatula.

Brownies

Brownies are rich, chocolate cakes named after their color. Brownies may or may not contain nuts.

Lemon Bars

Lemon bars are bar cookies that have a sweet, rich, tart, lemony custard top on a shortbread base.

Dropped Cookies

Dropped cookie batter is literally dropped from a spoon or portion control scoop onto a baking sheet. The batter contains just enough flour so the cookie will not spread out like a pancake when it is dropped onto the baking sheet. Figure 23-13 shows the desired spread of cookies during baking. Both spread and surface cracking are used to determine the baking quality of cookies (22). Chocolate chip, oatmeal-raisin, and meringue cookies are examples of dropped cookies.

Chocolate Chip Cookies

This is one of the most popular cookies in North America. According to Nestlé's website, this famous cookie was created in the early 1930s by Ruth Wakefield, owner of the Toll House Inn in Massachusetts. The generally accepted story is that she created incredible desserts that drew people to the inn. She was making a batch of "Butter Drop Do cookies" (a favorite Colonial recipe) with a Nestlé Semi-Sweet Chocolate bar cut up into small pieces, but they never melted into the batter. Ruth's recipe was published in newspapers, and the cookie's popularity grew. She reached an agreement with Nestlé that allowed the company to print the Toll House Cookie recipe on the wrapper of its Semi-Sweet Chocolate Bar in exchange for being supplied with all of the chocolate she could use to make her cookies. After 1939, Nestlé introduced tiny pieces of chocolate in convenient, ready-to-use packages.

Cialde (chee-al-day)

These Italian, anise-flavored cookies can be eaten plain or stuffed with fillings (usually fruit).

Florentines

Round, wafer-thin cookies are made from nuts and candied fruit that is coated with a sugar syrup. This chewy cookie is coated with chocolate on one side.

Fortune Cookies

Although frequently offered in Chinese restaurants after a meal, these cookies were invented in California after 1900 by an Asian American. These plain, thin, crisp wafer cookies are still warm when folded around a small strip of paper that often has a "fortune" printed on it. Cooling makes the cookie turn crisp and hard, so the only way to retrieve the "fortune" is to break the cookie open.

Macarons

Two soft, sweet meringue cookies placed together like a sandwich with an inner buttercream or jam filling. Due to their similar spelling (one "o" vs. two), these are often confused with "macaroons," which are coconut based.

Macaroons

As a close cousin to the meringue, macaroons are mound-shaped cookies often made from shredded coconut, sweetened condensed milk, and almond or vanilla extract folded into whipped egg whites. A typical macaroon is lightly browned and crisp on the outside, but soft and chewy on the inside.

Madeleines

Special pans with shell-shaped indentations are required to produce these often buttery-lemon-flavored cookies; other flavors are also available.

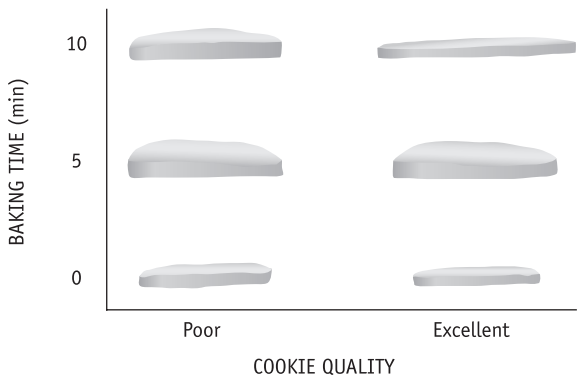
Meringues

These raindrop-shaped cookies have a delicate structure based on sugared, whipped egg whites (see Chapter 12 on eggs).

Wafers

Wafers are sweet, crisp, very thin and flat, dry cookies that may have an indented diagram or picture. They are consumed as is or served with ice cream.

FIGURE 23-13 Desired spread of a dropped cookie.



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Pressed Cookies

The flour mixture for pressed cookies is viscous enough to be stuffed into a pastry bag or cookie press and forced out through cookie dies. Examples of pressed cookies include tea cookies, ladyfingers (used to make tiramisu), and coconut macaroons.

Ladyfingers

These light, sweet sponge cake cookies look like big, flat fingers because of their whipped egg white content. Ladyfingers are created by piping génoise sponge cake batter into flat strips. These airy cookies can be eaten alone but are most commonly consumed as part of tiramisu. The different styles of ladyfingers demonstrate how many variations of the same cookie may be available. For making tiramisu, prepackaged cookie-style ladyfingers from Italy are recommended over those from North America, which are usually sold fresh-baked in supermarkets and are soft and cake-like. The Italian cookie-style ladyfingers will hold their shape when soaked in espresso, whereas those that are fresh-baked will be too soggy to hold their structure in the tiramisu dessert (11).

Russian Tea Cookies (Mexican Wedding Cakes)

These round, mounded cookies are based on a flour–butter–nut dough that is baked and then rolled in powdered sugar.

Molded Cookies

This dough is heavy enough to be formed or molded into balls, bars, or other shapes before being placed on the baking sheet. Molded and other cookies sometimes have powdered sugar sprinkled on top, which can be applied evenly by using a mesh tea strainer. Peanut butter cookies are an example of molded cookies.

Almond Cookies

These light and delicate Chinese cookies emit an almond aroma derived from almond extract.

Biscotti di Prato

These Italian cookies are first baked as a loaf and then cut into strips and baked again. The double baking creates a hard texture, making them excellent for serving with coffee or cappuccino. They are often flavored with almonds, anise, or chocolate. Traditionally, biscotti di Prato cookies were dipped in a dessert wine after dinner, and because they could be stored for long periods of time, they provided nourishment for seamen, explorers, and soldiers.

Peanut Butter Cookies

An unknown physician invented peanut butter for a chewing-challenged patient in 1890 by grinding peanuts through a meat grinder. However, George Bayle Jr. mechanized the process and began selling peanut butter to the public. Peanut butter cookies are credited to George Washington Carver (1864–1943), who came up with more than 100 ways to use peanuts.

Rolled Cookies

Rolled cookies are made from a slightly heavier dough than molded cookies. The dough is rolled out on a lightly floured board and cut into the desired shape. Using too much flour on the cutting board leads to hard-textured cookies. Powdered sugar may be used in place of flour on the cutting board, but obviously it will make the cookies slightly sweeter. Any leftover dough from the initial cuttings of cookies can be salvaged to make more cookies by rerolling it into a ball, spreading it out, and cutting it again without concern about additional gluten development. The most common type of rolled cookie is the sugar cookie. Shortbread cookies are also rolled.

Butter Cookies

Butter cookies are thin, crisp cookies made with butter, flour, and sugar. Butter cookies come in various shapes—circles, ovals, and squares.

Cannoli Shell

Italians sometimes stuff these cookies with a ricotta cheese-based sweet filling.

Gingerbread

Ginger is the major spice used to make gingerbread cookies, cakes, and houses. Cookies are often shaped into gingerbread men. The amount of ginger added to each of these desserts determines their spiciness and whether their color is light or dark.

Linzer Cookies

These cookies are uniquely identified by variously shaped hole(s) through which preserves can be viewed. Linzer cookies are white on top because of a fine dusting of confectioners' sugar.

Mandelbrot

Although similar to almond-flavored biscotti, these cookies are smaller and softer. They are typically sold in Jewish markets.

Shortbread

Scotland is the home of shortbread, a centuries-old baked product that preceded butter cookies. These rich, dense, crumbly cookies have a melt-in-the-mouth texture because they are made with a 3-2-1 proportion of flour, butter, and sugar. Sometimes ground rice or corn flour is added to further define the delicate texture that crumbles easily in the mouth.

Sugar

Cookies derived from a sugar-based dough (plus flour, butter, eggs, baking powder, vanilla, and salt) that is rolled and then cut into various designs by cookie cutters. Sugar sprinkles often decorate the top. The baking time largely determines whether they are soft and chewy or crisp. Removing sugar cookies from the oven while they are still moist in the middle promotes softness. Replacing 10 to 15% of the sucrose with glucose, honey, corn syrup, or invert sugar will also result in softer, chewier cookies (24). These sugars act as humectants and draw moisture from the air. Moisture can also be retained by wrapping the cookies or entire sheet pan topped with cookies while they are still warm.

Icebox/Refrigerator Cookies

The same kind of dough used for rolled cookies can be formed into a cylinder, wrapped, and placed in the refrigerator to harden. The chilled dough is then sliced into thin discs for baking. The commercially prepared cookie doughs sold in the refrigerator section of the supermarket are of the icebox/refrigerator type.

Cookies as Functional Foods

While cookies are not generally marketed for their health benefits, some manufacturers have begun to add healthful ingredients in order to market

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them as functional foods. For example, dietary fiber, flax, probiotics, vitamin E, and omega-3 fatty acids can be used as additives to improve the nutritional profile of baked sweets (2, 14, 32). β-Glucan, a natural dietary fiber, can be used to replace shortening in batter to reduce fat content (13). In addition, minerals such as magnesium and calcium or multivitamin mixtures can be added to cookies (30).

PREPARATION OF COOKIES

Ingredients and Mixing Methods

The type of cookie to be prepared determines the mixing method, but for most types the conventional cake method is used. The degree of gluten development is not as important for cookies as it is for cakes, which need a soft, delicate crumb, so all-purpose flour, rather than cake flour, is usually used for cookies. Cake flour is preferable if a puffy, soft cookie is desired, as noted in Table 23-5 and the How & Why feature. Because lower-protein flours such as cake flour absorb less water than those that are higher in protein, more water is available for steam generation, resulting in a more puffed cookie. In addition, the chlorination of cake flour tends to inhibit the spread of cookie dough, so flat cookies are less likely to result.

TABLE 23-5 Change the Ingredients, Change Cookie Character

Ingredient	Result
For puffy, soft, pale cookies:	
Cake flour (low-protein, acidic)	More steam and puff; less browning
Shortening (high melting point)	Less spread
All brown sugar (hygroscopic, acidic)	Soft and moist; less spread when used with egg
Egg	Moisture for puff; less spread with acidic ingredients
For thin, crisp cookies:	
All-purpose flour (high-protein)	Browning
Butter (protein)	More spread; browning
Baking soda (alkaline)	Browning
Corn syrup (glucose)	Browning; crisp
White sugar (sucrose)	Crisp
No egg	No puff; more spread

Source: Copyright © Shirley O. Corriher. From an article originally published in *Fine Cooking* 24:74–75, 1998.

How & Why?

Why is cake flour used for soft and puffy cookies?

Although cake flour is lower in protein than hard wheat flour, it is chlorinated, which reduces cookie spread. Soft wheat flour is preferred for puffier, softer cookies because it blends more easily with whipped egg whites (if included). In addition, it takes up less water than a higher-protein, hard wheat flour, leaving more water to dissolve the sugar. The sugar syrup that forms with this water makes the dough more relaxed and spreadable (22).

After the ingredients are chosen based on whether a flat or puffy cookie is desired, they are usually mixed together just until moistened because development of gluten is not necessary. In fact, the high sugar content in cookie dough inhibits gluten formation, while cracker formulations have less sugar to facilitate gluten formation (16). The cookies are then ready for baking unless chilling is required. Overmixing will cause the cookies to be hard because of the addition of too much air, which facilitates the formation of a protein foam.

Food Additives in Cookies

Commercial cookies often contain food additives to maintain their quality and consumer appeal. The type of food additive varies according to the product and the manufacturer, but all must be listed on the label. Like those used in cakes, cookie additives can vary widely, but a few are used more frequently than others (Table 23-6). Some commercial cookie manufacturers do not use additives.

Baking Cookies

Selection and Preparation of Pans

Cookie baking sheets are preferred for all except bar cookies. Their low or nonexistent sides allow hot air to circulate and bake the cookies evenly. A shiny top surface and a dull bottom allow even browning. Pans are usually greased for dropped, bar, or rolled cookies but not for pressed, molded, or icebox/refrigerator cookies. Cookies should be placed far enough apart on the baking sheet to prevent them from touching or flowing together during baking. To prevent spreading, cookie dough should be placed on cool cooking sheets or on a sheet of aluminum foil or parchment. Cookies bake better if the pan is placed in the middle or top rack in the oven with at least 2 inches between the pan and the oven wall. Better air circulation can be achieved with unrimmed cookie sheets that have one or two raised edges. Burned cookie bottoms may be prevented by inserting one

TABLE 23-6 Selected Food Additives in Cookies

Additive	Function
Calcium lactate	A salt produced when lactic acid reacts with calcium carbonate; used in foods as baking powder
Carnauba wax	A wax to add cohesion and shine to coatings
Cornstarch	Anticaking agent, drying agent, formulation aid, processing aid, surface-finishing agent
Malic acid	Flavoring; a colorless substance that occurs naturally in foods, for example, unripe fruit
Potassium sorbate	Preservative; a salt of sorbic acid used to inhibit molds and yeasts in many foods
Soybean lecithin	Emulsifier; assists the mixing of lipid-based ingredients with water-soluble ingredients
Whey	Dairy protein by-product used as a binder or extender to provide a uniform texture

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pan into another, leaving a pocket of air between them (21).

Temperature/Timing

Usually, cookies are baked at temperatures ranging from 325 to 375°F (163 to 191°C). Exceptions include meringue or sponge cookies, which bake at about 225°F (107°C). Higher temperatures help prevent the dough from spreading and facilitate browning, but if the temperature is too high, excessive drying and browning will result. Baking times average between 10 and 30 minutes, depending on the type of cookie.

Testing for Doneness

Cookies are done when the browning is complete and the centers are cooked. The easiest and most tasty way to determine doneness is to split a sample cookie open and do a taste test. Once done, cookies should be removed immediately from the pan and placed on a cooling rack. They should have a crisp or chewy texture, a uniform shape, even browning, and good flavor. The flexibility of a cookie just taken out of an oven soon disappears as it cools, attributable in part to the sucrose crystallizing out of solution (22). Cookies burned on the bottom can be salvaged by rubbing them on the coarse side of a grater. Excess browning can be prevented by double-panning, that is, using two cookies sheets of the same size, one placed on top of the other. Potential quality problems in prepared cookies and their causes are detailed in Table 23-7.

TABLE 23-7 Cookie Problems and Their Causes

Problems / Causes	Overbaking	Underbaking	Excess flour	Insufficient shaping	Excess rerolling or mixing	Cut too thick	Improper use of the cookie press	Placed dough on hot cookie sheet	Dough too cold or warm
Too brown	X								
Too pale		X							
Dry/crumbly	X		X	X	X				
Doughy		X							
Tough	X				X				
Soft		X				X			
Uneven shape		X					X	X	X
Excess spread		X						X	

High-Altitude Adjustments

When baking at higher altitudes, a slightly higher temperature may be needed. A decrease in the quantity of baking powder and sugar or more flour may also be necessary.

Microwave Preparation

Heating time for cookies is so short that using a microwave oven is often impractical and may be detrimental to cookie quality. However, microwavable prepared cookie mixes are available.

STORAGE OF COOKIES

Airtight containers are best for maintaining cookie freshness. As soon as they are cool, cookies are transferred to a flat dish or plate and covered with plastic wrap or metal foil. They may also be arranged in layers in a covered cookie jar or plastic zipper bag. Some commercially packaged cookies can keep for months. Most cookies (except those with fresh fruit fillings) are ideal for freezing because their relatively low moisture content means fewer ice crystals will form (15).

NUTRIENT CONTENT

The high sugar, fat, egg, and flavoring concentrations contribute to the **high kcalorie and fat contents** of cookies. Standard cream cookie fillings contain about 20–30% fat (5), though reduced-fat fillings are available.

The **carbohydrate (largely sugar) content** is of concern to people with diabetes or hypoglycemia, but sugar-free cookies are now available (10). Research continues in the development of a cookie dough containing no added simple sugars (18). One problem in reducing the amount of sucrose in cookies is that this diminishes the bulking properties sucrose contributes. Commercial cookie manufacturers get around this by using bulking agents such as maltodextrins, sugar alcohols, polydextrose, cellulose, and insoluble fiber compounds (33). Gluten-free cookies are increasing in popularity as bakers use rice flour, potato flour, almond meal, coconut flour, chia seed, and other ingredients to replace wheat flour (23).

CALORIE CONTROL
Cookies

Regular-size cookies (2 inches wide) average **50 kcalories each** (Table 23-8) even though the food industry has marketed many new products that are lower in fat or even fat free (1). Often, when the fat is removed, more sugar is added. Focus on portion control:

- 5 regular cookies provide 250 kcalories.
- **Jumbo cookies** (size of 10 regular cookies) provide **500 kcalories each**.

TABLE 23-8 Kilocalories in Cookies (average size)

<50 Kilocalories	50–100 Kilocalories	100+ Kilocalories
Animal cracker (13)	Chocolate sandwich (50)	Biscotti, almond (120)
Butter (23)	Chocolate chip (53)	Oatmeal raisin (200)
Wafer (26)	Fig bar (56–110)	Brownie, 4 inches square (224)
Ginger snap (29)	Peanut butter (71)	
Fortune (30)	Ladyfinger (87)	
Graham cracker (30)	Macaroon, coconut (97)	
	Brownie, 2 inches square (112)	

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PICTORIAL SUMMARY / 23: Cakes and Cookies

The simplest cookies and the most elaborate wedding cakes really derive from the same basic flour mixture as quick and yeast breads, but they are made with a higher proportion of sugar, fluid, and fat. And what a difference those additions can make!

TYPES OF CAKES



Shortened cakes: Also called butter or conventional cakes, these are made with fat. Examples are white, yellow, chocolate, and spice cakes.

Unshortened cakes: Also called sponge or foam cakes, these are made without fat, and rely on whipped egg-white foam for structure. Angel food and sponge cakes are two examples.

Chiffon cakes: These combine the characteristics of both shortened and unshortened cakes. Examples include lemon and chocolate chiffon cakes.

PREPARATION OF CAKES

Compared to breads, cakes have a higher proportion of sugar, milk, and fat to flour. Structural strength is provided by flour and eggs, with the latter also contributing to color, flavor, and leavening, and acting as emulsifiers. Fats and sugar both add tenderness and volume; sugar also contributes to sweetening and browning of the crust. Cakes are leavened by baking soda or powder, air, and/or steam, but a true pound cake is leavened only by air and steam. Flavorings provide variety in cakes.

Nutritionally, an average cake serving yields about 10 grams of fat and 225 kcalories. Per slice, angel food cake is the lowest in fat and kcalories (0.1 gram = 143 kcalories), whereas fruitcake (1 × 3 inches) is the highest in kcalories (15 grams = 417 kcalories).

Four considerations in baking cakes are the type and treatment of the pans, timing, temperature, and method of testing for doneness. Commonly used mixing methods include conventional, conventional sponge, pastry-blend, quick-mix, and muffin mix. Regardless of the type of mixing method used, too much or little stirring can cause problems, and special measures are taken at altitudes higher than 3,000 feet.



FROSTINGS/ICINGS



Either cooked or uncooked, frostings are spread on baked dessert products to improve their appearance, flavor, texture, and shelf life. The most common types of prepared frostings are the following:

- Flat (simple)
- Decorating (royal or ornamental)
- Buttercream (Swiss, Italian, French)
- Whipped cream
- Ganache and fondant

STORAGE OF CAKES

Cakes do not retain their freshness for very long and should be protected from any exposure to air. Iced cakes can be frozen and will keep their quality for up to 3 months, whereas unfrosted cakes can be kept frozen for up to 6 months.

TYPES OF COOKIES

In general, the fluidity of the batter or dough determines the type of cookie: bar, dropped, pressed, molded, rolled, and icebox/refrigerator cookies. All contain flour, sugar, salt, fat, and liquid. Cookies are usually higher in sugar and fat than cakes, although low-fat and nonfat cookies are available.

PREPARATION OF COOKIES

The type of cookie determines the mixing method. All-purpose flour is usually used instead of cake flour because the degree of gluten development does not dramatically affect cookies. With the exception of bar cookies, which are baked in a pan, baking sheets are the preferred pan for baking cookies.

STORAGE OF COOKIES

As with cakes, cookies' exposure to air should be minimized. Airtight containers or wrappings are crucial to maintaining the freshness of home-baked cookies. Most cookies freeze well because of their low moisture content.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. What is the name of a cake made with fat?
   a. Chocolate
   b. Shortened
   c. Unshortened
   d. Flat

2. Which category of cakes combines qualities of both shortened and unshortened cakes?
   a. Leavened
   b. Creamed
   c. Angel food
   d. Chiffon

3. The cream of tartar in angel food cakes has the following purposes:
   a. Leavening agent, strengthens egg-white foam, and acts as a preservative
   b. Strengthens egg-white foam, increases tenderness, and whitens color
   c. Increases tenderness, whitens color, and improves volume
   d. Leavening agent, increases tenderness, and firms egg-white foam

4. Which type of pan is used for baking bar cookies?
   a. Baking sheet
   b. Baking pan
   c. Skillet
   d. Sauce pan

5. Cake flour is not recommended for making most cookies because it contains _____, which reduces cookie spread.
   a. chlorine
   b. protein
   c. carbohydrate
   d. fat

6. Pastry chefs use three types of _____ frosting to fill their delicate pastries.
   a. flat
   b. decorating
   c. buttercream
   d. ganache

7. Cakes with a higher _____ content tend to retain their moisture and have longer shelf lives.
   a. butter
   b. sugar
   c. protein
   d. flour

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe the differences among shortened, unshortened, and chiffon cakes.
2. Which ingredients are used in a higher proportion in cakes than they are in breads? What characteristics does each of the ingredients, including cake flour, contribute to the prepared cake product?
3. What types of pans are best for cake preparation (i.e., smooth or rough, dull or shiny, metal or glass, light or heavy gauge)? How should the pans be prepared prior to pouring in the batter?
4. Describe the baking process for cakes, including the filling of the pan, the proper baking temperature and time, and how to test for doneness.
5. What adjustments must be made when preparing cakes at high altitude (over 3,000 feet)?
6. Which ingredients contribute to the tender texture of angel food cake? How do the ingredients and preparation methods for sponge cake differ from those for angel food cake?
7. How does the treatment of pans differ in the preparation of unshortened and shortened cakes?
8. What steps deter the staling of cakes and cookies?
9. How does the proportion of ingredients in cookies and cakes differ? How does this affect starch gelatinization and gluten formation?
10. What can cause the following problems in cakes: low volume, soggy crumb, and tunnel formation?

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24



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Pastries and Pies

Types of Pastry 471
Preparation of Pastry 474
Storage of Pastry 485

Pastry is essentially a type of bread product that is characteristically flaky, tender, crisp, and lightly browned. This delicate combination is not always easy to achieve. Unlike many other food preparations, pastries can be intimidating because they are made with precisely measured ingredients, in a time- and temperature-sensitive manner, and with an artistic touch. These labor-intensive pie shells and desserts are the true test of a food preparer's skill.

Lamination The arrangement of alternating layers of fat and flour in rolled pastry dough. During baking, the fat melts and leaves empty spaces for steam to lift the layers of flour, resulting in a flaky pastry.

Plain pastry Pastry made for producing piecrusts, quiches, and main-dish pies.

TYPES OF PASTRY

So many variations of pastries exist that there is no one standard way to classify them. Even the textures differ drastically among a few pastry examples such as piecrusts, apple turnover, strudel, and baklava. The major differences among pastries result from the type of fat (butter, lard, shortening, oil, etc.), the mixing method by which the fat is introduced to the flour, the major leavening source, the addition of sugar or salt, and the rolling, shaping, and/or baking techniques used.

Pastry Classification

This chapter focuses on the two main types of pastry, which are distinguished by whether the fat ingredient is (1) cut into the flour mixture (nonlaminated), or (2) repeatedly folded into the dough through **lamination**. Technically, all pastry is "laminated" or arranged in layers (and thus flaky) to some degree.

Nonlaminated Pastries

Nonlaminated or plain pastry dough products include piecrusts, tarts, tartlets, galettes, choux (pâte à choux), and brioche.

Plain Pastry

Plain pastry is also known as pie or shortcrust pastry and, as the name implies, is more compact and crumbly than light and flaky. Typically, chilled fat is cut into small pieces and cut into or rubbed into the flour, and a minimum of

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cold water is added to bring the dough together. The dough is then chilled to relax the gluten. Once chilled, it is rolled out with a minimum of strokes into a circular shape to fit into a pie pan. The pies baked with plain pastry are defined by their fillings, examples of which are listed in Table 24-1. Two varieties of plain pastry are hot-water crust pastry and short or sweet dough pastry.

Hot-Water Crust Pastry

This pie pastry serves as the base for potpies filled with meat, beans, and/or vegetables. The less flaky consistency of this pastry results because lard is melted in boiling water and poured into the flour to create a mixture that is then kneaded into a dough. The dough is then molded around the container that will be filled with meats and other ingredients before being baked.

Short or Sweet Dough Pastry

More sugar goes into this pastry dough to create a sweeter flavor and more crumbly crust. Tartlets and some crisp cookies (ginger snaps) are made with short or sweet dough.

Brioche Pastry

Brioche (bree-osh) pastries are made from a sweet yeast dough that is not laminated. It is commonly used to make airy buns and loafs (Figure 24-1).

Choux Pastry

The dough used to make choux pastries is called pâte à choux (paht-ah-shoo). Another name for the dough is choux paste because it is more like a thick paste than a dough. These pastries are often filled with cream; the most common examples are cream puffs, profiteroles (little cream puffs), and éclairs (Figure 24-1). A distinctive method is used to prepare this dough: 14 whole eggs are beaten into 1 pound of flour mixture that is then cooked until it forms a smooth paste. The thick fluid paste cannot be folded, so it is poured or piped onto baking sheets that are then placed in a hot oven. Unlike puff pastry that uses fat to "puff" up in volume, pâte à choux pastry relies on its high water content from the eggs to steam open the pastry into a round or oblong shape (steam leavened). The steam opens up the mounds of paste, creating a cream puff look that is similar to a cabbage head; in fact, pâte à choux is French for "cabbage paste" (6).

TABLE 24-1 Types of Pies

Dessert	Pies are baked in sloping pie pans. **Diameter:** 8 or 9 inches.	
Tart*	European cousins of the dessert pies. Tarts are open-faced pies baked in a short-sided, fluted-edged pan with a removable bottom. **Large tarts:** 9 or 10 inches. **Small tarts:** 3½–4 inches.	
Tartlet*	Single-serving versions of tarts. **Miniature tartlets:** 2–2½ inches. **Miniature barquettes:** 3 inches.	
Galette	Free-form pies made without pans. The dough is rolled out like a large cookie; the fruit fills the center, but a 2-inch border is left that is then pleated in folds over the fruit, which shows through the center.	
Main dish	Deep dishes are lined with pie dough to encapsulate hearty ingredients. The pie is served to accompany a meal or as an entire meal.	 Amy Brown

Possible Fillings

Dessert/Tart/Tartlet/Galette		Main Dish
Fruit	Vegetable	Fish
• Apple	• Pumpkin	Mincemeat
• Apricot	• Sweet potato	Potpies
• Blueberry	Cream	Potato
• Cherry	• Banana	Quiches
• Key lime	• Chocolate	Shepherd's
• Lemon	• Coconut	
• Peach	Custard	
• Plum	Chiffon	
• Raspberry	Ice cream	
• Rhubarb	Meringue	
• Strawberry	Pecan	

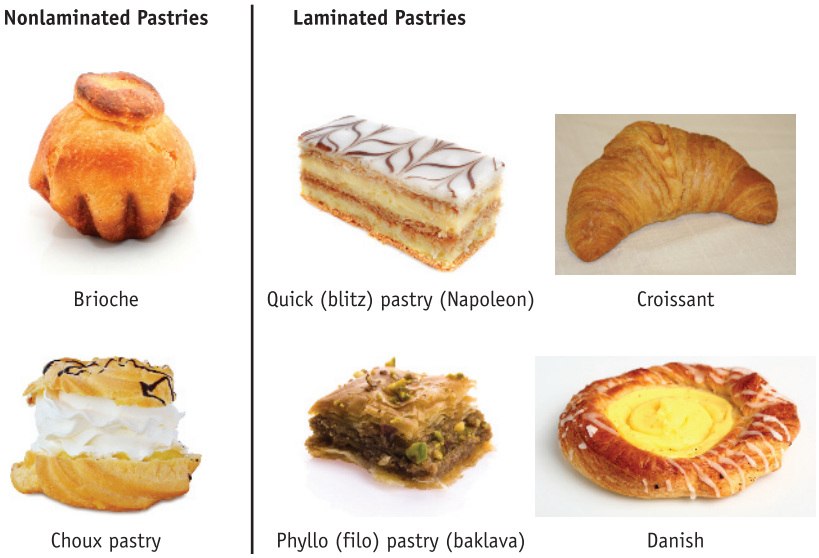
*Tarts and tartlets differ from pies in that they are freestanding on the plate.

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FIGURE 24-1 Types of pastry.



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The hollow (cleaned out) center is filled with a whipped cream or other type of filling and sometimes topped with powdered sugar or chocolate **glaze**.

Laminated Pastries

Laminated doughs are used to make puff, quick (blitz; strudel), phyllo (filo), croissant, and Danish pastries. Pastry produced through the process of lamination involves alternating layers of dough and butter that are rolled out, folded over, turned, and rolled out again repeatedly. Each time the dough is folded (a "turn"), the number of layers doubles, and these manipulations create many alternating layers of fat and dough (16), which make the pastry flakier with each added layer.

Puff Pastry

Puff pastry differs from piecrust in that its many layers cause it to "puff" or expand when baked. It is very light, airy, and flaky. The dough contains no yeast or chemical leaveners, yet can increase up to eight times its original size. This is equivalent to a one-fourth inch of pastry expanding to 2 inches. Puff pastry is leavened by the expansion of moisture and air in the oven's heat. Its unique flakiness is also achieved through extensive lamination. The necessity of folding many layers together makes puff pastry very time-consuming to produce. As a result, puff pastry can be purchased ready-made in the freezer section of some stores. Despite the time involved, puff pastry remains popular and is primarily found in desserts such as patty shells, tarts, and cream horns.

Patty shells are small, cup-shaped shells usually made from puff pastry that can be filled with creamed dishes of meat, poultry, fish, or vegetables. Their versatility allows them to be served as hors d'oeuvres, entrées, or desserts. If they are going to hold desserts such as ice cream, puddings, glazed fruit, and other sweet fillings, they are usually made from a sweet dough that will hold its shape better. Bakeries often sell fresh patty shells, while supermarkets sell the frozen, unbaked versions.

Quick (Blitz) Pastry

Quick, or blitz, pastry (*blitz* is German for "quick attack") is a type of puff pastry that is quicker and easier to prepare than the regular form. Although faster to make than the time-consuming puff pastry, it does not rise as high. Quick pastry combines the mixing technique of plain pastry with the rolling and folding technique of puff pastry. Examples of quick pastries are Napoleons and tart shells. Cream-filled pastries such as Napoleons are often referred to as French pastries (Figure 24-1). The word *strudel* refers to a Central European pastry believed to have originated in Austria. Strudel, a type of puff pastry, has an elastic nature that is derived from the flour's high gluten content, minimal fat content, and lack of sugar.

Phyllo (Filo) Pastry

The word *phyllo* (which can also be spelled filo or fillo; pronounced fee-low) means "leaf" in Greek and describes the characteristic tissue-thin sheets of dough that are made primarily with flour, water, and a small amount of oil. These numerous sheets of paper-thin pastry are each brushed with butter as they are stacked into layers that can then be rolled or folded into a variety of shapes. The Greeks and people from Middle Eastern cultures learned about preparing phyllo pastries from the Turks, who were in their region during the 400-year rule of the Ottoman Empire. As a result, similar phyllo pastries that are called by various names are served within the region and beyond. The type of filling dictates what a phyllo pastry product is called:

- **Baklava:** Honey and nuts (Figure 24-1)
- **Patatopita:** Potatoes
- **Spanakopita:** Spinach and feta cheese (*ispanakborek* in Turkey)
- **Tiropita:** Cheese (*peynir borek* in Turkey; *burekas* in Israel; *gibanica* in Serbia)

Croissant Pastry

This puff pastry obtains its flaky consistency from a laminated yeast dough. The pastry's classic crescent shape originates from a Turkish legend (Figure 24-1). One of several tales about the croissant's origin is that these pastries were invented by Europeans celebrating the defeat of the Ottomans, who often had a crescent on their flags.

Danish Pastry

The centers of this type of yeast-leavened puff pastry often contain sweet fillings such as jam, custard, or cream cheese, and the pastry is usually covered with sugary toppings (Figure 24-1).

Glaze A sugar-based icing poured over pies or pastries that hardens to provide flavor and structure. (*Note:* The word *glaze* has a second, much different meaning: a concentrated soup stock used for flavoring; see Chapter 18.)

Puff pastry A delicate pastry that puffs up in size during baking because of its many alternating layers of fat and flour.

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TABLE 24-2 Pastry Dough Formulas Compared to Bread Dough (Based on 1 Pound of Flour)

		Nonlaminated Doughs				Laminated Doughs			
	Basic Bread Dough	Pie Dough	Short Dough	Brioche Dough	Pâte à Choux	Quick Puff Pastry	Puff Pastry	Croissant Dough	Danish Dough
Flour	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)	1 lb (455 g)
Butter (Margarine in Danish)	2 oz (55 g)	10 oz (285 g)	14 oz (400 g)	5 oz (140 g)	6½ oz (185 g)	1 lb (455 g)	1 lb (455 g)	11½ oz (325 g)	17 oz (485 g)
Yeast	1 oz (30 g)	0	0	1 oz (37 g)	0	0	0	1¼ oz (30 g)	1½ oz (40 g)
Sugar	1 oz (30 g)	0	6 oz (170 g)	2½ oz (70 g)	0	0	0	7 tsp (35 g)	1½ oz (40 g)
Eggs	0	0	1	4	14	0	0	0	2
Water	0	3 oz (90 mL)	0	0	0	3⅓ C (800 mL)	3 oz (90 mL)	6½ oz (195 mL)	0
Milk	8 oz (240 mL)	0	0	1½ oz (45 mL)	0	0	0	9 oz (270 mL)	6½ oz (195 mL)
Salt	2¼ tsp (11.25 g)	2½ tsp (12.5 g)	0	2 tsp (10 g)	1¼ tsp (6.25 g)	2½ tsp (12.5 g)	2½ tsp (12.5 g)	2½ tsp (12.5 g)	⅔ tsp (3 g)
Other	0	3 oz (85 g) lard	1 tsp (5 mL) vanilla extract	0	0	0	1½ tsp (7.5 mL) lemon juice	Few drops lemon juice	⅔ tsp cardamom
Mixing/ production method	Dissolve the yeast in warm milk. Form the dough by combining the flour, sugar, and salt. Mix in the butter. Knead the dough before proofing, forming, and possibly proofing again.	Combine flour and salt. Add butter and lard into flour mixture by cutting them into marble-sized pieces. Add water and mix just until the dough holds together.	Mix for a few minutes at low speed: butter (softened), sugar, egg, and vanilla. Mix in flour, but just until incorporated.	Dissolve the yeast in warm milk. Add the sugar, eggs, and salt. Add the flour. Add the butter. Knead the dough before proofing in the refrigerator, shaped, and proofed again.	Boil a mixture of the water, butter, and salt. Stir in the flour and cook the roux for a few minutes. Cool slightly before adding the eggs.	Combine flour and salt. Cut butter into large pieces and add to flour mixture without thorough mixing. Add water just until dough holds together.	Form butter block by mixing together most of the butter, ⅓ of the flour, and lemon juice into a block. Form dough by mixing the remaining ingredients.	Form butter block by mixing together butter, some flour, and lemon juice. Form the dough by dissolving the yeast in milk and kneading in the remaining ingredients with the dough hook.	Form margarine block. Form the dough by dissolving the yeast in the cold milk and eggs and adding the remaining ingredients.

Examples of Danish pastries include cheese pockets, envelopes, pinwheels, and turnovers.

PREPARATION OF PASTRY

Pastries are the most delicate of all baked products, and their success depends on the right proportions of ingredients and the correct preparation technique. It takes skill to correctly distribute the fat and develop the gluten to the point of creating a crust that is flaky, tender, and crisp. Each type of pastry, especially the various types of puff pastries, has its own ingredient requirements and unique instructions for mixing, rolling, filling, and baking, but the general guidelines are discussed next.

Ingredients of Pastry

Most pastry flour mixtures contain at least four ingredients: flour, fat, liquid, and salt. Eggs and sugar, the latter sometimes added for its flavor and browning properties, are optional. Except for croissant, Danish, and brioche doughs, which make use of yeast, the leavening agents for most pastry doughs are steam and air. The type and quantity of each of these ingredients determine the final quality of the pastry product. Table 24-2, which compares the ingredients of these pastry doughs with those of bread dough, reveals that pie and pastry doughs contain more fat than other baked products. In fact, they include 50% as much fat as they do flour, by weight, and may contain as much as an equal amount of fat and flour. Compare this to bread doughs, which usually contain only about 12% fat. Although the basic ingredients of pastries do not vary much, a wide assortment may be prepared, partially because the flour mixtures can be handled so many different ways.

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TABLE 24-3 Tenderizers and Toughening in Flour Mixtures

Tenderizers	Toughening
Acid	Egg white or whole egg
Egg yolk	Flour
Fat	Milk
Sugar	Water

Among all the doughs listed in Table 24-2, short dough is most commonly used in the preparation of pastries (6). The term *short* describes the tenderness of the resulting baked product. Shortbread cookies are very tender and give way very easily when eaten. The tenderness of shortbread cookies is achieved by using a lot of sugar and shortening to interfere with gluten development.

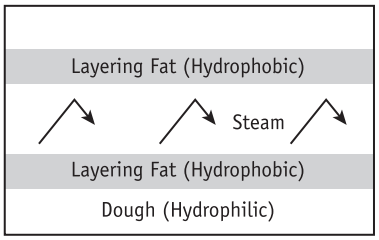
The ingredients in a flour mixture are either tenderizers or toughening (Table 24-3). Each of these ingredients is now discussed in more detail with regard to their ability to tenderize or toughen pastry.

Flour

Pastry quality depends heavily on the type and amount of flour used and how it is handled. The most popular are pastry flours and unbleached all-purpose flours. There is less protein in pastry flour, and professional bakers prefer it, but the easy availability of all-purpose flour makes it more popular with the general public. If all-purpose flour is used, however, the gluten formation increases, which may result in a tougher pastry, so additional fat is sometimes necessary to increase tenderness. Cake flour, which is even lower in protein than pastry flour, is sometimes used.

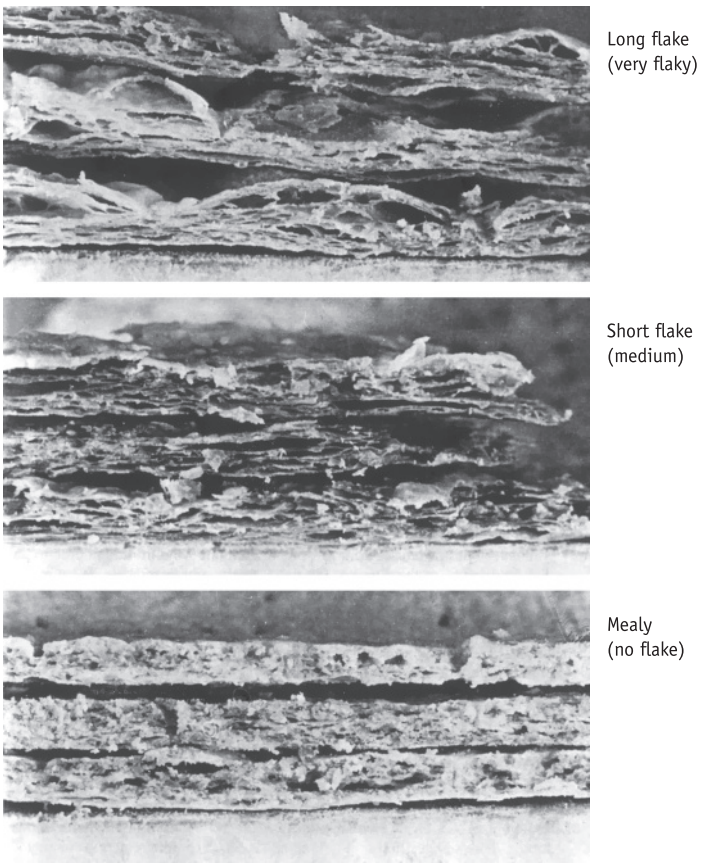
Too much of any type of flour will toughen pastry because one of the major influences on tenderness is the concentration and distribution of gluten. Excess gluten formation toughens pastry. The flakiness of pastry is attributed in part to its limited gluten formation achieved by using a very small amount of chilled water, coating the flour with fat, and chilling the dough briefly before handling. Other techniques that can contribute to tenderness include adding acid in the form of unflavored vinegar, lemon juice, yogurt, or sour cream to break apart the long gluten strands; handling the dough minimally (the warmth of the hands can melt the fat); and using as little water as possible because it facilitates gluten formation (13).

FIGURE 24-2 The role of fat in producing flaky pastry.



- Water in the dough turns to steam upon baking.
- The layering fat creates an impervious layer.
- The steam stays inside each dough layer, forcing it to expand because of the pressure it develops underneath each impervious fat layer.
- Fat melts and is absorbed by the dough, improving the eating properties of the pastry.

FIGURE 24-3 Pastry flakiness.



Fat

The proportion of fat is probably the most important determinant of quality in pastry, especially in creating flakiness. Large amounts of fat are required to produce a flaky crust (Figure 24-2), with the proportion varying depending on the type of pastry. The specific factors influencing flakiness and tenderness are discussed next.

Flakiness

Fat—the size of its particles, its firmness, and how evenly it is spread—is the major contributor to flakiness. In the baking industry, flake consistency is described as long flake (very flaky), short flake (medium flaky), or **mealy** crust (no flake) (Figure 24-3). Flake size is controlled by fat particle size. When fat is cut in small, cold pieces that are incorporated into the dough without being creamed or absorbed by the flour, the fat will then melt during baking, leaving empty spaces where steam may collect to leaven and lift the layers of dough. These "pockets" vacated by

Mealy Refers to a pastry with a grainy or less flaky texture, created by coating all of the flour with fat.

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FIGURE 24-4 The type of fat influences pastry flakiness.



Tender pastry results when fat (such as oil) mixes thoroughly with the flour.



Flaky pastry is achieved when cold fat (such as butter) is cut into pea-size balls and lightly combined with the flour.

Amy C. Brown

fat create the characteristic flakiness of pastry. The more pockets there are in the pastry (sometimes created by many layers), the more flaky the pastry will be.

To maximize flakiness, keep everything cold—fat, flour, water, countertop (a cold marble pastry board is an ideal surface), and hands (use fingertips and minimize contact). Sometimes the dough is placed in the refrigerator between rollings. The process starts with cold fat that is cut into chilled flour to form a fat/flour mixture. Keeping the fat cold increases the flakiness of pastry in two ways: (1) less fat is absorbed by the flour, and (2) more pea-size balls of fat are dispersed and surrounded with flour to become pockets of air during baking. The fat is added to the flour before any liquid to protect the flour and its proteins from water, which would increase the formation of gluten (14).

The type of fat used in making the pastry also affects flakiness (see Chapter 22 for descriptions of the various fats). Firmer, plastic, 100% fats such as hydrogenated shortenings and lard produce the flakiest pastries, although lard is being used less often because of its tendency to go rancid and its high saturated fat content. Shortening is softer and more pliable than cold butter, so it coats the flour more easily and can be rolled out even when refrigerated. Butter and margarine may be used in pastry making, but their water content causes increased gluten formation. Butters vary in water content, with the highest-quality butters having the lowest water content, making them the number one choice for the finest pastries. Because of butter's desirable flavor, it is often selected to prepare pastries. Unlike dough containing margarine, however, butter-containing dough tends to harden when refrigerated and requires more effort to roll out (17). The food industry has combined the positive aspects of both butter and hydrogenated shortenings by producing a butter-flavored hydrogenated shortening. Oil is the least desirable fat for making flaky pastry because it coats each flour particle, resulting in an extremely tender but mealy (grainy) texture (Figure 24-4) (9).

Tenderness

Tenderness differs from flakiness, and, in fact, factors that contribute to one may detract from the other (Table 24-4). Tenderness is described as the ease with which pastry gives way to the tooth. Fat, a major ingredient in pastry production, increases tenderness by inhibiting gluten development. This occurs when fat coats the flour. To achieve maximum tenderness in pastry, the fat must be thoroughly combined with the flour. For most pastries, including piecrusts, the ideal is a combination of tenderness and flakiness achieved by having some fat absorbed by the flour and leaving some fat in pea-size pieces to melt and let off steam during baking. Tough, dry, or flat-flavored pastry may result from excess gluten formation caused by not cutting enough fat into the flour; by using more flour than necessary, especially during rolling; by adding too much water; or by excessive manipulation of the dough. It is also important to work quickly: the greater the amount of time allowed between adding water to the dough and baking the pastry, the less tender the pastry will be because the gluten will have more opportunity to be hydrated by the water (17).

On the other hand, too little gluten development results in a pastry that is too tender and crumbly. This occurs when fat is cut into pieces that are too small; when oil, rather than shortening, is used as the fat; when too little water is added; or when the dough is undermanipulated. It may also happen when conditions are too warm during handling, causing fat to melt and coat the flour, inhibiting gluten development. When using butter, the goal is to work quickly and to put the bowl back in the freezer for about 5 minutes whenever the butter starts to soften (18).

Liquid

The liquid (usually water or milk) component of pastry dough is important for leavening, hydration, and the crispiness of the crust. Pastry is leavened by steam, so liquid is necessary for that purpose. Liquid is also needed to hydrate the proteins, so gluten can develop, and to dissolve the salt. The pastry structure is set primarily by the coagulation of flour proteins during baking. As little liquid as possible should be added when

TABLE 24-4 Making a Tender, Flaky Pastry

To Make Tender Pastry	Why
Blend soft fat into the flour before adding any liquid.	Fat coats the proteins and prevents them from forming gluten.
Instead of water, use an ingredient that is part fat, such as sour cream, cream, or egg yolks.	Gluten can't form without water, and the additional fat contributes to tenderness.
Add acid to the dough in the form of lemon juice, vinegar, or sour cream.	Acid breaks long gluten strands.
To Make Flaky Pastry	**Why**
Keep the fat cold and in large, pea-size pieces.	Large, cold pieces will remain firm in the oven long enough to create flakes.
Flatten large pieces of cold fat.	Chunky pieces will make holes in the crust rather than act as spacers.

Source: Corriher S. The secrets of tender, flaky piecrust. *Fine Cooking* 17:78–79, 1996.

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CALORIE CONTROL
Pastries and Pies

Pastries contain more fat than cakes, so they are usually higher in kcalories as well.

- **Limit number of portions.** Avoid seconds. An **average slice of pie** (⅙ of an 8-inch pie) provides **300 kcalories** (without whipped cream or ice cream) and about **14 grams of fat** (Table 24-5). Two slices double that amount to provide 600 kcalories. Be aware that just half a pie (three slices) holds 900 kcalories. It would take only two slices to equal the same amount of kcalories if the 8-inch pie was cut into four larger slices.
- **Control portion sizes.** Cut a normal **pie slice in half** to reduce the **kcalories to 150.**

TABLE 24-5 Kilocalories and Fat in Pies* and Pastries (kcalories/fat grams)

<200 Kilocalories	200–300 Kilocalories	300 + Kilocalories
Fruit turnover (83/4)	Toaster pastry (204/5)	Lemon meringue pie (303/10)
Coconut cream (143/8)†	Cream puff, 3 1/2 × 2 inches (238/17)	Cherry pie (304/13)
Fruit strudel (195/8)	Chocolate mousse pie (247/15)‡	Banana cream pie (387/16)‡
	Apple fritters, 2 (260/11)	Chocolate cream pie (344/22)
	Eclair, 5 × 2 × ¾ inch (262/16)	Pecan pie (503/22)‡
	Coconut custard pie (270/14)	
	Blueberry pie (271/12)	
	Apple pie (277/13)	

*1/6 of 8-inch pie unless otherwise specified. †1/8 of 7-inch pie. ‡1/8 of 9-inch pie.

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making pastry because too much water will cause shrinkage and a tougher crust from excess gluten development (10). The effect on gluten formation means that liquids tend to make pie and pastries tougher; however, too little water results in a crumbly crust.

More liquid may be needed at higher altitudes, where water evaporates more quickly. Vinegar or lemon juice may be added to the cold liquid because acid helps to inhibit gluten formation, contributing to more tender pies and pastries (14).

How & Why?

Why is pastry so crisp?

A crisp crust is created, in part, by water evaporation. In addition, the very little water that is used in pastry preparation inhibits starch gelatinization, which would make the pastry less crisp (12). Other factors influencing crispness are baking time and temperature, thickness of the rolled dough, whether the rolled dough is baked immediately or refrigerated or frozen first, and the moisture content of pie fillings.

Eggs

Egg yolks are high in fat, so they tend to tenderize pastries. On the other hand, whole eggs or their whites will make pastries tougher by acting as binders or by adding more liquid, so they should be used in moderation. Eggs also add color, flavor, and richness to pastry dough. Sometimes the egg yolk alone is used because the water and protein contents of the white contribute to toughness. Egg yolk can also be mixed with a minute amount of water and then brushed over the pastry to produce a golden crust.

Salt

In pastry, the only function of salt is to add flavor. It can be omitted, but the crust will lack flavor. Sometimes sugar is added for the same reason, and it has the additional benefit of browning the crust.

Sugar

Sugar sweetens the pie or pastry flour mixture, but it is not always added. If added, it acts as a tenderizer by competing with the flour for water, which prevents gluten formation.

Flavorings

Several different flavorings give pies and pastries their unique tastes that are sometimes difficult to duplicate. Some examples include alcohol, essences, extracts, and flavored oils. The use of vanilla extract is well known, but extracts of lemon, orange, pineapple, and other fruits can also be added. Flavored oils extracted from some of these same fruits and others, such as coconut-flavored oil for making coconut cream pie, are also available.

Alcohol

The flavors of many foods are improved through the addition of wine, liqueurs, and spirits (see Chapter 27 on beverages). Liqueurs, that is, alcohols sweetened with sugar, are especially flavorful. A common example of an alcohol-based flavoring is amaretto, an almond-flavored liqueur used in the manufacture of macaroons.

Essences

A few drops of these aromatic flavors distilled from fruits, spices, and other plants are enough to change a food's flavor profile.

Extracts

Extracts are basically essences that have been diluted in alcohol because the latter acts as a preservative. Common extracts include almond, peppermint, and vanilla. Using some of these extracts to flavor alcohol results in schnapps, a general term used to describe a flavored alcoholic beverage. Schnapps can then be used to flavor foods or drinks.

Flavored Oils

Essences diluted in oils include those obtained from various fruits (apple, cherry, grapefruit, lemon, lime, orange, tangerine, etc.). They are more potent in their flavor than extracts that are alcohol-based. Nuts can also have their flavors removed by cold-pressing. However, heat will destroy the flavor of nut oils, so it is best to use them in cold dishes or after heating is complete.

Thickeners (for Fillings)

Pies get their dense or viscous quality from thickeners. These thickeners are often starch-based, but nonstarch-based thickeners include egg yolks, cream, gums or other fibers, and gelatin. Starch-based thickeners are discussed in Chapter 18 on starches and sauces because they are also used to thicken soups, stews, sauces, puddings, and

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gravies. The appropriate uses of several common starches used to thicken pies—arrowroot, cornstarch, ClearJel®, and tapioca—are described here.

Arrowroot

The low boiling point of this high-gloss starch makes it undesirable for fruit fillings because it will thicken before the fruit boils.

Cornstarch

This common low-gloss thickener made from corn is used to thicken fruit fillings as long as they are not acidic. Low-pH ingredients interfere with the ability of cornstarch to gel. As a result, lemon, lime, or similar acidic foods are not added to pie filling until after it has completed cooking. Another drawback to using cornstarch is that it might leave a "starchy-tasting" residue.

ClearJel®

Commercial bakers frequently use this modified cornstarch to thicken fruit pie fillings. This chemically altered cornstarch is superior to regular cornstarch because it resists breakdown from acidic ingredients such as citrus fruits, is stable to high temperatures, and reduces the tendency of pie fillings to "weep" during storage.

Tapioca

Two types of high-gloss tapioca are available to thicken pies and pastry ingredients—quick-cooking (pearl) and powder. The quick-cooking tapioca, which can also be ground into a powder, is usually used in two-crust pies because it does not always completely dissolve and looks like little "eyes." Tapioca powder is a flavorless thickener that holds fruit fillings together.

Adding Thickeners

The preceding starches thicken only when heated. The process is begun by slowly stirring cold liquid into the fine white starch powder (about 2 tablespoons for a pie) until the two are thoroughly mixed into a paste. The paste is combined with sugar and then either (1) combined with the fruit, where it will be heated in the pie or pastry during baking, or (2) whisked into a hot liquid and heated to gelatinize the starch. The heating time in hot liquid should not exceed 1 minute, or the starch granules will rupture. As a result, the starch will lose its thickening power and may even become thin again. It may also lump, as it would if the hot liquid were added to the starch.

Mixing Methods

One of the main differences among pastry doughs is how the fat is introduced into the flour mixture. Plain or pie pastry relies on the incorporation of pea-size balls of fat into the flour, whereas puff and other types of flaky pastry depend on the process of lamination, in which numerous folds and turns create layers of fat within the dough. Potpie flour mixtures are based on melted fat being worked into the flour.

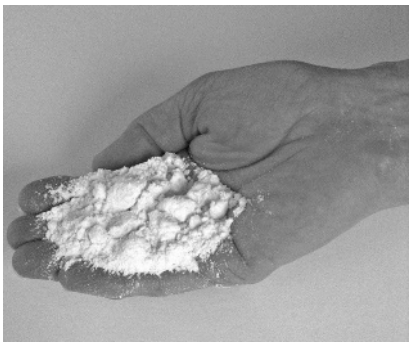
Plain (Pie) Pastry

The classic pastry method is used to mix the ingredients of plain pastry. Flour and salt are first sifted together and then chilled. Cold fat is cut into the chilled flour and salt mixture using a pastry blender or forks, or by crisscrossing two knives together until the particles of the mixture are reduced to the size of peas (Figure 24-5), and no large chunks of butter remain (2). This can also be achieved in a food processor. The loose mixture is then bound together using as little water and manipulation as possible. Cold or ice water is sprinkled evenly, 1 tablespoon at a time, over the flour. A spray bottle of chilled water achieves the same results. After each addition, the mixture is tossed lightly with a fork or pastry blender until the flour is just moistened (Figure 24-6). Only just enough water to moisten all the flour and make the particles hold together is used. Overmixing or adding water beyond the "just moistened" stage results in a tough pastry. When the dough no longer clings to the side of the bowl, it is pressed lightly into a flat disk, wrapped in waxed paper or plastic wrap, and refrigerated for about 15 minutes (overnight is best, but time-consuming) to chill the fat. It is then ready for rolling. Avoid overworking the dough during mixing or rolling because it elongates the gluten strands, creating a chewy pastry instead of one that crumbles lightly.

Puff Pastry

In the preparation of puff pastry, two components—a fat component (or butter block) and a flour mixture (dough)—are mixed separately, chilled, and then combined together in the lamination (rolling) process. The butter block consists of fat, flour, salt, and perhaps an acid, which are mixed together by hand and shaped into a ¼-inch thick, 12-inch-square block. The dough is made from flour, salt, water, and often a little fat. Puff pastry usually contains both cake and all-purpose flours because its dough is manipulated more than that of plain pastry, and the inclusion of cake flour lessens the likelihood that excessive gluten will form.

FIGURE 24-5 Fat cut into pieces of the correct size.



Fat is too lumpy.



Fat is just right.



Fat is too fine.

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FIGURE 24-6 Mixing pastry ingredients.



1. The flour and salt are mixed together with a pastry blender, and the fat is cut into the size of tiny peas.



2. Water is sprinkled into the flour, a tablespoon at a time. A fork is used to mix it with the flour until all the flour is moistened.



3. The dough is mixed just until the sides of the bowl are clean, indicating a correct amount of gluten development.

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The flours are sifted together, and chunks of butter, if used, are cut into the flour with the fingertips until the mixture forms particles the size of coarse crumbs. An electric mixer might be used as an alternative to hand mixing. The mixture is formed into a mound with a well in the center into which the water and salt are poured. The flour or flour–fat combination is integrated into the water with both hands, and more water is added, if needed, to make a dough that is sticky but manageable. Both the butter block and the dough are refrigerated for 30 minutes. Refrigeration keeps the fat firm and prevents it from being absorbed by the flour. After refrigeration, the dough and the butter block are ready to be folded and rolled together.

Cream Puffs and Éclairs

A variant of this method is used for pâte à choux pastry dough. This flour mixture, used to prepare cream puffs and éclairs, may be referred to as a paste rather than a dough. It has the highest proportion of liquid of any of the pastry doughs, which contributes to the very light weight of the resulting pastries. The large air cell that forms, leaving a hollow middle, results from steam leavening during baking.

The liquid, usually water, is combined with the fat and salt in a saucepan and heated to boiling (Figure 24-7).

FIGURE 24-7 Preparing a pâte à choux.

1. Pâte à choux in progress



2. Add eggs one at a time





3. Mixing the dough



4. Piping the dough

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As the mixture boils, the flour is added (often all at once) and constantly stirred to keep lumps from forming. The paste is then cooked and stirred for about 3 minutes until it is sufficiently dried out to pull away from the sides of the pan. The paste is then transferred to a bowl, where it must be allowed to cool only slightly before eggs are added, one or two at a time. When the dough is glossy and soft enough, it is placed in a pastry bag, which is used to extrude it onto the baking sheet into small rounds for cream puffs or long, narrow shapes for éclairs. During baking, pâte à choux expands in such a way as to leave a hollow center. This will be filled with whipped cream for cream puffs or cream filling for éclairs. The top is covered with a chocolate syrup. Specific problems in preparing pâte à choux pastry and their causes are listed in Table 24-6.

Rolling

Both plain and puff pastry dough must be rolled, with minimum hand contact, in order to spread the fat and gluten in fine sheets layered on top of each other in the lamination process. Overmanipulating the dough by rolling it too much, too hard, or too often will decrease the flakiness, tenderness, and crispness of the pastry.

Chilling the Dough

The first step in rolling pastry dough is to let the dough chill in the refrigerator for a set amount of time (minutes, hours, or days) to make it easier to handle and to keep the fat from melting

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TABLE 24-6 Choux Pastry Problems and Their Causes

Problem	Cause
Volume of the pastries is too small.	Insufficient roux formation; starch insufficiently gelatinized; batter too firm, not enough eggs added.
Contours of the pastries are diluted; they expand too much laterally.	Batter too soft, eggs added too quickly, or too many eggs added.
Small volume, thick crust, dense cells.	Lack of steam during baking.

into the flour. Properly wrapped dough can be refrigerated up to 4 days or be frozen for up to 6 months (13). Chilling the dough in the refrigerator allows the flour more time to rehydrate and gives the gluten strands an opportunity to relax so that during baking they can expand at the same rate as the gases. Gluten is like a rubber band in that it wants to snap back after being rolled or stretched out, so refrigeration relaxes the dough and makes it easier to manipulate. After it is taken out of the refrigerator, the cooled dough is allowed to sit at room temperature until it is malleable enough to roll.

Rolling Surface

A cold surface is best for rolling out the dough, which is why marble rolling boards are often used. Any other surface can be cooled by placing an ice water–filled roasting pan on it for a few minutes and then drying it well (13). Dough tends to stick if the surface or fat ingredients are not cold enough. Too much liquid also causes a sticky dough. Some of the surface moisture on a dough is eliminated by sprinkling the rolling surface lightly with flour. Another option is to rub a minimal amount of flour into a pastry cloth covering a cutting board. The rolling pin can also be covered in cloth and/or lightly floured to prevent sticking, but the amount of added flour should be kept to a minimum.

General Technique

Next, the dough is placed on the rolling surface and flattened slightly on top with a hand or the rolling pin to provide a starting point. Short strokes are made with the rolling pin from the center outward in a circle until the dough is flattened to ⅛ inch thick. Less pressure is used at the end of each roll to avoid excessive thinning of the edges. Lifting the edge of the dough intermittently and dusting the surface with flour as needed will help prevent sticking. It is best to roll as lightly and as little as possible and to avoid rolling repeatedly in one area to obtain the desired thickness. This will toughen and shrink the pastry by creating too much gluten.

Rolling the pastry too thin will make it too weak to hold fillings and may cause it to become too brown or to burn during baking. Pastry dough rolled too thick and used as a top crust may form a raised dome when baked.

Rolling Plain Pastry

For plain pastry, the dough is rolled out in a circle 1 to 2 inches larger than the bottom of the pan. The wider diameter allows sufficient dough to cover the sides of the pie pan. Roll the dough one crust at a time. After the dough is rolled, the simplest way to transfer it to the pan is to fold it in half and then in quarters to form a wedge shape (Figure 24-8). Rolling the dough on wax paper is an option that makes it easier to pick up because only the edges of the wax paper need be lifted to accomplish the folding. The wedge is placed in the pie pan with the point in the center and the outside edge on the pan rim and then unfolded so it covers the bottom and sides of the pan. The dough circle should be large enough to cover the pan without stretching because stretching dough at this stage may cause it to shrink back during baking. The dough is then pressed gently to eliminate any air bubbles and squeezed together to patch up any tears or holes. Bottom crusts to be baked empty and filled later must be pricked with a fork so air can escape. Bottom crusts are not pricked if the filling is to be cooked in them because pricking allows the filling to leak out.

The top crust is placed over the filling using the wedge procedure, or by lifting the wax paper and dough together, gently turning it over onto the filling, and slowly peeling off the wax paper. Top crusts are usually pricked with a fork, slashed with a thin knife, or opened with picturesque designs to create vents that allow the steam to escape during baking (Figure 24-9). This prevents the contents from boiling over. A decorative open latticework crust can also be made by cutting strips of rolled dough and arranging them on top of the filling. Another option, especially with one-crust apple pies, is to sprinkle the filling with a **streusel topping**. Adding a crimped edge gives pies a finished look and helps to seal top and bottom crusts together in a two-crust pie. The crust edges can be pinched together with fingers, a utensil handle, or the prongs of a fork to make various designs (Figure 24-10).

FIGURE 24-8 Transferring a rolled piecrust to a pie pan.



Method 1: Fold the rolled-out circular pie dough in half and in half again for easy transfer; unfold in pie plate.



Method 2: Roll the pie dough onto the rolling pin, place on edge of pie plate, and gently unroll.

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Streusel topping A crunchy, flavorful topping that can be strewn over the top of pies; it is made by combining flour, butter or margarine, brown sugar, and possibly spices (cinnamon) and chopped nuts (pecans, walnuts, or almonds).

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FIGURE 24-9 There are many artistic ways of venting a pie's top crust; this allows steam to escape so the contents don't boil over.



1. True Woven Lattice



2. Direct cut



3. Free form

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How & Why?

How do you avoid a soggy bottom crust?

To avoid a soggy bottom crust, it is important to fully thicken the filling before pouring it into the pie shell. Another method is to prebake the bottom crust on the lower shelf of an oven set at 450°F (232°C) for at least 3 minutes, and then move it to the center shelf to bake at 350°F (177°C) for the remaining three quarters of an hour or until the filling is ready. The baked pastry is then chilled before lightly coating the bottom crust with cold fat and adding the filling. Another method to prevent a soggy crust is to prepare a mealy crust, which is more resistant to fluid absorption than a flaky crust. Using vegetable oil, completely melting the fat, or cutting up the fat to resemble cornmeal results in a mealy pastry.

Alternative Piecrusts

Flour is not the only ingredient that can be used to create piecrusts. Other options, not strictly considered pastry, include crushed graham crackers, cereal flakes, granola, and cookies. Crisp cookies make a crust with the best texture, and a food processor can easily pulverize the cookies (5). All can be made into a cohesive mass by mixing them with a little fat and sugar. This type of crumb crust is then shaped by laying plastic wrap over the cookie crumbs (to prevent sticking to hands) before pressing them against the sides of the pie pan. It is then baked or left unbaked, depending on what the individual recipe indicates.

Rolling Puff Pastry

Production of puff pastry, which is higher in volume and fat than other pastries, relies on first folding the fat block and dough together before rolling. Repeated folding creates numerous layers of alternating fat and dough. If the fat does not stay as a separate layer, the pastry will have fewer layers and a gummy texture (6). These numerous folds contribute to the puffing up that occurs when the steam generated during baking forces the layers apart.

Laminating Puff Pastry Dough

To begin, the chilled dough is rolled into a ¼-inch-thick rectangle. The chilled fat, which is in a block two-thirds the size of the dough rectangle, is placed on top of the dough. Then the dough and the butter are folded together (Figure 24-11). The package of dough is then turned 90 degrees so that the fold is running vertically and rolled out to its original size. The fat must be at the right temperature; if too warm, it will flow into the dough, and if too cold, it will damage the dough. If butter is used, it can be partially softened by pounding it with a rolling pin to make it malleable while still cool. The folded, layered dough is then chilled, folded, and rolled again. The process is repeated two or more times before it is ready to be cut. Figure 24-12 shows the results of insufficient or excessive folding of puff pastry dough. Cutting must be done with a sharp knife, or the layers will press together, drastically decreasing the volume achieved during baking.

FIGURE 24-10 Decorative pie crust edges.



Plain fork



Herringbone



Flutes

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The several extra layers of fat in puff pastry dough make its resulting baked products extremely tender, rich, flaky, delicious, and, of course, high in kcalories.

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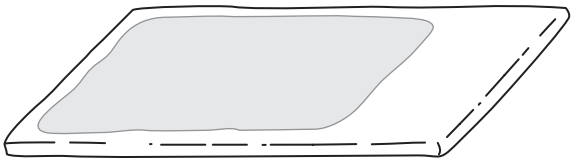
FIGURE 24-11 Rolling puff pastry.



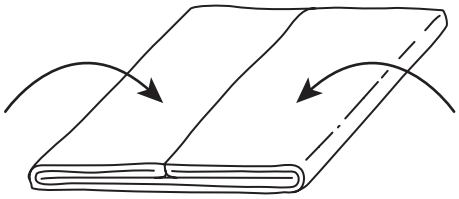
1. ROLL THE CHILLED DOUGH into a rectangle ½" thick and three times as long as it is wide.



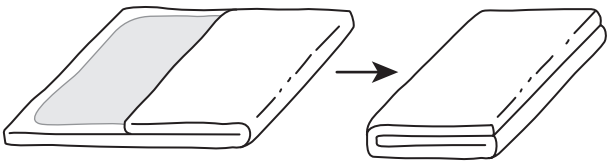
5. SECOND ROLL OF DOUGH. Repeat step 1 without pressing down excessively because it will join the layers, preventing the pastry from rising.



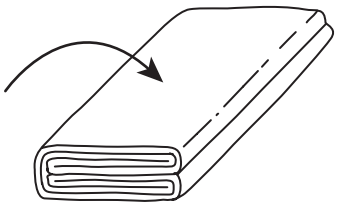
2. SPREAD THE CHILLED BUTTER ⅔ over the dough but leave 1-inch margins.



6. FOLD right and left sides so edges touch in the middle.



3. FOLD right and left sides over center.



7. DOUBLE FOLD. Fold one side over the other.



4. TURN dough. This readies it for rolling the gluten out in the next step.

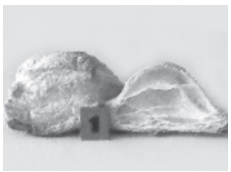


8. FINISHED. This is what a well-laminated dough with a double fold looks like.

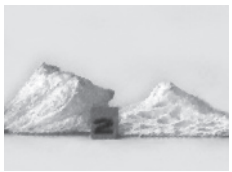
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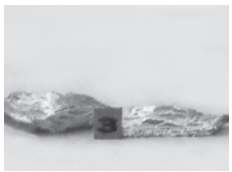
FIGURE 24-12 Puff pastry that was insufficiently or excessively folded.



Insufficient folding



Optimal folding



Excessive folding

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Frozen Rolled Phyllo Dough

Phyllo dough that has already been rolled is available in the frozen-food section at supermarkets. It is sold as thin sheets, approximately 12 inches wide and 16 to 20 inches long, that are rolled and packaged into long, thin cardboard boxes. Defrosting the phyllo dough slowly results in the best pastry texture. The dough should be allowed to defrost in the refrigerator for about 12 hours and for an additional hour at room temperature so that the sheets separate more easily. Phyllo dough, which contains no eggs and is extremely thin, should be protected from drying out by covering it with a layer of plastic wrap and then a clean, moist towel (11). The phyllo dough can be brushed with melted butter to keep it supple, and then cut and rolled or shaped into

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FIGURE 24-13 Handling phyllo dough.



1. Cover phyllo dough so it won't dry out. Work with one sheet at a time; cover the rest with plastic and a moistened kitchen towel.



2. To keep the dough supple, brush it with melted butter. Begin by buttering the edges, which dry out faster, and then work toward the center.



3. Use a sharp knife or scissors to cut the dough to size. Buttering and layering the sheets before cutting is faster and keeps the phyllo more pliable.



4. Versatile phyllo dough can be made into many shapes and will hold sweet or savory fillings. Shown here: apple strudel.

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the desired pastry (Figure 24-13). Brushing each phyllo dough sheet with a thin layer of fat keeps it supple; too much, however, will weaken the dough, whereas too little will result in a thick, heavy pastry (15). Tearing of the delicate sheets is not uncommon during handling; this can be remedied by covering the rip with another sheet of phyllo dough. Phyllo dough that is ripping excessively may have already been accidentally defrosted at the supermarket or have dried out with age. Neither problem can be detected by looking at the frozen phyllo dough, so it is best to purchase it at a store with a high turnover rate, such as a market specializing in Middle Eastern foods.

Fillings

The list of possible pie and pastry fillings runs the gamut from fruits to nuts (Table 24-1). Main-dish pie options include quiches with egg, vegetable, and meat fillings. Then there are desserts such as fruit pies, cream pies, ice cream pies, custard pies, chiffon pies, and meringue pies. There are one-crust versions of pies known as tarts, and smaller versions, called "tartlets," that are produced as individual servings (Table 24-1). There is a pie to fit almost any occasion.

Fruit Fillings

Successful fruit pie fillings depend on the proper combination of fruit, fruit juice, sweetener, and starch thickener. Gelatin is sometimes used to glaze fruit pies or tarts that are not to be baked. Fruit for pies can be fresh, frozen, cooked, canned, or even dehydrated if it is soaked and simmered before being used. Sugar is usually added, but too much will draw water out of the fruit, causing it to become shriveled and tough. The usual thickening agent is cornstarch or tapioca, but modified starches such as waxy maize create a clear gel and are best for fruit pies. Flour is not recommended because it has a tendency to cloud the filling.

There are three methods of preparing fruit pies:

- The old-fashioned method
- The cooked-juice method
- The cooked-fruit method

Old-Fashioned Method

In the old-fashioned method, the sweetener, spices, and starch thickener are mixed together and then combined with the fruit. This filling is then placed in the unbaked pie shell. Thin slices of butter are sometimes strewn across the top of the filling before it is covered with a top piecrust and baked.

Cooked-Juice Method

The cooked-juice method allows the uncooked fruit to retain more of its shape, flavor, and texture. Most frozen or canned fruit pies and berry pies can be prepared by this method. The juice is drained from the fruit, and water is added if needed. The liquid is brought to a boil, and a mixture of starch dissolved in cold water is stirred into the boiling liquid, followed by the sweetener and spices. When the mixture is thick and clear, it is cooled slightly and poured over fruit that has been previously arranged in a prebaked crust. The pie is then refrigerated.

Cooked-Fruit Method

If not enough juice is available from the selected fruit, the other option is the cooked-fruit method. This method is the same as the cooked-juice method except the fruit is added to the thickened juice and the mixture brought back to a boil. The results are poured directly into a prebaked pie shell. No further baking is required unless it is a two-crust pie.

Cream Fillings

Cream pie fillings are made by heating a mixture of milk, sugar, flavoring, cornstarch, and often egg until the starch gelatinizes, and then pouring this mixture into a one-crust prebaked pie shell. (The principles of starch gelatinization are covered in Chapter 18.) Whole, low-fat, or nonfat milk, light or heavy cream, or evaporated milk may be used. Cream pies such as chocolate, banana, or coconut are often topped with a whipped topping or meringue.

Custard Fillings

Custard pies are one-crust pies made with a milk and egg filling; examples include pumpkin and coconut pies.

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Cheesecake, in spite of its name, is really a custard pie because it relies on the coagulation of eggs for structure. The custard pie mixture is thickened by the eggs; an average custard pie contains 2 eggs per 1 cup of milk. During baking, the egg proteins coagulate and set the filling. Because the egg-based custard filling coagulates much more quickly than the crust can bake, the two are often baked separately, with the cooled filling being placed in the cooled shell right before serving. Another method is to start the custard pie on the bottom rack of a 425 to 450°F (218 to 232°C) oven for the first 10 minutes. Then, after the crust sets, to ensure that it will be crisp, the oven temperature is lowered to 325 to 350°F (163 to 177°C), where it remains for the rest of the time, usually about 25 to 40 minutes.

Chiffon Pies

The use of gelatin in their preparation distinguishes chiffon from other types of pies. The foam structure of chiffon pies imparts a light, fluffy texture. Egg whites or whipped cream is often an ingredient in these delicate pies. Only the shell is baked, so nondairy whipped toppings or rehydrated dried egg-white powder whipped into a foam can serve as substitutes for raw whipped egg whites to eliminate the risk of *Salmonella* contamination sometimes posed by raw eggs.

Meringue Pies

Meringue pies are simply cream or chiffon pies covered with soft meringue (see Chapter 12). The meringue should be spread to cover all parts of the crust edge so it will not shrink back during baking. The meringue is swirled on top and quickly browned in the oven. For serving, an easy way to cut through the meringue topping is to butter or oil the knife blade.

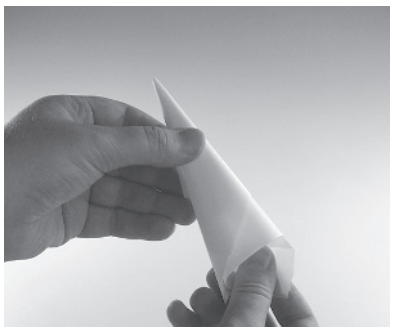
Pastry Fillings

Possible fillings for pastries include custards, creams, Bavarian creams, mousses, jams, fresh or cooked fruits, chocolate, and even cheese, cooked poultry, fish, or ham. The preparations of these fillings are discussed in the respective chapters devoted to their food type. Cones and pastry bags are frequently used to fill pastries; they are usually made from canvas, paper, plastic, nylon, or some other material (Figure 24-14). The plastic or metal piping tips allow the filling or topping used in or on the pastry to be piped into unique shapes (leaves, stars, plain lines, dots) of different sizes.

FIGURE 24-14 Parchment cones and pastry bags.



1. Parchment bag: Making a pivot point



2. Parchment bag: Rolling into funnel shape



3. Cloth bag with tips



4. Cloth bag: Hand position for piping

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Toppings

Pie fillings can be crowned by a wide variety of toppings that contribute additional textures and flavors. A two-crust pie has another crust to cover its filling, whereas a single-crust pie may be served plain (nothing added) or topped with whipped cream, meringue, glaze, or a crumb topping. The simplest decoration is sprinkled sugar (large crystals such as turbinado sugar) over a piecrust lightly brushed with a beaten egg white (8). The more complicated toppings, whipped cream and meringues, are discussed in Chapter 10 (on milk) and Chapter 12 (on eggs), respectively. Glazes and crumb toppings are briefly discussed next.

Glazes

An icing unique to pastries can be prepared by combining confectioners' sugar, heavy cream, corn syrup, and a flavoring (vanilla, orange, chocolate, etc.) (4). The glaze needs to be thick enough to hold its structure upon cooling but sufficiently liquid to drape over the pastry. If it is too thick, cream can be added a tablespoon at a time until the right consistency is reached.

Crumb Toppings

A crunchy, crumbly texture is added to the top of fruit pies (especially apple) by topping them with a crumb topping. The texture and the size of the crumb can be controlled by changing the proportion of the ingredients—flour, butter, sugar, and salt (6). Crumb topping is essentially a pie dough with added sugar that is mixed, collected together into a clump, and refrigerated. The difference is that instead of rolling, it is broken apart into the desired crumb sizes and sprinkled over the pie filling to act as a loose top crust. Texture is affected by the ingredients: dusting with confectioners' sugar or adding melted butter makes it look more like

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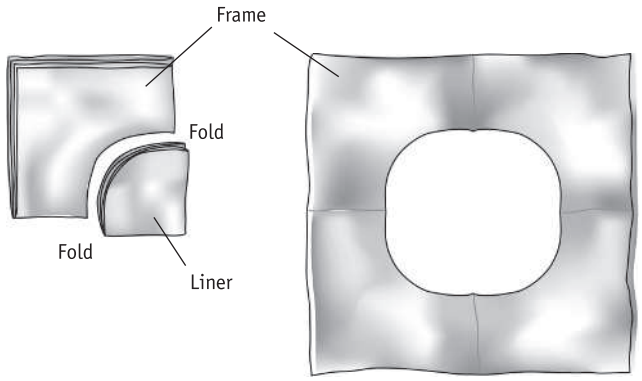
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coffee cake; brown sugar increases the crunch and caramelized look (7).

In addition to being used as a topping for pies, crumb toppings are important for the preparation of fruit cobblers. These are dishes in which fruits coated with sugar water are then mixed and sprinkled with crumb toppings before being baked in a deep dish. The flour mixture in and around the fruit gives cobblers their baked bread-like characteristics. Cobblers are often served topped off with whipped cream.

FIGURE 24-15 Creating a foil cover.



Baking

Whether using a conventional oven, convection oven, or microwave oven, the type of pan, the temperature, the heating time, and the method of testing for doneness are important to the finished pastry product.

Pan Selection and Preparation

Either Pyrex™ glass pans or pans with dull finishes are best for pies because they help absorb the heat. Shiny metal pans, which deflect heat, and thick metal pans, which take too long to heat, are not recommended (13). Piecrusts are usually baked in 8- or 9-inch pans with sloping sides and an edge designed to catch escaping juices. The size of the pan determines the number of pie slices, but smaller slices are better for portion control. The more common slice used for calculating calories per slice is either ⅙ of an 8-inch pan or ⅛ of a 9-inch pan:

- 8-inch pan = four or six slices of pie
- 9-inch pan = six or eight slices of pie
- 10-inch pan = eight or ten slices of pie

Puff pastries are baked on cookie sheets or specially prepared pans. Pies and puff pastries should be baked in the center of the oven, making sure the pan or cookie sheet does not touch the sides. Custard-based pies, however, should be placed on the bottom rack so the crust will bake quickly and not have time to get soggy. An extra crispy, flaky bottom crust can be obtained by placing a cookie sheet on the rack prior to heating the oven. The direct contact between the bottom of the pie pan and the cookie sheet delivers more direct heat.

Temperature and Timing

The oven should be preheated to approximately 425 to 450°F (218 to 232°C) for baking pies and puff pastries. Slower baking would contribute to shrinking and result in hard, flat pastries. The high heat helps generate steam, melt the fat, and set the gluten. Adjustments to temperature are sometimes made, depending on the type of filling.

Pie shells that are **blind baked** tend to bubble, lose their shape, and brown unevenly. These faults can be prevented by pricking the pie dough with a fork and/or weighting it down with beans, which are removed a few minutes before the baking is completed. Aluminum foil placed around the edge of the piecrust can prevent it from overbrowning or burning (Figure 24-15).

Fillings should not be added until immediately before baking. It is important not to prick the bottom crust of pies to be baked already filled because the juices will run through. The bottom crust can be moisture-proofed by several methods: brushing beaten egg glaze or fruit preserves on the pie dough and then placing it in the oven for a short prebaking; placing a very thin layer of melted butter or flour on the bottom crust; or making sure the filling is very hot when it is poured into the crust.

Several decorative touches can be added just before baking. For example, the top of a two-crust pie can be brushed lightly with water and sprinkled lightly but evenly with granulated sugar or coarse decorating sugar. For a shiny or glazed look, the top can be brushed with an egg wash (milk and beaten egg yolk combined with an equal amount of water). Be aware, however, that although glazes make pastry crusts appealing, they also make them tough. A crunchy crust is achieved by sprinkling about 2 tablespoons of sugar (white, brown, sanding, turbinado) on the egg wash (3).

Testing for Doneness

A lightly, delicately browned crust signals that baking is complete. Adding a thin layer of butter on the crust helps it to brown. Once done, all pies should be cooled in the pan on a wire rack to prevent moisture condensation, which results in a soggy lower crust. Table 24-7 lists several reasons why the baked pastry's appearance, tenderness, texture, or flavor may not be up to par.

STORAGE OF PASTRY

Pastries are best consumed when freshly baked, but most keep longer when refrigerated than they would if left at room temperature, and some can even be frozen. Pastry doughs can be kept frozen up to 6 months; however, frozen pastry crusts should go as

Blind bake To bake an unfilled piecrust.

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TABLE 24-7 Pastry Problems and Their Causes

Problems	Undermixing	Overmixing/Handling	Too much Fat	Too Little Fat	Too much Flour (in mix or on board)	Too much Liquid	Too Little Liquid	Overbaking	Underbaking	Rolled too Thick	Rolled too Thin	Oven Temperature too Low	Filling too Moist	Pastry Stretched too Tight	Not Pricked with Fork	Fat Cut too Finely	Dough Stored too Long in refrigerator
Tough	X			X	X	X											
Too tender (falls apart)		X	X				X										
Crumbly		X	X				X										
Doughy						X			X								
Dry/mealy							X								X		
Too brown/burned								X			X						
Pale/dull color				X	X	X			X	X		X					
Soggy bottom crust												X					
Shrinks	X									X	X			X			X
Blistered shell												X		X	X		

quickly as possible from the freezer into a preheated oven. Unbaked pies will last about 4 months in the freezer, whereas baked berry pies can be frozen for 6 to 8 months.

Not all pies can be frozen, especially if they contain egg and milk products, which may separate out. Custard and cream pies are frozen commercially, but freezing is not recommended for home recipes. Like all foods containing milk and/or eggs, custard, cream, and meringue pies should be kept refrigerated to avoid the growth of bacteria and possible foodborne illness.

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PICTORIAL SUMMARY / 24: Pies and Pastries

Pastry is essentially a bread that is flaky, tender, crisp, and lightly browned. But this delicate combination is not always easy to achieve, and piecrusts and pastries are the true test of a food preparer's skill.

TYPES OF PASTRY

Lamination is a series of folding, rolling, and turning manipulations that result in alternating layers of fat and flour in pastry dough. Pastry is considered laminated if produced from separate dough and fat components that are rolled together in this way, or nonlaminated if the fat is simply cut into the flour.

Nonlaminated

- Plain pastry (pie or shortcrust)—piecrusts, tarts, tartlets, galettes
  - Hot-water crust—main-dish pies
  - Short or sweet—desserts
- Brioche
- Choux—cream puffs

Laminated

- Puff
- Quick (blitz) puff
  - Napoleon
- Phyllo (filo)
  - Baklava
- Croissant
- Danish



PREPARATION OF PASTRY

The main ingredients in pastry are flour, fat, liquid, and salt (egg is optional). Either pastry or all-purpose flour can be used. Fat is probably the most important ingredient because it contributes the most to a pastry's flakiness and tenderness as well as its taste. It also, however, contributes to making most pastries high in fat and kcalories. Liquid is needed to develop gluten and leaven the pastry with steam, and salt is needed for flavor.



Plain and puff pastries are the most delicate of all baked products, and their preparation requires skill to correctly distribute the fat and develop gluten to the point of creating a crust that is flaky, tender, and crisp. Mixing, rolling, type of filling used (fruit, cream, custard, chiffon, or quiche ingredients), decorations (sugary, shiny, glazed, or frosted surface), and baking all contribute to the success of the finished product.

STORAGE OF PASTRY

When held for later consumption, pastry and pastry products will keep longer when refrigerated than they will at room temperature. Pastries vary in how successfully they may be frozen. Custard, cream, and meringue-topped pies should not be frozen but need to be refrigerated to avoid bacterial growth and thus prevent foodborne illness.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Which word is used to describe a pastry with a grainy or less flaky texture that results when all of the flour is coated with fat?
   a. Tender
   b. Moist
   c. Tough
   d. Mealy

2. The proportion of what ingredient is probably the most important determinant of quality in pastry, especially in regard to flakiness?
   a. Flour
   b. Sugar
   c. Liquid
   d. Fat

3. The liquid component of pastry dough is important for _____.
   a. leavening
   b. hydration
   c. crispness of the crust
   d. all of the above

4. Lamination is a process used to make ____ pastry.
   a. pie
   b. puff
   c. choux
   d. brioche

5. If you are baking a pie that has six slices, what size pie pan should you use?
   a. 9-inch
   b. 6-inch
   c. 10-inch
   d. 12 inch

6. Cream puffs and éclairs are made from a _____ pastry dough.
   a. phyllo
   b. puff
   c. choux
   d. brioche

7. Which starch-based thickener should not be used for fruit pies because it will thicken before the fruit boils?
   a. Arrowroot
   b. Cornstarch
   c. ClearJel®
   d. Tapioca

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe the characteristics of good-quality pastry.
2. What is the difference between plain and puff pastry? Give examples of each.
3. How do pastry flour mixtures differ from those used to prepare bread doughs? Explain the role of each of the following ingredients used in pastry preparation: flour, fat, liquid, eggs, and salt.
4. Explain the difference between flakiness and tenderness and how each is achieved during pastry preparation.
5. Fat plays a critical role in pastry production. Explain how fat contributes to a flaky pastry through the process of lamination.
6. Flour is not the only ingredient that can be used to make piecrusts. What are some of the other options?
7. Briefly define the following terms: *mealy crust, streusel topping,* and *blind bake.*
8. List the basic ingredients of the following types of pie fillings and explain how the fillings are prepared: fruit, cream, custard, and chiffon.
9. What is the best temperature for baking pastries? Why is this temperature recommended?
10. State the possible causes of the following problems associated with pastry preparation: low volume, insufficient flaking, fat flows out.

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25



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Candy

Classification of Candies . 489
Preparation of Candy . 490
Chocolate 496
Storage of Candy 502

The words *love* and *sweets* have been interwoven in everyday language through such terms of endearment as *sweetheart, honey,* and *sugar.* There are few who disapprove of love or dislike sweets such as candy. This is especially true in the United States, which produces more candy than any other country in the world. Despite the high production of confections in the United States, it is people from Europe who consume the most candy (30). However, Americans are not far behind in intake, approximately half of which is in the form of chocolate with the rest from other types of sugar confectioneries (12).

In pursuit of the gratification of the sweet tooth, candy making has developed into a many-faceted art. No one really knows how candies first got their start, but evidence points to the ancient Arabs, who used refined sugar to make medicinal lozenges. One of the factors supporting the role of Arabs as the first confectioners is that "candy" is derived from *qand,* the Arabic word for sugar (20). Granulated sugars (specifically sucrose), along with their close relative, corn syrup, are the foundational ingredients of almost all candies and are essential to the process of confectionery production. Sugars are mixed with liquid and other ingredients into a solution that is then heated to concentrate its sweet taste. The type and concentration of ingredients, the temperature to which the mixture is heated, the degree to which it is then cooled, and any stirring or manipulation that follows determine the type of candy produced. This chapter discusses the classification of candies and their basic preparation methods.

CLASSIFICATION OF CANDIES

The thousands of different candies produced can be classified according to their ingredients and/or preparation method (Table 25-1). Two major classification schemes used by the confectionery industry are (1) syrup phase versus fat phase, and (2) crystalline versus noncrystalline (amorphous).

Syrup Phase versus Fat Phase

One way of categorizing candies according to ingredients is to divide them into groups termed *syrup phase* (or sugar phase) and *fat phase*. Most candies are syrup phase, meaning they are made from a **simple syrup** mixture. Examples of some syrup-phase candies are hard candy, fondants, marshmallows, nougats, jelly beans, gums, caramels, and fudges. These candies are basically sugar with added flavorings.

Simple syrup A liquid produced by boiling sugar and water together. The ratio of sugar to water determines whether it is a light, medium, or heavy syrup.

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TABLE 25-1 Types of Candy

Class	Comments
Candied or crystallized fruits	Certain fruits (cherries, citrus peels, plums, etc.) are prepared and dropped into a syrup at 234°F (112°C). They are simmered until clear, spread on a screen, and dried until no longer sticky.
Caramels	Caramels contain sugar, corn syrup, milk, cream, and butter, and they are cooked to stiff-ball stage of 246°F (119°C). After being poured into a buttered pan and allowed to cool, they are turned out and cut into squares.
Chewing gums	Chewing gum is not eaten; it is chewed. Its sugar content allows it to be classed as a candy.
Chocolates	Chocolate liquor is the fundamental ingredient of most chocolate products. Other ingredients can include cocoa butter, sugar, milk products, and flavorings.
Fondants	For fondants, the syrup is cooked to the soft-ball stage (238°F/114°C), poured into large platters, cooled until lukewarm, stirred, and then kneaded until smooth.
Fudges	Fudge is made by gently boiling sugar and corn syrup with milk to 238°F (114°C), adding butter, cooling, and then beating until it holds its shape. It is spread in a buttered pan and, when hard, cut into squares.
Glacé fruits and nuts	Similar to candied fruits, but the fruit is not cooked. The fruit or nut is dipped into the syrup, which has been cooked to 300°F (149°C), and dried on a rack.
Hard candies	Hard candies are the simplest form of candy—they are made mainly from sugar and syrup and are usually boiled to 300°F (149°C). They come in all shapes, sizes, colors, and flavors.
Jellies	The main ingredients for jellies (jelly beans, gum drops, etc.) are sugar, corn syrup, and a gelling agent such as gelatin, natural gums, pectin, or starch.
Licorice	Licorice sticks are made with flour, molasses, sugar, and corn syrup, and flavored with licorice extract.
Marshmallows	Marshmallows are made by whipping a combination of sugar, corn syrup, gelatin, and/or egg whites. This makes a light, fluffy-textured candy that can be served plain or as a filling for chocolate Easter eggs.
Marzipan	Egg whites are beaten and mixed with almond paste plus sugar. It is not cooked. After standing 24 hours, it can be shaped, stuffed, or dipped.
Nougats	The syrup is cooked to 246 to 250°F (119 to 121°C) and then poured over the well-beaten egg whites, or gelatin, or both. Fat is added and it is beaten until cool.
Peanut brittle	The syrup is cooked to 300°F (149°C). It is poured over the nuts spread out on a pan, allowed to cool, and then broken into pieces.
Popcorn balls	The sugar, corn syrup, and water are cooked to the medium-crack stage (280°F/138°C), flavoring is added, and the mixture is poured over the popcorn and stirred. Then, with buttered hands, the mixture is shaped into balls.
Spun sugar	The syrup is boiled to 310°F (154°C). Then the pan is put into cold water to stop cooking and back into a warm pan before it crystallizes. Using a wooden spoon, the threads of syrup are wrapped across the greased handles of two wooden spoons that have been anchored into a drawer.
Taffy	Similar to a caramel mixture except more concentrated and pulled to incorporate air.
Toffee	Toffee is hard caramel.

When chocolate or nut pastes such as peanut butter are used, the candy is considered fat phase. A combination of both fat and syrup phases is found in candies such as chocolate-covered candy bars.

Crystalline versus Noncrystalline (Amorphous)

Another way to classify confectioneries is based on the method of preparation, which determines whether the candy will be crystalline or noncrystalline in nature. **Crystalline** candies, in which the sugar is present in the form of crystals, are typically soft, smooth, and creamy; examples are chocolate, creams, fudge, fondant, nougats, marshmallows, pralines, lozenges, and divinity. **Noncrystalline (amorphous** [without form]**) candies** are those in which the sugar is present in an uncrystallized form. Examples include caramel, toffee, taffy, hard candy, brittles, and gummy candies such as jelly beans, gummy bears, fruit slices, and gumdrops. The difference in texture between the two types depends on how the candy's ingredients are combined and/or manipulated.

Crystalline candy A type of candy formed from a sugar solution handled so that the sugar crystallized; most crystalline candies are characterized by many fine, small crystals.

Noncrystalline (amorphous) candy A type of candy formed from a sugar solution that did not crystallize.

PREPARATION OF CANDY

When it comes to preparation, candies are temperamental. Confectionery production is highly sensitive to timing, temperature, and the skill of the preparer. Making confections is an art successfully executed only with practice and patience. Adding to this difficulty is the fact that there are more recipes than the number of candies available. For example, there are more than 1,000 different formulas for making marshmallows alone.

This chapter describes the preparation of candies based on whether they are crystalline, noncrystalline, or chocolate. A brief summary of confectionery preparation follows in order to put the various types of candies in perspective.

Confectionery Preparation Overview

Controlling crystallization is one of the most important aspects of producing confections (9). The preparation of many, but not all, confections can be generally summarized by four basic steps that revolve around controlling the formation of sugar crystals (33):

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Step 1: Creating a syrup solution
Step 2: Concentrating the contents of this mixture via heating and evaporation
Step 3: Cooling
Step 4: Beating *or* leaving undisturbed

These steps and how they differ in the preparation of crystalline and noncrystalline candies are discussed in the following sections.

The preparation of many crystalline and noncrystalline candies starts out the same—a syrup or sugar solution is heated to melt the sugar, evaporate the liquid, and concentrate the sugar. The formation of sugar crystals from this syrup solution is the basis of crystalline candies, whereas the goal in preparing noncrystalline candies is to inhibit their formation. This is achieved in part by the way their sugar solutions are cooled and beaten. Rapid cooling and beating results in crystalline candies, whereas slow cooling without agitation forms noncrystalline candies (2).

Crystalline Candies

Crystalline candies are classified based on the size of their crystals as either (1) candies with large crystals such as rock candy, or (2) cream candies with crystals too small for detection by the tongue (fudge and fondant). Crystals are a compilation of loosely packed sugar molecules organized around **nuclei**. The size of the sugar crystals is determined by the rate or speed of nucleus formation. If the nuclei appear slowly in the syrup solution, there is more time for the sugar molecules to aggregate around the nuclei and form large crystals. The goal in preparing creamy crystalline candies is to develop numerous, very fine nuclei in the syrup solution, which will serve as the foundation of the sugar crystals. Confectioners generate small nuclei by (1) controlling the proportions of ingredients, especially sugars and **interfering agents**; (2) controlling the temperature at which crystallization begins; (3) controlling the final cooking temperature to achieve the desired concentration; and (4) stirring correctly. As the solution cools, the sugar hardens out, or crystallizes, creating a candy.

Candies Start with a Syrup Solution

Sugar is dissolved in water until no more sugar can be added (this is known as a saturated solution, having about 1 pound of sugar for every cup of water). Sucrose is the most common sugar used, but sometimes another sugar that can function as an interfering agent, such as glucose, invert sugar (a mixture of glucose and fructose), or corn syrup, is added to make sucrose more soluble and less likely to form large crystals. Interfering agents are added to candy syrup to inhibit crystallization and ensure formation of small crystals. However, this interference can also cause a problem if too many added monosaccharides make the syrup so runny that it never crystallizes.

The two main interfering agents used in confectionery production are corn syrup and cream of tartar, but certain other ingredients added in large amounts can also contribute to preventing crystallization. The inhibiting action of cream of tartar results from the formation of invert sugar from sucrose; commercial invert sugar achieves the same purpose. When it is added to chewy candies, invert sugar's hygroscopic nature also prevents the candies from drying out. The benefit of adding corn syrup is that, like invert sugar, it contributes to chewiness and also adds viscosity, slows the dissolving rate of candies in the mouth, and strengthens the structure of sugar crystals so they are less likely to be affected by temperature or mechanical shock (34). Both interfering compounds provide more time for cooling and/or beating, which promotes small crystal formation (as discussed in later sections) (2).

In the confectionery business, glucose is referred to as dextrose, and fructose as levulose (34). Both of these sugars crystallize more slowly than sucrose and, when combined, are sweeter than sucrose. Other foods, such as chocolate, fat, milk, cream, and eggs, are often added and help to interfere with large crystal formation.

Heating the Syrup

Temperature is important in confectionery production because it influences crystallization at all stages of heating and cooling. The next step in creating confections is to heat the syrup mixture. The purpose is to increase the amount of sugar that can be added to the solution so that it becomes supersaturated, as discussed in Chapter 21 (Figure 25-1). As the heat evaporates the water, the syrup solution becomes more concentrated. As the concentration increases, so does the boiling point. Temperatures exceed the normal boiling point of pure water and leave behind the solids, primarily sugars, which then form into a hard mass—the candy.

Controlling the degree of sugar concentration determines what kind of candy will be produced. However, it's difficult to measure changing concentrations accurately, so boiling point is used as an indirect measure

How & Why?

How do interfering agents work?

Both crystalline and noncrystalline candies contain interfering agents, which are ingredients that either inhibit or completely prevent crystallization of sucrose, depending on their concentration. Interfering agents include the following:

1. Other sugars, such as glucose, fructose, invert sugar, or corn syrup. Structurally, these sugars are not the same shape as sucrose, so they do not fit properly into the regular crystal lattice. After the regular, ordered shape has been disrupted, it is more difficult for the crystal to grow, and so crystallization is inhibited.
2. Butter, cream, and other ingredients that coat the sucrose crystals, forming a physical barrier that inhibits further crystallization.
3. Ingredients that increase the viscosity of the candy syrup, such as corn syrup. As the solution cools, it thickens further, and molecular movement slows down, thus slowing crystal growth. Note that corn syrup both increases viscosity and disrupts the crystal lattice.

Nuclei Small aggregates of molecules serving as the starting point of crystal formation.

Interfering agent A substance added to the sugar syrup to prevent the formation of large crystals, resulting in a candy with a waxy, chewy texture.

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FIGURE 25-1 Saturated and supersaturated solutions are important for candy formation.

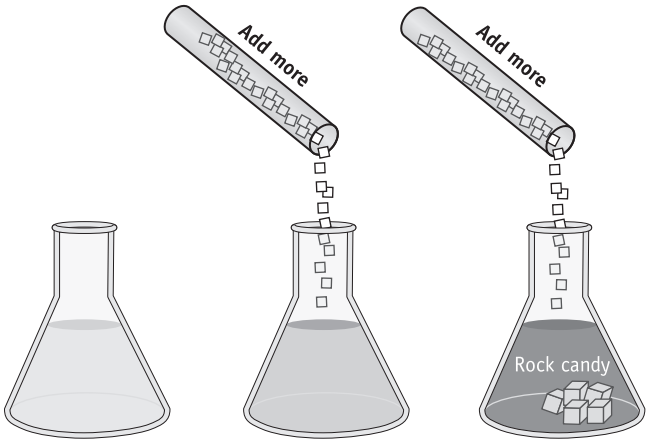


TABLE 25-2 Candy Syrup Temperatures and Doneness Tests

Candy	Doneness Test	Final Temperature of Syrup Begins at* °F	°C	Description of Test†
Jelly		220	105	Syrup runs off spoon in drops that merge to form a sheet.
Syrup	Thread	230	110	Syrup spirals a 2-inch thread when dropped from spoon.
Fondant Fudge Panocha	Soft ball	234	112	Syrup forms a soft ball that flattens out between fingers.
Caramels Nougat	Firm ball	244	118	Syrup forms a firm ball that retains its shape when held between fingers.
Divinity Marshmallows Popcorn balls	Hard ball	250	121	Syrup forms a ball that is hard enough to hold its shape, yet plastic enough to roll out.
Butterscotch Hard candies Taffies	Soft crack	270	132	Syrup separates into threads that are hard and brittle under water, but become soft and sticky when removed from the water.
Brittle Glacé Some hard candies	Hard crack	300	149	Syrup separates into threads that are hard and brittle, but do not stick to fingers.
Caramel	Light brown liquid	338	170	No cold water test. The sugar liquefies and becomes light brown.

*For each increase of 500 feet in elevation, cook the syrup to a temperature 1°F lower than the temperature called for at sea level. If readings are taken in Celsius (centigrade), for each 900 feet of elevation, cook the syrup to a temperature 1°C lower than called for at sea level.

†Remove pot from heat while testing to avoid overcooking. Drop one drop from an eyedropper of syrup into fresh cold water, which is replaced with each test.

of concentration (9). Table 25-2 shows the final temperatures of syrups for each of the different types of candies. For example, a syrup heated to a high temperature will result in a harder candy (peanut brittle) than one heated to a lower temperature (jelly or fudge). Lower temperatures evaporate less water, and the more water a candy mixture retains, the softer its consistency.

How & Why?

Why do confectionery makers check the weather before preparing candy?

Simple syrups can absorb moisture from the air during a humid day, causing dilution of the syrup mixture and making the candy softer than desired. As a result, cool, clear days when there is little humidity in the air are preferred for candy making (2).

Even the weather is a factor when making the syrup solution because high-humidity days are not conducive to making confections.

Overheating and Underheating

One problem sometimes encountered in confectionery cooking is overheating the solution, which results in a too-hard, sometimes excessively brittle candy. Overheating can also cause color and flavor changes. On the other hand, too cold a temperature results in a too-soft, runny consistency.

There are two ways to determine the correct final temperature during candy making: (1) using a candy thermometer, and (2) the cold-water test.

Thermometer Test

Candy thermometers have been specifically designed for the high temperatures reached by syrup mixtures, and they have a clip on the side to hold them inside the pan. Home-use candy thermometers have a range of about 100 to 320°F (38 to 160°C). Commercial models are longer to fit larger pans, and they have a broader temperature range of 60 to 360°F (16 to 182°C) (36). A candy thermometer's bulb should be completely immersed in the mixture without touching the bottom of the pan. The top of the mercury line should be read by bringing the eyes level with the thermometer, not the thermometer to eye level.

Before each use, and especially at high altitudes, it is important to check the candy thermometer for accuracy. This is accomplished by determining the boiling point of water on the thermometer, which should be 212°F (100°C) at sea level, and 1°F lower for each 500-foot increase in elevation above sea level (1°C lower for each 900

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feet in elevation). If the boiling point of the thermometer is below the standard 212°F (100°C), then the number of degrees below this point is subtracted from the recipe's cooking temperature. After the thermometer has been used to make candy, immersing it immediately in very hot water makes it easier to clean and reduces the risk of breakage (36).

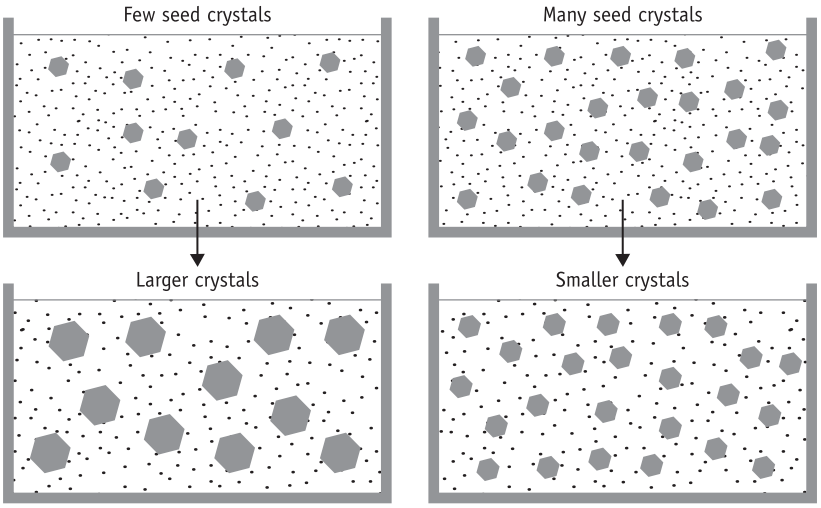
Cold-Water Test

The older and still viable method of testing the temperature of candy mixtures is the cold-water test, which measures the syrup's consistency. This test is carried out by placing a very small amount of the candy mixture, about 1 drop from an eyedropper or ¼ teaspoon, into a cup of very cold (not ice) water, after which the drop is observed for softness or firmness and possibly double-checked by pinching it between two fingers. Drops of the syrup, when cooled at successive stages during the cooking process, will form first a soft ball, then a firm ball, and finally a hard ball. Because the mixture can move from one stage to the next fairly rapidly, the saucepan should be removed from the heat source before any testing is done. Experience is the best teacher in learning the precise look and feel of the candy mixture at different stages.

Avoiding Agitation during Heating

Stirring, or agitation, is another factor governing crystal formation. It is important to avoid vigorous boiling or stirring when heating the solution to its final temperature. Syrup splashing onto the sides of the pan can prematurely **seed** the solution and initiate crystal formation. One sugar crystal falling into the mixture from the side can start a chain reaction, resulting in a large sugar mass. This can be prevented by covering the boiling syrup solution with a lid, creating steam that returns the syrup on the sides of the pan back into the solution before it can form crystals. The pan must then be uncovered later in cooking to allow the water to evaporate and the temperature to rise. To prevent crystals from forming during this final cooking stage, the sides of the pan may be frequently wiped with a wet pastry brush or a damp paper towel or cheesecloth. If this is not done, large crystals, instead of the desired small ones, will likely form.

FIGURE 25-2 Correct cooling is critical to the formation of many small crystals.



Smoother candies result if sugar crystals are kept small. This can be achieved by starting off with more (top right) rather than fewer (top left) seed crystals so that there are more sites on which the remaining sugar can crystallize. A greater number of starting points results in smaller crystals (bottom right).

Cooling and Beating

Agitating the mixture during heating can result in some premature (unwanted) crystal formation. The crystallization actually desired for candy making begins during the cooling of a supersaturated solution. After the correct temperature is reached, the solution is cooled immediately, without any additional movement, not even to stir in flavoring or move the thermometer or spoon in the mixture. As the mixture cools, it becomes supersaturated, which allows for the formation of nuclei. Immediate cooling also prevents further evaporation of the water.

Cooling Is Crucial

Cooling at the correct rate is crucial for candy production. Sugar molecules move rapidly in a hot solution, but drastically slow down as the temperature drops. Small crystals are less likely to aggregate in a hot solution, in which molecules are moving rapidly. At the same time, the small crystals that do occur grow large because the greater frequency of contact among sugar molecules encourages their growth. The syrup mixtures for crystalline candies such as fudge and fondant are quickly cooled to slow molecular movement, and they are stirred to form small crystals by fostering aggregation of the molecules. Figure 25-2 shows that starting off with a greater number of small nuclei results in smaller crystals.

How & Why?

How are small sugar crystals created when making candy?

The steps to formation of small crystals in a crystalline candy are as follows:

1. Combine sucrose, water, and other ingredients (interfering agents, flavoring agents, etc.). Interfering agents inhibit sucrose crystallization and aid in the formation of small crystals.
2. Heat the mixture to the desired boiling temperature. This determines the final sucrose concentration (Table 21-7 in Chapter 21).
3. Cool without disturbance to form a supersaturated solution. If crystals form too soon, they will grow slowly and become large, and the candy will be grainy and not creamy (Figure 25-2).
4. When the candy is sufficiently supersaturated, beat or stir vigorously. This will cause many crystal nuclei to form, and the sucrose will deposit rapidly on these nuclei, forming many small crystals.

Seed To create nuclei or starting points from which additional crystals can form.

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Stirring during Cooling

Stirring the mixture after it cools promotes the formation of numerous small crystals that contribute to a smoother consistency in the candy, but this is done only after the desired cooler temperature has been reached. Then the crystallization is initiated by beating the mixture rapidly until its shiny, glossy appearance turns dull. If it is cooled too long before beating, the development of the finer crystals necessary to produce a smooth, crystalline candy will be inhibited.

Types of Crystalline Candies

In the preparation of crystalline candies, small crystals form when many nuclei quickly appear. This allows less time for the sugar molecules to collect around the nuclei and divides the available sugars among a larger number of nuclei, meaning fewer sugar units aggregate around each nucleus. The smooth, creamy texture of fondant, fudge, and divinity depends on the formation of numerous, small sugar crystals (Figure 25-3). These three crystalline candies and their preparation are discussed next.

Fondant

Fondant is a crystalline candy made from a sugar syrup that has been crystallized into a creamy, white paste. It serves as the soft, rich filling of many chocolates, mints, and candy bars (Chemist's Corner 25-1). Fondant is also used as an icing to glaze and decorate pastries, sealing baked products from air and the loss of moisture (14). Professional bakers buy it ready-made or in powder form, but large amounts can also be prepared by hand.

Fondant preparation starts with sugar, preferably glucose, which is combined with half as much water and a little cream of tartar or corn syrup. The mixture is heated in a covered saucepan to a rapid boil. The solution is then cooked to the soft-ball stage, or 234 to 240°F (112 to 115°C). After reaching the final temperature, the mixture is poured onto a flat marble slab and cooled to about 120°F (49°C). The fondant should be poured, with no scraping or shaking, over a wide surface for even cooling. When the proper temperature is reached, a spatula or wooden spoon is used to mix the candy until it becomes white and creamy. The color and consistency come from the formation of fine, uniform crystals (24). At this point, ½ teaspoon of vanilla or other flavor extracts or colorings may be added. The mixture is then kneaded until smooth. The end product should be stored overnight or even for several days in a tightly covered jar until it becomes soft enough to use (14). Fondant can keep up to several weeks on the shelf if kept in an airtight container in a cool, dry location away from high humidity, and it can be kept up to several months after it is surrounded by chocolate.

CHEMIST'S CORNER 25-1

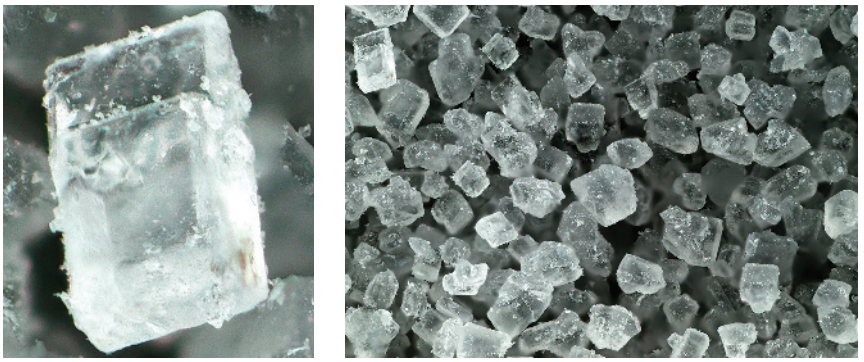
Liquid Fondant

The fondant of cream-filled centers is often prepared with an invertase enzyme that slowly hydrolyzes the sucrose to invert sugar. The higher solubility of this invert sugar as compared to sucrose makes it melt under the chocolate layer, turning the center into a creamy liquid (34).

Fudge

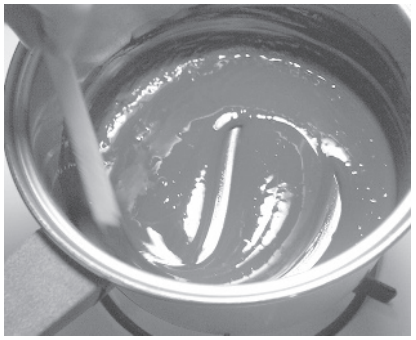
Fudge is the most popular of all crystalline candies. It is made by adding chocolate, cream, milk, and butter to a simple syrup. Table 25-3 lists the functions of dairy ingredients in the manufacture of fudge and other candies. After the ingredients have been heated to the soft-ball stage (234 to 240°F/112 to 115°C), the mixture must be cooled to about 120°F (49°C). The fudge is then beaten until the gloss dulls and the texture turns creamy smooth. Beating fudge too long hardens it, but this can be corrected with recooking (Figure 25-4). After cooling and beating, the fudge should be poured at once into a greased pan. Covering it will prevent it from drying out, as will waiting until serving time to cut it into squares. Panocha or penuche is similar to fudge except it is made with brown, instead of white, sugar and contains no chocolate or cocoa.

FIGURE 25-3 Sugar crystal size changes during candy preparation.



William Andrew/Getty Images

FIGURE 25-4 Beating fudge.



Adequately beaten fudge is smooth, and the gloss has just dulled.



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Overbeaten fudge becomes hard and loses its gloss.

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TABLE 25-3 Functions of Dairy Ingredients in Confections

Dairy Ingredient	Function in Confections
Milk fat	• Gives rich flavor, texture, and mouthfeel. • Provides lecithin and monoglycerides, which aid in emulsification. • Contains precursors of key flavor compounds formed by cooking. • Acts as a flavor carrier. • Provides a moisture barrier. • Inhibits bloom defect. • Oxidation and/or hydrolysis produces distinctive desirable flavor compounds. (However, under certain conditions of processing and storage, off-flavors [rancid, fishy, stale] may develop.)
Milk proteins	• Aid in emulsification and miscibility of various ingredients. • Assist in whipping and foam formation. • Absorb moisture due to water-binding capacity. • With heat, can yield protein fiber network that gives rigidity, shape, texture, and chewability. Furthermore, they impede movement of water molecules, leading to retardation of sugar crystallization. • Contribute to flavor and color development. • Improve nutritional profile.
Lactose	• Imparts chewiness and graininess. • Causes sandiness defects under certain conditions, for example, at high lactose concentrations. • Acts as a flavor carrier. • Polymerizes to form a flexible and extensible matrix (textural effect). • Caramelizes to generate color and flavor compounds in caramels and toffees. • Provides reducing sugar moiety that can participate in Maillard browning, which affects color and flavor. • Acts as a precursor of pyrazines (nutty flavor), maltol and isomaltol (caramel flavor), furfural and furfuraldehyde (cooked cereal). • Contributes to dark color and bitter taste defects under certain conditions of overcooking.

NUTRIENT CONTENT

Candy contains **primarily carbohydrate from refined sugar and possibly fat** from butter, cocoa butter, or other fats. See the Calorie Control feature for their contribution to kcalorie intakes.

Divinity

Divinity is prepared like fondant and fudge up to the point of beating. When the mixture has reached 250 to 266°F (121 to 130°C) (the hard-ball stage), it is poured slowly over stiffly beaten egg whites and continuously beaten. The beating continues until the candy holds its shape when dropped from a spoon. At this point, it can be poured into a buttered pan or dropped by spoonfuls onto a buttered surface.

Noncrystalline Candies

Noncrystalline candies are easier to make because the goal is to ensure that the sugar does not crystallize. Two major methods are used to inhibit crystallization: (1) creating very concentrated sugar solutions, and/or (2) adding large amounts of interfering agents to block the sugar molecules from clustering together. The high viscosity of the concentrated syrup then inhibits crystallization by impeding molecular movement.

Concentrating the Sugar Solution

Using high temperatures to evaporate much of the water results in a very concentrated syrup, and the degree of evaporation determines the percentage of moisture in noncrystalline candies. Sugar-syrup-based candies containing 2% moisture or less include hard candies, sour balls, butterscotch, and nut brittles. Caramel and taffy have a high moisture content (8 to 15%), and marshmallows, gumdrops, and jelly beans contain an even higher moisture level (15 to 22%) (34).

Interfering Agents

Interfering agents may inhibit crystallization in several ways:

- By inhibiting formation of nuclei
- By physically coating the crystals, which prevents their growth
- By decreasing water activity, leaving less water in which the sugar can dissolve

Types of Noncrystalline Candies

Noncrystalline candies vary in their degree of sugar solution concentration and the types of interfering substances added. The preparation of a few of these noncrystalline candies is discussed in more detail here.

How & Why?

Why does hard candy turn "soft"?

Citric acid is added to some candies for flavor. The only problem is that the acid, being very hygroscopic (tending to draw moisture from the air), turns the candy somewhat liquid so that it sticks to the wrapper. The confectionery industry has bypassed this side effect of citric acid by encapsulating candies in a film or coating (17). However, the coating's effectiveness does not last as long as the hard candy, which is why very old candy left out in a bowl turns soft and sticky.

Hard and Brittle Candy

All but 0.5 to 2% of the moisture from simple syrup is removed when making hard candies (13). Flavorings and colorings are then added, with centers or fillings being optional. Baking soda is added to brittle candies such as peanut brittle and toffee. To make brittle, the syrup is heated to the high temperatures of caramelization and then spread out on a hard surface to cool (Figure 25-5). The bubbles in these candies come from the carbon dioxide gas produced by the baking soda.

Caramels

To inhibit the formation of crystals when making caramel, large amounts of interfering substances such as fat, cocoa butter, concentrated milk products, and/or corn syrup are added to the sugar syrup. The amount of fat added to caramels is

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CALORIE CONTROL
Candy

Sugar is the main ingredient in candies. In fact, hard candy is really just flavored sugar. Chocolate bars are about half sugar and half fat (primarily cocoa butter). The fat prevents crystallization, achieving that creamy, smooth mouthfeel.

Candies deliver plenty of kcalories because sugar delivers about 16 kcalories for each teaspoon and 45 kcalories for each tablespoon. That translates to about **100 kcalories per ounce of hard candies, jelly beans, gumdrops, or taffy. Chocolate adds 146 kcalories and 9 grams of fat per ounce**. That totals around **200 to 300 kcalories and 10 grams of fat** for the average **chocolate bar**.

Several ways to portion control confectioneries include the following:

- Choose miniature, "snack," or "fun" sizes over a full-size chocolate bar.
- Cut a chocolate bar up into 4 pieces. 200 kcalories divided by 4 pieces = 50 kcalories each; or 300 kcalories divided by 4 pieces = 75 kcalories each.
- Satisfy the sweet tooth with individual pieces of hard candy, licorice, jelly beans, or other nonfat candies.
- Set a limit for the maximum number of pieces of candy you will eat each day.
- Choose lower-sugar or sugar-free candies.

FIGURE 25-5 Spreading peanut brittle to cool.



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Thick gloves protect against the hot candy that is stretched as thin as possible.

high—about ¼ cup of fat for every cup of sugar. The result is a candy with a waxy, chewy texture. Dairy products also contribute protein, calcium, and flavor. Milk helps create the characteristic color of caramel candies. Ironically, the tan color is not from caramelization, but from the Maillard reaction, which occurs as sugars interact with the milk proteins (26). The color starts to develop when the temperature reaches about 325°F (163°C); however, if it is allowed to become too dark, a bitter taste results (24).

Taffy

Taffy is very similar to caramel except that it is made from a more concentrated solution, which makes it firmer. The other difference is that, once solidified, the syrup mass is pulled to aerate the mixture by incorporating air bubbles. This pulling transforms the mass into a candy that is lighter, chewier, and paler than caramel. Different flavorings can be added to create various types of taffy.

Aerated Candies

Corn syrup serves as the foundation for aerated candies such as marshmallows, jelly beans, and gumdrops. Candy can be aerated physically (pulling), chemically (adding sodium bicarbonate), or by the addition of foams for structure. Marshmallows, for example, incorporate an egg-white foam (2). Gummy textures are formed by adding gelling agents such as starch, gelatin, pectin, and gums to the sugar. Gelatin can be used in confectionery production to stabilize marshmallows and other aerated products. It also adds elasticity to gums and jelly beans. Lastly, gelatin softens and binds water in caramels and other chewable sweets (21).

Food Additives in Candy

Candies are so numerous that the list of food additives used in their manufacture is too long to present here. Some of them are listed in Appendix E.

CHOCOLATE

Chocolate is a chief ingredient for many confections and is consumed in the form of chocolate bars; as a syrup topping; or as a coating (or center) for candy bars, candies, ice cream, cookies, nuts, and fruit (6). It is even used to create fanciful swirls on plates and in latte art.

Cacao Tree

The origin of chocolate confections starts with the tropical cocoa or cacao tree (Figure 25-6). Warm, moist climates within 20 degrees up or down from the equator (latitude) provide the best environment for the growth of cacao trees (25). Botanists believe the tree originated in the Amazon–Orinoco river basin in South America; the crop is now cultivated primarily in Africa, Indonesia, and Brazil.

History

The tree's cacao beans played an important role in the Aztec's traditions,

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FIGURE 25-6 Cacao tree with pods (fruit).



Maria Nelasova/Shutterstock.com

religion, and legends. Historians suggest that it was the Aztecs who first came up with chocolate beverages and who believed that the cacao tree had a divine origin, leading to its botanical name, *Theobroma*, meaning "food of the gods." The Aztec's term for their drink, "bitter water" or "cocoa water," was *xocolatl,* which the Spanish later converted to "chocolate." Hernando Cortez brought cacao beans from Central America back to Spain in 1758, and, from there, they quickly spread to other parts of Europe. The popularity of chocolate may be related to its almost addiction-like attraction for some people (29).

Chocolate Production

Carefully selected cacao beans are fermented, dried, roasted, freed from chaff (winnowing), and ground to release their chocolate liquor. This rich liquid is then pressed to produce either cocoa powder or cocoa butter. Chocolate liquor can also be processed to produce chocolate by mixing it with cocoa butter, sugar, and/or milk. Flavor and consistency are then developed through the process of conching, while tempering the chocolate makes it more resistant to temperature changes, does not melt in your hands, and has a smooth, hard, and glossy finish. The last step of molding into bars or depositing the chocolate as "chips" determines its shape (see Figure 25-7 for an overview). The remainder of this chapter discusses these basic production steps in more detail, the types of chocolate products produced, and the storage of candies.

Cocoa Beans Produce Chocolate Liquor

The first step in chocolate production is the manufacture of chocolate liquor, the basic ingredient for all chocolate products. The following steps of creating chocolate liquor are now described: cacao bean selection, fermentation, drying, blending/roasting, winnowing, blending, and grinding.

Cacao Bean Selection

Selecting the right cacao beans from three cacao tree varieties determines the chocolate's quality. The most common beans come from the Forastero variety, producing approximately 80% of the world's cacao beans. These beans yield a chocolate that is generally mild. The Criollo (cree-yo-yo) variety yields the highest quality chocolate with the best flavor, smoothness, and lingering aftertaste. Susceptibility to disease lowers the Criollo trees' global cacao bean production to about 5% overall. Trinitario varieties (thought to be first grown in Trinidad) are hybrids of the first two types of cacao trees, with a resulting chocolate flavor varying between average and superior.

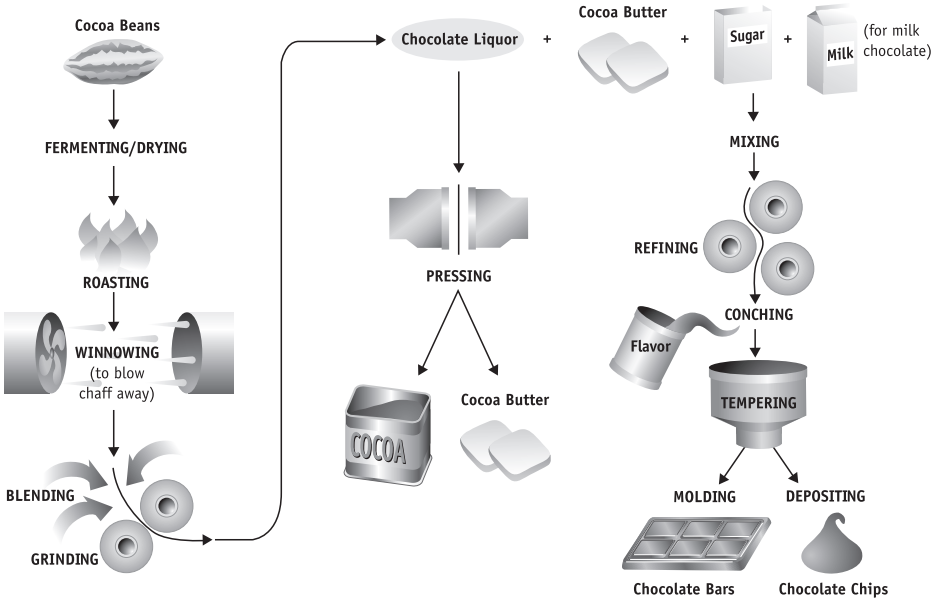
Fermentation

After the cacao pods (seeds) are picked, their cacao beans are scooped out and heaped into large piles and covered with banana leaves or placed in wooden sweating boxes, and allowed to ferment. This process improves the flavor and color of the beans and liquefies the pulp (25, 27).

Drying

The beans are then dried to a 7% moisture level to further develop their flavor

FIGURE 25-7 The process used to manufacture chocolate.



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and color and to give them good keeping quality before they are shipped to a chocolate manufacturer.

Blending/Roasting

Upon arriving at the manufacturing plant, the beans are blended into various combinations to obtain specific flavors and colors, which are further developed by roasting.

Winnowing

A winnower machine cracks and deshells the cacao beans before breaking them into smaller pieces (nibs) that are then spun in wind turbines at high speeds to remove their husks and skins.

Grinding

Nibs, the essence of chocolate, are finely ground under heat to produce chocolate liquor, a liquid containing approximately 54% cocoa butter and 46% cacao solids. (Figure 25-7). Grinding also contributes to the final chocolate's mouthfeel (9). The cocoa butter in chocolate liquor has a melting point just below body temperature and is responsible for chocolate's melt-in-the-mouth appeal and brittle snap at room temperature (14).

Chocolate Liquor

At this stage, chocolate liquor can be either (1) pressed to produce cocoa cakes (which can be ground to cocoa powder) and cocoa butter, or (2) combined with additional cocoa butter and sugar (and sometimes milk) to produce chocolate. If producing chocolate, the chocolate liquor is refined through the important steps of conching and/or tempering.

Conching

A chocolate's characteristic flavor and consistency are developed through conching, which is constant kneading in a mixer that is continually scraped. Preprocessed chocolate is not smooth and has a very acidic flavor, but conching allows some of the distasteful volatile components to escape. However, excessive conching results in a bland chocolate. To start, warmed chocolate (usually between 70°F and 160°F (21°C and 71°C) is kneaded (conched) and aerated by machines to increase its smoothness, viscosity, and flavor (35). Several ingredients may be added during this time. These include flavorings, additional cocoa butter, and lecithin, which increase viscosity and cause the chocolate to develop a velvety smooth coating. With conching complete, the chocolate may be poured into blocks or molds and cooled before being packaged; at this point, it can be stored without any major problems for up to a year (10).

Tempering The process of heating and cooling chocolate to specific temperatures, making it more resistant to melting and imparting a smooth, glossy, hard finish.

Bloom An undesirable, fuzzy, grayish appearance on chocolate's surface due to the recrystallization of fat or sugar. It results from improper cooling, fat incompatibility, high humidity, or temperature fluctuations during storage.

CHEMIST'S CORNER 25-2

Tempering and Chocolate Melting Point

Cocoa butter can solidify into several different polymorphic shapes, meaning that it can take on several crystal forms. Table 25-4 shows the six possible crystal forms (I through VI), of which only one is stable (9). Each has its own unique melting point, and the stable form, Form V, has one of the higher melting points. The purpose of tempering is to encourage more of the cocoa butter crystals to change into the stable Form V through heating and cooling. Controlling crystal formation allows the crystals to pack tightly together (25). Slow rather than rapid cooling is recommended to avoid conversion back to an unstable form (25).

TABLE 25-4 Forms and Melting Points of Cocoa Butter

	Melting Point	
Crystal Form	°F	°C
Form I	63.1	17.3
Form II	73.9	23.3
Form III	77.9	25.3
Form IV	81.1	27.3
Form V	92.8	33.8
Form VI	97.7	36.3

How & Why?

Why does a grayish film sometimes form on chocolate?

The grayish bloom, which usually appears after the chocolate has been stored or allowed to get warm, is caused by one of two factors: (1) fat crystallizing onto the surface, or (2) moisture in the air reacting with the sugar on the surface (23). Fat bloom may be caused by improper crystallization; incorrect temperatures in heating or cooling; insufficient stirring; or inadequate conditions where the chocolate is prepared, such as less than optimal room temperatures, humidity, or drafts. It also may occur when the soft fat centers or added fats of candies are incompatible with cocoa. Even if the chocolate has been tempered well, it may bloom if stored for too long (9). Sugar bloom occurs when chocolate is stored under damp conditions (sugar in the chocolate absorbs water) and is then exposed to a drier environment (moisture on the surface evaporates, causing sugar to recrystallize on the surface) (23, 38).

Tempering

Chocolate may also undergo **tempering** before it is formed and packaged. The purpose is to develop an even, smooth color and a shiny gloss, an ability to contract in any mold, stability (so that it does not melt in your hands), and a longer shelf life (1). Proper tempering is also what gives high-quality chocolate that "snap" when bitten into or broken in half (Chemist's Corner 25-2). Untempered or improperly tempered chocolates may exhibit gray patches, or **bloom**, on their surface when hardened. Bloom is considered a defect in chocolate manufacturing not only because of its discoloration but also because it affects flavor (23).

The three basic steps in tempering chocolate are complete melting (122°F [50°C]), cooling to the point of crystallization (90°F [32°C]), and rewarming to convert any unstable crystals (84 to 88°F [29 to 31°C]) (32). Smaller chocolatiers complete the cooling step of this process by spreading the melted chocolate mixture back and forth over cooled marble until it starts to thicken. Whether performed by a

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TABLE 25-5 Confectionery Problems, Causes, and Solutions

Problems	Causes	Solutions
Soapy, rancid flavor	Lipase activity	Check incoming ingredients for off-flavors.
Burned, medicinal, fishy, or chemical taste	Oxidation of oils or fats during product storage	Minimize exposure to light and maintain cool temperatures. Check incoming ingredients for off-flavors.
Scorched or burned taste	Overheated sugar and milk solids	Control temperatures and times during heating and cooling.
Lack of brown color and flavor notes	Insufficient Maillard browning	Increase amount of milk products. Use a slower cooking process.
	Too little caramelization	Increase sugar content. Cook at higher temperatures and/or for longer times.
Poor caramel texture	Too thick or poor elasticity	Decrease milk protein level.
	Too thin	Increase milk protein level to increase viscosity.
Gritty or grainy texture	Change in sugar crystal type	Adjust balance or levels of sugar types for proper crystallization.
	Large sugar crystals formed	Reduce lactose content. Check seeding and agitation during heating and cooling.
	Sugar crystals formed on product surface	Optimize storage conditions (humidity and surface temperature) to prevent migration of fat and water to surface.
Bloom (white, dusty appearance)	Fats not in proper phase	Check melting temperatures and cooling temperatures and times. Check amount and type of seed materials to ensure proper tempering. Increase tempering time.
	Incompatible fats	Use fats with melting points that are appropriate for the processing conditions. Avoid lauric fats in coatings. Include milk fat in formula.
	Improper storage temperatures	Store at recommended temperatures (80 to 86°F/27 to 30°C).

machine or by hand, tempering promotes the formation of smaller crystals that act as seeds for further crystal growth. Ultimately, this results in a smoother chocolate with an increased melting point that is resistant to temperature changes.

Enrobing

Confectioners can use tempered chocolate as a liquid to **enrobe** candies and other foods such as ice cream bars, fruits such as raisins and strawberries, cookies, nuts, and doughnuts (37). The chocolate manufacturing industry often automates the enrobing process by pouring a sheet of molten chocolate over products placed on a moving belt (38). Chocolate can also be used to enrobe soft, high-fat centers such as truffles, nut pastes, and peanut butter (7).

Fat bloom can be distinguished from sugar bloom by its greasy feeling. Bloom and other problems of chocolate production along with several solutions to these problems are listed in Table 25-5.

Factors Affecting Tempering

The chocolate product selected, temperature, and timing are crucial factors in tempering. A certain amount of fat is needed to produce a smooth, glossy coating, so using the right chocolate is imperative. Baking chocolate and cocoa, for example, are too low in fat for dipping candies and will not respond to tempering. The weather also affects chocolate consistency; too much humidity can interfere with the solidification of the chocolate. Clear, cool days not exceeding 70°F (21°C) are preferred (31). A minimum of 1½ pounds of chocolate is required for tempering. Using any less than this amount will yield results that are too unpredictable with the rapid temperature changes that will be necessary to temper the chocolate (24). When used for coating candies, 1½ pounds of chocolate will cover about ninety ¾-inch centers (36). Prior to heating, the chocolate should be chopped or grated to allow for faster, more uniform melting. Chopping is easier if the chocolate is at room temperature and a clean, dry cutting board is used.

The three most common tempering methods are tabliering, seeding, and the cold-water method.

Tabliering Method

Melting the chocolate pieces is the first step in the tabliering technique. Chocolate is never melted over direct heat; a double boiler is used to keep temperatures from rising too high. A bowl placed over a saucepan of simmering water might also be used. The bowl should not touch the water and must be large enough to prevent steam escaping and condensing back onto the chocolate.

In either case, the chocolate is stirred constantly to promote melting and prevent burning. The spoon or spatula should be wooden or plastic because these materials are poor conductors of heat. A metal utensil will conduct heat away from surrounding areas of the chocolate. This cools the chocolate and makes the mixture more saturated. For the same reason, cold liquids in the form of milk, cream, or liqueur should never be added directly. This will also prevent lumping. On the other hand, melting the chocolate at too high a temperature or too quickly can scorch it or cause the cocoa butter to separate out, forming undesirable lumps.

When the temperature reaches about 115 to 120°F (46 to 49°C), it is kept there for about 30 minutes with continued stirring. The temperature should not be allowed to exceed 125°F (52°C). The chocolate is then cooled by removing it from the heat and placing one-third of it on a marble slab (Figure 25-8). It is scraped back and forth until it cools to just under 80°F (26°C), at which point, it will crystallize and thicken, signaling that it is to be added back to the other two-thirds. Then it is again warmed slowly to 85 to 90°F (29 to 32°C), where it reaches a consistency that can be worked. The entire process should be repeated if the

Enrobe To coat food with melted chocolate that hardens to form a solid casing.

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FIGURE 25-8 Further cooling and manipulation of chocolate.



Working chocolate on marble helps to keep it cool.

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FIGURE 25-9 Tempering chocolate for dipping.



Chocolate chopped for uniform melting.



Checking chocolate temperature.



Dipping item to be coated in chocolate.

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FIGURE 25-10 Coating foods with chocolate.

Raisins



Almonds



Pamela D. Maxwell/Shutterstock.com; oksana2010/Shutterstock.com

temperature is allowed to rise above 91°F (33°C) (24).

Seeding Method

Slight variations of the tabliering method have resulted in two other tempering techniques, the seeding and cold-water methods. In seeding, already tempered chocolate is melted in the double boiler but then removed from the heat source, at which time more unmelted tempered chocolate pieces are added. The chocolate is cooled to 80°F (26°C) and stirred for 2 minutes at this temperature before being warmed again to 85 to 90°F (29 to 32°C) (14).

Cold-Water Method

The cold-water method consists of placing the bowl of chocolate in a larger bowl of ice water to cool instead of pouring it onto a slab. The chocolate must be stirred as the bowl is lowered into the ice water because it starts to set immediately. As in the other methods, the chocolate is then rewarmed to 85 to 90°F (29 to 32°C) so that it can later be cooled and shaped.

Tempering for Chocolate Dipping

A slight variation is made in the tempering process if the chocolate is to be used for dipping fruits, nuts, or other items (Figure 25-9). After it reaches its maximum temperature, it is cooled to about 83 to 85°F (28 to 29°C), the ideal temperature for dipping. Items must be dipped quickly because the temperature range in which the chocolate stays at the right consistency is extremely narrow. It is kept from getting too cool by leaving it in the double boiler on reduced heat. After the items have been dipped, they are held up for a moment in the air, allowing the excess to drip off; then they are placed on wax paper in such a way that the hardening chocolate does not form an unsightly line or an undesirably large base. A broad base is caused by using too much chocolate or having the temperature too high.

Commercial Chocolate Coating

The food industry often enrobes (coats) nuts, raisins, and other small foods with chocolate (Figure 25-10). Chocolate is unique as a coating in that it solidifies on cooling rather than being absorbed by the food (8). Roasted nuts sprayed with chocolate yield a semi-rough surface. Their surfaces become smoother as the coated nuts tumble in the mixer. The glossy, shiny exterior of chocolate-covered nuts is often achieved by adding a natural gum to seal the chocolate, a shellac solution, and a final layer of edible wax.

Nontempered Coatings

The inconvenience of tempering and the risk of bloom can be entirely avoided by using **nontempered coatings**. Known as *coating chocolate, chocolate icing, confectionery coating*, or *nontemp chocolate*, these products are not true chocolates. The cocoa butter in nontemp chocolates has been replaced with other fats, such as hydrogenated palm kernel, lecithin, soy, or cottonseed oil. Nontempered coatings are available in white, milk, and dark chocolate flavors and are easier to use than tempered chocolate, but they fall

Nontempered coating A coating resembling chocolate that is not subject to bloom because it is made with fats other than cocoa butter.

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short of real chocolate in flavor and texture. They are accordingly reserved for use as glazes or decorations rather than as fillings or major ingredients (14). Their major benefit is that items can be dipped in them without the preparer having to follow the detailed, time- and temperature-dependent steps of tempering.

Types of Chocolate Products

Most chocolate products start with chocolate liquor. Chocolate manufacturers create different chocolates by adjusting how much cocoa butter and or other ingredients are added and how the mixture is manipulated. Chocolate confections are made by combining cocoa butter, cocoa powder, sweeteners, milk (sweetened condensed milk, whole milk powder, or evaporated milk), and other ingredients, such as nuts (9). Chocolate standards of identity have been established to define various chocolates, and chocolate products often contain more cocoa butter than cocoa powder.

Baking Chocolate

Baking chocolate is chocolate liquor that has cooled and solidified into cakes. It is also sold as bitter, unsweetened baking chocolate, but, in any form, it must have a chocolate liquor content of at least 35%. Other possible ingredients include sugar, cocoa butter, lecithin, and flavoring (24). Lecithin is often used in confections because it can replace some of the cocoa butter in chocolate bars (22).

Cocoa

Removing most of the cocoa butter from chocolate liquor results in cocoa. This reduces the fat content to less than 22% in cocoa, as compared to about 38% in eating chocolate and 50% in unsweetened baking chocolate (39). The lower fat proportion gives cocoa a very concentrated chocolate flavor. Cocoa is made by pressing much of the cocoa butter out of the heated liquor as it hardens into cakes. The cakes are then ground into cocoa powder that comes in a wide variety of colors, particle sizes, and flavors (37). Two main types of cocoa are available: natural cocoa, which is slightly acidic, and the less bitter cocoa, which may be called "alkalized," "Dutch-processed," or "Dutch cocoa." A Dutchman started one of the first hard-chocolate businesses by inventing the process of *Dutching,* which consists of treating crushed cocoa beans or chocolate liquor with an alkali (usually potassium carbonate or sodium carbonate) to raise the pH. This improves taste by decreasing bitterness (25). The degree of alkalization of the cocoa determines its color, which ranges from deep reddish brown to charcoal black. As the color darkens, the chocolate's flavor becomes more bitter and astringent (18). Europeans prefer the darker, reddish-colored Dutch cocoa for their recipes, whereas North Americans predominantly use natural cocoa.

Semisweet or Sweet Chocolate

Granulated sugar and extra cocoa butter are added to the chocolate liquor to produce the sweeter, smoother taste of semisweet or sweet chocolate. Semisweet chocolate must contain at least 15% chocolate liquor, whereas equal parts of chocolate liquor and sugar are present in sweet chocolate (24).

Milk Chocolate

Milk chocolate candy bars were first produced in 1875. A Swiss manufacturer added condensed milk to chocolate liquor and other ingredients. Condensed milk had just been invented by another Swiss, Henri Nestlé. A little over 25 years later, in 1903, Milton Hershey formed the first company to mass-produce milk chocolate in the United States, which later became the largest chocolate manufacturing plant in the world. The name of the Pennsylvania town where the factory was built was eventually changed to Hershey (14). Today, milk chocolate is the most frequently consumed type of chocolate in the United States (3).

Milk chocolate has a lighter color and sweeter, milder flavor than other chocolates. It is made like semisweet and sweet chocolate except that it contains less chocolate liquor (10% minimum), more granulated sugar, more cocoa butter, and dried whole-milk solids (12% minimum) (39). The milk is added in powder form to prevent the chocolate's consistency from becoming too liquid. At the molecular level, milk chocolate is a suspension in which the continuous phase is the cocoa butter and milk fat, whereas the dispersed phase consists of the cocoa, sugar, and nonfat milk solids (19).

Imitation Chocolate

Some or all of the cocoa fat is replaced with vegetable fat in imitation chocolates. These less costly versions of chocolate, which are also less likely to melt during the warmer summer months, are sometimes used to coat candies, ice cream bars, and crackers.

White Chocolate

Technically, white or ivory chocolate is not chocolate, nor is it recognized as such by the Food and Drug Administration (FDA), because it contains no chocolate liquor or cocoa (15). Its basic ingredients are sugar (no more than 55%), cocoa butter (at least 20%), milk, natural flavor, lecithin, and vanillin. Removing the cocoa butter from white chocolate results in *white coating* or *confectionery coating.*

Functional Chocolate

A new trend in chocolates is to maximize their health benefits (40). Although the high fat and sugar content of chocolates prohibits them from being labeled as *functional,* some manufacturers are

How & Why?

Why do various chocolates taste different?

The various types of chocolate just discussed, along with the ratio of added ingredients, affect flavor, but so do the origin of the cocoa bean and differences in roasting and alkalization techniques, which result in variations of cocoa powder colors, aromas, and flavors (5). The amount of chocolate liquor not only affects flavor—which becomes stronger as more chocolate liquor is added—but actually determines how chocolate is defined (4):

- Chocolate liquor or unsweetened, bitter, baking, or cooking chocolate = 100%
- Bittersweet or semisweet chocolate = not less than 35%
- Sweet chocolate = not less than 15%
- Milk chocolate = not less than 10%

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adding ingredients known to benefit health. For example, flavonols (antioxidants), fiber, and omega-3 fatty acids have been added to boost the benefits of chocolate (41). Dark chocolates are extolled for their higher antioxidant concentrations, derived from polyphenols, as compared to milk chocolate (11, 5). This is seen in labeling or advertisements highlighting the high percentage of cocoa. Low-carbohydrate chocolates made with less sugar are also available (16).

STORAGE OF CANDY

Storage requirements vary depending on the candy. Those lowest in water content, such as hard candies and brittle, keep indefinitely if properly wrapped because they do not support the growth of microorganisms. Extended storage and subsequent exposure to moisture in the air, however, can cause their surfaces to become gummy. Candies such as fudge and fondant, which have a higher moisture content, get softer and smoother in texture if left in an airtight container, but after about a day, a graininess develops as the sugar crystals become larger. Ingredients other than sugar, such as fat or milk products, are subject to rancidity, which results in off-flavors and odors; however, this degradation can be delayed by refrigeration or freezing. Ingredients that improve shelf life include humectants, which act to hold moisture. Common humectants incorporated into candies include glycerin (glycerol), sorbitol, pectins, and gums (34).

Shelf Life of Chocolate

Chocolates can stay on the shelf for over a year as long as they are not subjected to wide fluctuations in temperature and humidity. The exceptions are milk and white chocolates, which have slightly shorter shelf lives of about 8 months to 1 year because of their milk content.

In order to maximize its shelf life, chocolate should be properly wrapped and stored in a cool, dark place, the ideal temperature being 65°F (18°C) with the humidity at 50% (24). Even slight melting may result in fat bloom as the cocoa butter crystals form a grayish or whitish film on the chocolate's surface. Sugar bloom, which is rougher in appearance and texture, can result under conditions of high humidity.

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PICTORIAL SUMMARY / 25: Candy

The United States produces more candy than any other country in the world. Americans eat an astonishing 25.5 pounds of confectioneries per person per year, with a little over half of this in the form of chocolate.

CLASSIFICATION OF CANDIES

The thousands of different candies can be classified according to their ingredients and/or preparation method.

Classification by Ingredients

Syrup phase (or sugar phase): Most candies fall into this category; they are made from a simple syrup, which is a mixture of boiled sugar and water. Composed of sugar and flavorings, syrup-phase candies include the following:

- Hard candy
- Nougats
- Caramels
- Marshmallows
- Jelly beans
- Gums
- Fudges
- Fondants





Fat phase: When chocolate and/or peanut butter are added, the candy is considered fat phase.

Combination of both fat and syrup phases can be found, for example, in a chocolate-covered nougat candy bar.

Classification by Preparation Method

Crystalline candies, which are soft, smooth, and creamy, are formed from sugar solutions yielding many fine, small crystals. They include fudge, fondant, and divinity.

Noncrystalline candies are formed from sugar solutions that did not crystallize and are amorphous, or without form. They include caramel, toffee, hard candy, and gummy candies.



PREPARATION OF CANDY

The art of confectionery production, highly sensitive to timing, temperature, and skill, requires patience and practice.

The preparation of many, but not all, confections can be generally summarized by four basic steps:

1. Creating a syrup solution
2. Heating this mixture to concentrate the contents through evaporation

These steps are basically the same for crystalline and noncrystalline candies.

3. Cooling
4. Beating or leaving undisturbed

Crystalline candies: Goal is to form sugar crystals, so the mixture is rapidly cooled and beaten.

Noncrystalline candies: Goal is to avoid the formation of sugar crystals, so the mixture is cooled slowly, without agitation.

CHOCOLATE

Chocolate from the tropical cacao tree is the main ingredient of many different types of candies. Cacao beans are ground very fine and heated to yield chocolate liquor, the basic ingredient for all chocolate products—cocoa, baking chocolate, milk chocolate, semisweet chocolate, and sweet chocolate. Other ingredients can include cocoa butter, sugar, milk products, and flavorings.



STORAGE OF CANDY

Candies lowest in water content (hard candies/brittle) keep the longest if properly wrapped; however, extended storage times or exposure to moisture can cause their surfaces to become gummy. Fat or milk added to candies makes them prone to rancidity, but refrigeration or freezing delays this process. Humectants added to candies improve their shelf life.

Chocolates can stay on the shelf for over a year, except for milk and white chocolates, which last about 8 months to 1 year. All chocolate should be properly wrapped and stored in a cool (65°F [18°C]; humidity, 50%), dark place. Unsightly grayish or whitish film observed on a chocolate's surface is "bloom," which results from either fat or sugar crystallizing on the surface.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Fudge is classified as a _____ candy.
   a. noncrystalline
   b. crystalline
   c. divinity
   d. hard

2. The size of the sugar crystals is determined by the rate or speed of _____ formation.
   a. nuclei
   b. fat crystal
   c. syrup
   d. invertase

3. Identify the correct order of steps, from beginning to end, for preparing creamy crystalline candy.
   a. Cooling, beating, heating, creating a syrup solution
   b. Creating a syrup solution, heating, cooling, beating
   c. Beating, heating, cooling, creating a syrup solution
   d. Creating a syrup solution, heating, beating, cooling

4. Which ingredient is used to ensure that the sugar does not crystallize when preparing noncrystalline candies?
   a. Emulsifiers
   b. Sugars
   c. Interfering agents
   d. Seeds

5. What is the name of the process by which warmed chocolate is kneaded and aerated by machines for several days?
   a. Blooming
   b. Enrobing
   c. Tempering
   d. Conching

6. The process of heating and cooling chocolate to make it shiny and more resistant to melting is called _____ .
   a. conching
   b. seeding
   c. tempering
   d. blooming

7. White chocolate is technically not chocolate because it does not contain:
   a. Invert sugar
   b. Chocolate liquor or cocoa
   c. Cocoa butter
   d. Conched chocolate

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Many (but not all) candies can be prepared by using which four basic steps?
2. How do the principles of preparation differ for crystalline and noncrystalline candies? Give examples of each type of candy.
3. Why is glucose, invert sugar, or corn syrup added to sucrose when making crystalline candies? What happens if too much is added?
4. Describe the influences of the following factors on crystalline candy formation: overheating, underheating, and weather.
5. Explain the proper use of a candy thermometer, including how to check the thermometer for accuracy, how to immerse it in the mixture, and how to read the thermometer.
6. How do beating and cooling the syrup solution affect the formation of crystals in candy?
7. List several examples of interfering agents used in the preparation of noncrystalline candies. How does each one inhibit crystallization?
8. Explain how the following products differ according to the amount of cocoa and other ingredients they contain: baking chocolate, cocoa, milk chocolate, imitation chocolate, and white chocolate.
9. Discuss the processes of conching and tempering in the production of chocolate, and describe their desired results.
10. What are the possible causes of the following problems associated with candy preparation: rancid flavor, lack of brown color, and gritty texture?

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26



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Frozen Desserts

Types of Frozen Desserts 505
Preparation of Frozen Desserts 508
Storage of Frozen Desserts 514

Frozen desserts have remained popular through the ages. One of the earliest known frozen desserts was made with winter snow (from the mountains of what is now Turkey) mixed with fruit and drizzled with molasses. In AD 62, the Roman emperor Nero sent slaves to the mountains to retrieve ice, which was then flavored with nectar, fruit pulp, and honey to be enjoyed by him and his court. Marco Polo brought the formula for water ices to Europe from Asia, where they had been enjoyed for at least a thousand years. George Washington and Thomas Jefferson were both reputed to have made ice cream in their homes, and Dolly Madison is known to have served ice cream at the White house in 1812 (31). By 1840, ice cream had moved from palaces and mansions to the streets of America's largest cities. The ice cream scoop was invented 66 years later, and, by 1921, ice cream was served to immigrants arriving on Ellis Island as part of their first American meal. Now global consumption of ice cream and other frozen desserts is greater than ever.

TYPES OF FROZEN DESSERTS

Ice cream and other commercially frozen desserts, from simple water ices to elaborate ice cream cakes, are probably the most commonly consumed desserts in North America. Newer frozen desserts or modifications of old ones appear on the market regularly in the form of pies, mousses, cakes, parfaits, pudding sticks, frozen yogurt, popsicles, and new flavors of ice cream.

What makes one frozen dessert different from another is the ingredients, especially the type and proportion of fat (milk fat) and milk solids-not-fat (MSNF)—proteins and lactose. In the United States, the government regulates the names of frozen desserts based on the types and quantities of ingredients that go into them. Another factor that differentiates desserts is the way in which these and other ingredients are combined. Common ingredients other than milk fat and MSNF include sugar, **stabilizers** (gums), emulsifiers, water, air, and flavorings. Ice cream, imitation ice cream, frozen yogurt, sherbet, sorbets, water ices, and still-frozen desserts, their ingredients, and their preparation are the subjects of this chapter.

Stabilizer A compound such as vegetable gum that attracts water and interferes with ice crystal formation, resulting in a smoother consistency in frozen desserts.

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FIGURE 26-1 Ice cream is the most popular of the frozen desserts—and also the highest in fat.



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TABLE 26-1 Types of Ice Cream

Dessert	Description
Bombe	A decorative dessert of two or more different ice cream flavors layered in a mold.
Frozen custard	Also known as French ice cream; has a higher percentage of egg yolks (1.4% egg-yolk solids) and cream than standard ice cream.
Ice cream	Frozen mixture of dairy ingredients containing at least 10% milk fat and weighing at least 4.5 pounds per gallon. Marketing terms include regular ice cream, economy ice cream (lower price), premium ice cream (higher fat content), and super-premium ice cream (high fat content—at least 12% milk fat, but 16–18% preferred—and the best ingredients).
Ice cream cone	Born at the 1904 St. Louis World's Fair, when a vendor selling ice cream ran out of dishes and created a "cup" from waffles being sold at a nearby stand.
Light ice cream	Contains 50% less total fat or 33% fewer kcalories than regular ice cream.
Low-fat ice cream	Contains no more than 3 grams of total fat per serving.
Neapolitan	Alternating lengthwise layers of 2 to 4 ice cream flavors.
Nonfat ice cream	Contains no more than 0.5 gram of total fat per serving.
Parfait	Alternating layers of ice cream and fruit or syrup in a tall, slender glass.
Reduced-fat ice cream	Contains at least 25% less total fat than regular ice cream.
Sundae	Ice cream topped with syrup, nuts, whipped cream, and a cherry. There are many stories about its origin; one is that when ice cream became illegal to sell on Sunday (blue laws) in the United States, vendors got around this law by adding chocolate, nuts, and whipped cream so that it was not called ice cream.

Ice Cream

Although ice cream sales are at an all-time low because people are pursuing healthful trends (8), Americans consume more ice cream than any other nation in the world, undeterred by the fact that it is the frozen dessert with the highest fat content (Figure 26-1). The many variations of ice cream and some of their compositions are described in Table 26-1. Ice cream is a food prepared by simultaneously stirring and freezing a pasteurized mix of dairy (milk, cream, butterfat, MSNF, etc.) and nondairy ingredients (sweeteners, stabilizers, emulsifiers, possibly eggs, colors, and flavors) (Chemist's Corner 26-1).

Body The consistency of frozen desserts as measured by their firmness, richness, viscosity, and resistance to melting.

CHEMIST'S CORNER 26-1

The Chemistry of Ice Cream

Ice cream is a colloid food foam consisting of frozen ice crystals, air bubbles surrounded with fat globules and coated with an emulsified protein layer, and an unfrozen liquid phase containing sugars and salts in solution (23).

Ice Cream Ingredients

Federal and state regulations determine the minimum levels of fat and MSNF for many frozen desserts (29). Legal definitions for ice cream differ among countries, but in the United States, by law, regular ice cream must contain at least 10% milk fat (by weight) to be called *ice cream*. Some super-premium brands of ice cream have up to 20% milk fat, making them very rich and creamy. The legal definition prevents manufacturers from using less cream to reduce their costs, while still claiming that their product is ice *cream*. Another ingredient, other than milk fat, that must be included in ice cream is MSNF; the amount varies depending on the percentage of milk fat (3). Less MSNF content is required for ice creams made with bulky flavoring ingredients such as chocolate or fruit (36). The amount of MSNF is important because it influences ice cream's flavor, **body**, texture, dispensing qualities, shelf life, and nutritive value, specifically in terms of protein, B vitamins, vitamin A, and calcium (3).

Vegetable fats are often used in other countries, but in the United States, it has to be milk fat. Milk fat in frozen desserts comes primarily from milk products such as cream, butter (unsalted), sweetened condensed milk, or whole milk. The egg yolk that is used in some ice cream may be an additional source of fat and also provides cholesterol, as do cream and butterfat.

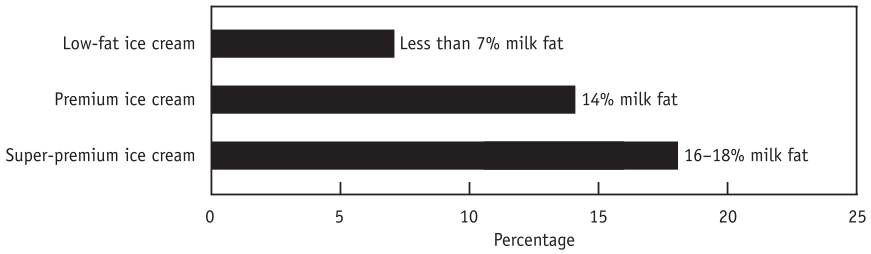
The percent milk fat differentiates low-fat (formerly called "ice milk"), premium, and super-premium ice creams from one another (Figure 26-2). Expensive ice cream brands labeled "premium" and "super premium" are denser, smoother, richer, and higher in kcalories because they use heavier cream than that used in standard ice

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FIGURE 26-2 Percent milk fat in low-fat, premium, and super-premium ice creams.



cream. Because milk fat is the most expensive ingredient, the more that is used, the higher the frozen dessert's cost. Other ingredients usually found in ice cream include eggs, sugar, stabilizers (gums, gelatin), flavoring, and coloring. When real cocoa or other forms of chocolate are added, the fat content rises even higher.

Low-Fat Ice Cream

Low-fat ice cream, once called "ice milk," usually contains more sugar than milk (by weight) and less fat. Low-fat ice cream was first introduced during the Great Depression as a lower-cost alternative to ice cream (22).

Aiming to encourage lower-fat eating patterns, the Food and Drug Administration (FDA) exempts low-fat ice creams from the 10% milk fat requirement. The FDA's definitions for commercial low-fat ice creams are based on comparisons of equal quantities of the referenced products with either an average of the leading regular brands or the company's own brand (35):

- "Reduced-fat" ice cream: at least 25% less fat than the original product
- "Light" ice cream: 50% less fat or 33% fewer kcalories per serving
- "Low-fat" ice cream: less than 3 grams of fat per serving
- "Nonfat" (fat-free) ice cream: less than 0.5 grams fat per serving

Ice Cream as a Functional Food

The increased attention toward healthier lifestyles has inspired product development in the ice cream arena. Some manufacturers are offering ice creams with vegetable flavors—cucumber, carrot, pumpkin, and beet. Blueberries, known for their possible health benefits for the heart, eyes, and brain (memory), are becoming a popular flavor in frozen desserts. Although ice cream manufacturers have been slower to introduce herbal extracts into their products, researchers have experimented with adding green or herbal tea or their extracts to ice cream to increase their phenolic content (4, 33). In addition, ice creams have been fortified with probiotics, prebiotics such as inulin, dietary fiber, polyunsaturated (omega-3 and -6) fatty acids, and minerals (1, 33). Antioxidants can be added through the use of vanilla or natural fruits and fruit extracts (33). Low-carbohydrate, lactose-free, sugar-free, and other nutrient-modified ice creams are also offered to accommodate dietary needs or habits (6).

Imitation Ice Cream

Replacing the milk fat and MSNF in ice cream with other ingredients results in imitation ice cream. Mellorine is a frozen dessert similar to ice cream except that the milk fat has been replaced with other fats, usually vegetable fat. Another type of imitation ice cream contains soybean products such as tofu, soy protein, or soy isolate, and milk fat is usually replaced by corn oil. Parevine is a frozen dessert that is free of any milk fat or MSNF and meets the kosher requirements set by Jewish food laws (26). An example would be a frozen dessert made with tofu. Frozen desserts made for diabetics usually replace the sucrose with sorbitol.

Gelato

Gelato is the Italian word for "ice cream" (7). Just as there are many ways to make ice cream, there are also numerous methods of producing gelato. As a result of these differing preparation methods, gelato tends to be creamier in the north of Italy but icier in the south of the country. Gelato is more smooth and creamy than ice cream because it is denser—it contains less cream and more milk (milk incorporates less air than cream)—is churned more slowly, and is served at higher temperatures.

Frozen Yogurt

Frozen yogurt represents a small but noteworthy segment of the retail frozen desserts market—most large frozen dessert manufacturers offer frozen yogurt products (18). The increasing demand for frozen yogurt (Figure 26-3) is due in part to its taste, texture, lower fat content, "good-for-you" image, and effective marketing strategies (11). Most frozen yogurt contains no live yogurt cultures, although some manufacturers ensure that live and active cultures are present.

Sherbet

Sherbets (often incorrectly pronounced *sherberts* in American English) fall into a category of frozen desserts separate from ice cream (Table 26-2). The base of these frozen desserts is iced, sweetened fruit juice or puree, so their fat content is lower than that of low-fat ice cream. The law states that they must contain less than 2% milk fat. Sherbets are often made with egg whites and/or

FIGURE 26-3 Frozen yogurt is a popular dessert.



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TABLE 26-2 Types of Non–Ice Cream Frozen Desserts

Dessert	Description
Frozen yogurt	Frozen dessert made from a cultured dairy product with added sweeteners and flavors.
Gelato	Frozen dessert with intense flavor and colors. It contains sugar, milk, cream, egg yolks, and flavoring.
Granita	A frozen fruit slush (sugar, water, and flavorings) popular in Italy.
Mellorine	A product made without milk fat. Other fats from either animal or vegetable sources can be used as long as fat content is not less than 6%.
Mousse	A French term meaning "foam" or "froth" and used to describe an airy, rich dish that can be hot, cold, or frozen. The dish can be a savory main meal (meat, fish, shellfish, cheese, or vegetables) or a dessert that is cold or frozen. The fluffy texture is from either whipped cream or egg whites, and its structure is often strengthened by adding gelatin.
Sherbet	Frozen dessert containing less than 2% milk fat and often more sugar than ice cream.
Sorbet	Similar to sherbet, but it contains no dairy, fat, egg, or gelatin ingredients.
Still-frozen desserts	Frozen desserts not stirred during freezing—mousses, bombes, and parfaits.
Tofu-based	Tofu is the foundation of this dairy-free dessert.
Water ice (glacé)	Frozen dessert made from sweetened water and fruit juice.

gelatin to give them a creamy consistency. To compensate for the loss of body resulting from less fat, more sugar is added to the basic milk and fruit juice mixture. This makes sherbet's kcalorie content similar to and sometimes higher than that of ice cream (Figure 26-4).

Sorbet

Sorbets differ from sherbets in that they are made without fat, eggs, gelatin, or dairy products (MSNF). This yields a harder consistency than that of either ice cream or sherbet. Sorbets consist of pureed fruit or fruit flavoring and a sugar syrup made of equal amounts of sugar and water simmered together. Countless flavors are possible and include any of the fruits or combinations thereof.

Water Ices

Water ices (glacés), made from a base of sweetened water and fruit juice, lack both fat and MSNF. They may contain gelatin, vegetable gums, egg whites, flavorings, and/or colorings.

Popsicles

Popsicles are water ices that evolved from frozen lemonade on a stick (25).

Granitas and Granités

The word *granités* is often used interchangeably with *granitas*. Granitas are technically frozen fruit slushes, shaved ice, or beverages and not frozen desserts. *Granita* comes from the Italian word meaning "grainy" (30). Granités from Italy are flavored ices that contain fruit and are quickly frozen to promote the formation of the large ice crystals that give them a rough texture. They are generally stirred a few times during freezing to further promote large crystalline formation. Although made from a similar mixture, they are different from granitas in that they are frozen solid.

Frappés

A frappé is another type of ice dessert that is crushed and served as a slush after it is frozen.

Still-Frozen Desserts

A still-frozen dessert is one that is not stirred during freezing. Examples include mousses, bombes, and parfaits. The light, airy, smooth, velvety texture of these desserts comes from the incorporation of whipped egg whites or whipped cream into the mixture. The foam structure acts as a physical barrier, preventing large ice crystals from forming.

PREPARATION OF FROZEN DESSERTS

The preparation of frozen desserts can be very time-consuming, whereas commercial frozen desserts are convenient and widely available. Thus, food-service establishments and individuals do not routinely prepare ice cream or other frozen desserts. Some frozen desserts, however, do lend themselves to preparation on certain occasions, and this section discusses that option.

Factors Affecting Quality

The structure of frozen desserts depends on the crystallization of water from a sugar mixture (29). The ice crystals in many frozen desserts are made by either churning (agitating) a mixture while it is in the process of freezing or placing it in a mold where it is allowed to freeze (2). The three general factors crucial to the quality of frozen desserts are flavor, texture, and body.

Flavor

When making frozen desserts, it is important to remember that cold temperatures mute flavors, so the mixture must be boldly flavored before freezing. The number of possible flavors that may be added to the foundation mixture of frozen desserts is almost limitless. When it comes to ice cream, however, vanilla is the most popular followed by chocolate chip mint, and cookies and cream (6). Other flavor choices include, but are certainly not limited to, strawberry, butter pecan, Neapolitan, cherry, peach, pineapple, orange, raspberry, and coffee. Flavor may be further enhanced by the addition of nuts, candies, cookies, and other ingredients.

Texture

A smooth texture is preferred in most frozen desserts, with the exception of frozen ices and granités. All are crystalline products whose textures are dependent on the formation of ice crystals. The size of the ice crystals determines the smoothness of the frozen dessert: The smaller and more evenly distributed these crystals are, the smoother and creamier the texture will be. Larger crystals yield a coarser (grainy) texture (21). How is ice crystal size determined? It is directly related to the number of nuclei. The greater the number of nuclei present, the smaller the crystal size, and the smoother the consistency (12). Other factors determining texture are the

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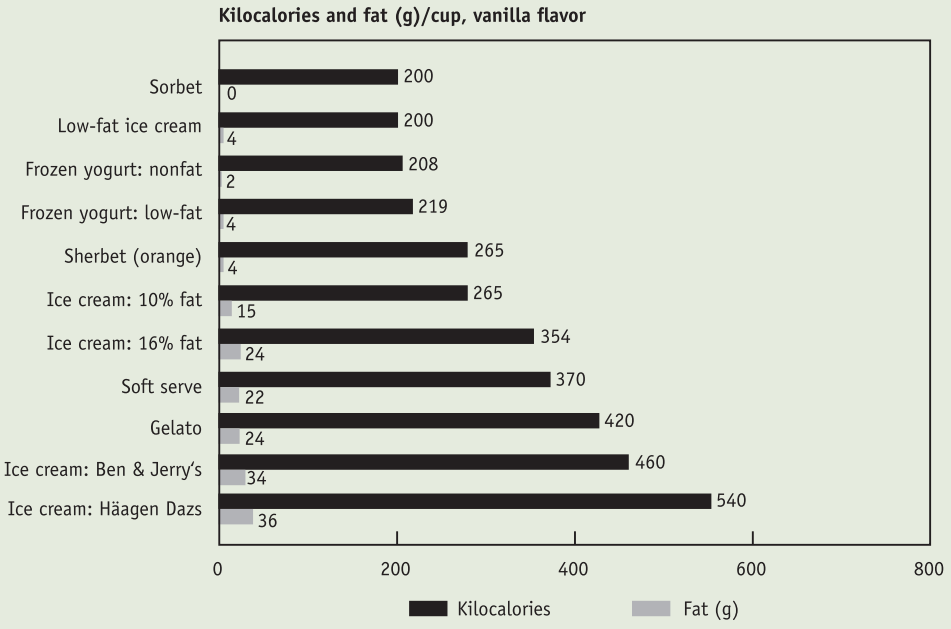
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CALORIE CONTROL
Frozen Desserts

The frozen desserts listed in Figure 26-4 **average approximately 300 kcalories for each cup** but **range widely from 200 to 540** kcalories. Thus, eating frozen desserts daily can add on the pounds. To enjoy desserts without exceeding kcalorie limits, do the following:

- **Practice portion control.** Satisfy the sweet tooth with a ½-cup serving. If you splurge, stick to one cup or large scoop (300 kcalories), not two (600 kcalories) or three (900 kcalories).
- **Choose lower-kcalorie toppings.** Opt for fruit and sprinkles over nuts, whipped cream, or sauces (caramel, chocolate) that deliver 50 to 100 kcalories for each ounce. Chocolate and caramel syrups, though fat-free, provide 54 and 50 kcalories per tablespoon, respectively; whipped cream provides 25 kcalories and 3 grams of fat per tablespoon.
- **Try popsicles or smaller ice cream bars.** They average about 100 to 150 kcalories each (read the Nutrition Facts label).
- **Choose a lower-kcalorie dessert.** Go light on premium ice creams. Soft serve appears "light" but is actually higher in kcalories than regular ice cream. Gelato delivers 420 kcalories and 24 grams of fat for each cup. Sherbet may be lower in fat than ice cream, but it has a higher sugar content, so the kcalorie counts are nearly the same. Frozen yogurt is not kcalorie free. Brands differ, so read the Nutrition Facts labels.

FIGURE 26-4 Kilocalories and fat in frozen desserts (per cup).



© 2010 Amy Brown

frozen dessert's content of MSNF, fat, sugar, and other substances. About 50% of the total solids in ice cream and many other frozen desserts consist of dairy products (15).

Sugars lower the freezing temperature of water, so lower-fat ice cream, sherbet, and water ices, which all contain more sugar and less fat, feel harder and colder on the tongue than ice cream. Monosaccharides lower the freezing point even more than sucrose; consequently, corn syrup and dextrose (glucose) are commonly added to commercial frozen desserts (29). The freezing point is lowered with added sugar so that the ice cream mixture does not freeze completely. Otherwise, ice cream could not be scooped. The semisoftness of ice cream is maintained because as the water freezes, the other ingredients become more concentrated, preventing the frozen dessert from freezing into a solid block of ice.

Other factors contributing to texture are air cells, emulsifiers, and the type of treatment. Ice cream is a foam of air cells, each surrounded by a layer of fat coated with emulsified protein films, and a network of ice crystals (Figure 26-5). The millions of air cells found in every bite of ice cream make the frozen mixture light and airy.

Emulsifiers/surfactants such as monoglycerides and diglycerides, egg yolk, and/or lecithin are often added to

How & Why?

Why is MSNF sometimes added to frozen desserts?

One reason MSNF or fat is added to frozen desserts is to help produce a smooth texture (9). The addition of MSNF results in smaller ice crystals, tinier air cells, and thinner air cell walls. Fat assists in separating water molecules and coating the frozen crystals to create the sensation of smoothness (28). Use of excess MSNF, however, produces a sandy texture because of the precipitation of lactose, the least soluble of sugars (9).

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FIGURE 26-5 The structure of ice cream. Ice cream is a foam of air bubbles trapped in frozen liquid. The liquid contains the dissolved sugar and milk solids.

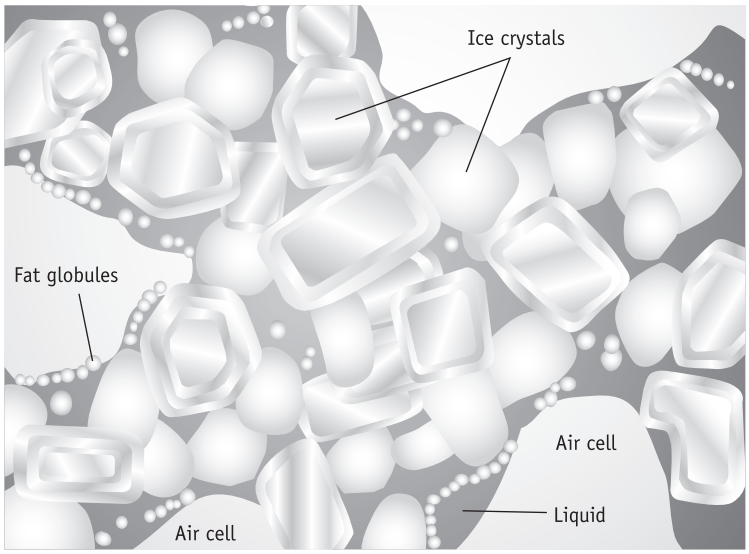
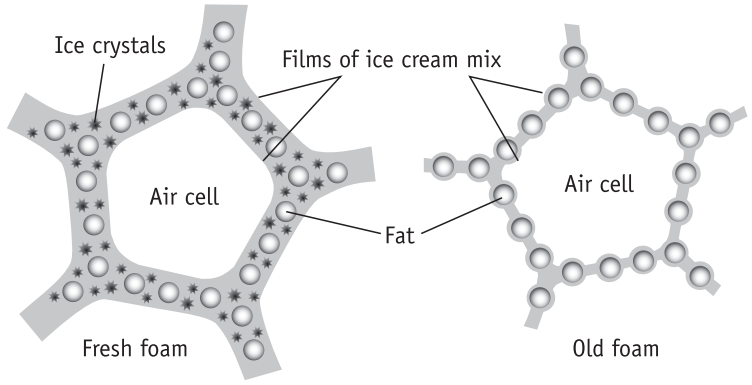


FIGURE 26-6 Why ice cream shrinks as it ages.



create a smoother texture by stabilizing the dispersion of air in the foam (28). Rapid freezing and correct storage temperatures also contribute to the smooth texture of frozen desserts. Commercial ice creams are aged (held at refrigerator temperatures for a given period of time). Glycerol monostearate (GMS) may be added to destabilize the emulsion by displacing protein from the fat globules, allowing them to partially aggregate. This results in a smooth texture and more resistance to melting (10).

Heat shock Repeated cycles of temperature fluctuations between cold and warm that cause larger ice crystal growth, reducing the quality of frozen desserts.

Body

Commercial ice cream has more body than homemade ice cream because of the added stabilizers (no more than 0.5%). These include gelatin and vegetable gums such as sodium carboxymethylcellulose (CMC), carrageenan, guar gum, agar, acacia, alginate, furcelleran, karaya, locust bean, tragacanth, and xanthan (37). These food additives (see Appendix E and Chapter 29) are primarily of natural origin, although a few are chemically modified. The food industry uses gums because they contribute to body, resistance to melting, viscosity, and reduced ice crystal formation during storage (21). Stabilizers are common ingredients in frozen desserts because they produce a smooth body and texture. They work by attaching to any water that is freed from the melting ice crystals during an increase in temperature such as the opening of a freezer door. The water bound to gums cannot attach to existing ice crystals and make them larger, which would adversely affect quality (19). The use of stabilizers also reduces the amount of cream needed to maintain body, which reduces production costs. Using less cream also results in fewer kcalories, which appeals to dieters.

Ice Cream Shrinks as It Ages

The volume of ice cream shrinks as it ages because of the collapsing films around the air cells (Figure 26-6). Another cause of shrinkage is mechanical compaction caused by a dipper being pressed against ice cream during scooping (31).

Heat Shock

One of the biggest problems for ice cream manufacturers is **heat shock**. After ice cream is produced, its ice crystals continue to grow until they eventually become detectable within the mouth and/or visible around the edge of the ice cream (32). The quality shifts from smooth and creamy to rough and slightly off-flavored. Ice crystals cannot be detected in new ice cream because they are numerous and small.

Recrystallization

During storage, however, they undergo recrystallization, a process that affects changes in their number, size, and shape. Two processes are involved in recrystallization. The first is *accretion* where two more adjacent crystals form a larger crystal. The second is *migration* where with each temperature increase, some smaller ice crystals "disappear" or become liquid and move toward the surface of the larger crystals, which keep growing (21). The number-one way to prevent recrystallization is to avoid heat shock (27). Heat shock can be prevented by freezing the ice cream quickly and avoiding temperature fluctuations during storage and transport. Stabilizers are often added to ice cream to combat heat shock by entrapping melted water so that it cannot contribute to the creation of larger ice crystals.

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Overrun

The purpose for pumping air into the original frozen dessert mixture to expand it and create **overrun** is twofold (23). The first reason is that it improves body by making it softer and creamier. The numerous small air cells created by overrun prevent the ice cream from being too hard, dense, or cold. This is one of the reasons why homemade ice cream has a harder consistency than commercial ice cream. The overrun for commercial ice cream is usually 70 to 100% (31). A 100% overrun means that the volume of air is equal to the volume of the mix before it was churned. Too much overrun damages body by creating a foamy texture, but too little results in heavy, compact ice cream with a coarse texture. The finest ice creams have between 3% and 15% overrun.

The second reason is that maximizing product volume is economically advantageous; however, excessive overruns are prevented by federal standards that protect customers by setting the minimum weight for ice cream at 4.5 pounds per gallon (the exception is reduced-fat ice cream at 4 pounds per gallon) (16). Ice cream with lower overrun and higher fat content is classified as premium ice cream, whereas very low overruns, higher fat content, and the best ingredients constitute super-premium ice cream (5). Overruns greater than 150% are possible if more stabilizers and emulsifiers are added, but the product is then classified as a "frozen dairy dessert" instead of ice cream.

Mixing and Freezing

Ice Cream

Commercial mixes are used by the food industry to produce many different kinds of ice cream (Figure 26-7). Cream is the main ingredient; this provides a smooth mouthfeel. In addition, sugar and flavorings such as vanilla bean, chocolate, strawberry, mint, pistachio, candy, cookie pieces, brownie chunks, and caramel or chocolate sauce are added.

Cooked versus Uncooked Ice Cream

A basic custard serves at the base for cooked ice creams. Custards are created by stirring egg yolks into milk, sugar, and cream over low heat. More specifically, the cream is heated to scalding, and the eggs and sugar are beaten into a smooth paste and then added to the cream. The mixture is then heated until it thickens while being stirred constantly with a whisk or wooden spoon. The mixture should be heated to at least 180°F (82°C) to protect against the growth of any *Salmonella* that may be present. The mixture is removed from the heat before the flavoring agents are added. The addition of flavorings may be delayed until after the ice cream has been churned (see following) and is still soft to prevent the breakage of ingredients such as nuts and chocolate chunks. The ice cream mixture is cooled for several hours or overnight in the refrigerator before it is processed into a frozen product.

Uncooked ice cream can bypass the cooking and refrigeration stage. Care should be taken to ensure that only pasteurized products are used in either cooked or uncooked ice cream to reduce the risk of foodborne illness. The consistency of uncooked ice cream is closer to that of sherbet, which has a grainier consistency. This can be compensated for to some degree by using thick fruit pulp (17). Food safety guidelines dictate that uncooked ice cream, commercial or homemade, should never be prepared with raw eggs because of the risk of *Salmonella* foodborne illness.

Flavorings

Whether it is cooked or uncooked, the number and combination of flavorings added to ice cream continues to grow (Table 26-3). If fruit is used for flavoring, it should first be combined with a sugar syrup or liqueur to eliminate the unpleasant effect of solidly frozen fruit chunks on the texture. The acidity of fruit flavors is balanced by sugar; thus, twice the amount of sugar used for ice cream is usually added to frozen desserts such as fruit sherbets (34).

Heating and Aging

Commercial preparation of ice cream consists of combining the liquid ingredients in a mixing vat, where they are heated to 104°F (43°C), warm enough to dissolve the added sugar and other dry ingredients. The ice cream mix is pasteurized and homogenized; the latter improves the overall texture and body of ice cream. Commercial mixes are then aged from 3 to 24 hours at 40°F (4.4°C) in vats. During this stage, several beneficial changes take place: (1) the fat solidifies; (2) there is a swelling of milk proteins, gelatin, and other stabilizers, which increases the viscosity of the mix; and (3) smoother texture, improved body, and resistance to melting also result (31).

FIGURE 26-7 Making a frozen dessert from a commercial mix.



A complete mix comes all ready to just add water and blend. It can be combined with hundreds of flavors to produce an endless variety of ice cream desserts. The reconstituted mix is transferred to the freezer equipment.



RossHelen/Shutterstock.com

Ready to serve.

Churning and Freezing

After being aged, ice cream mixes are ready to be frozen. The ingredients are churned during freezing for several reasons. Churning promotes the formation of the numerous small ice crystal nuclei necessary for a smooth, velvety texture. The second reason to whip the mixture is to partially disrupt the membranes of the homogenized (smaller and separated) fat globules and encourage them to rejoin with similarly disrupted fat globules to form a larger mass that is detected by the consumer as "creamier" (Figure 26-8). It also aids in the incorporation of air to increase volume.

Overrun The volume of a frozen dessert over and above the volume of the liquid mixture from which it was produced; this increase in volume results from the incorporation of air during freezing.

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TABLE 26-3 Ice Cream Flavorings

The number of flavorings added to ice creams continues to grow.

Flavoring	Examples
Fruit	Strawberry, peach, mango, kiwi, lemon, orange, dried fruit (raisins), jam, etc.
Nuts	Walnut, peanut, almond, pistachio, pecan, etc.
Chocolate	Chips, shavings, chunks
Beverages	Coffee, tea, rum
Candy/Cookies	Marshmallow, candy bar pieces, gum, cookie dough
Spices	Ginger, cinnamon, mint, lavender

Source: Adapted from Lebowitz D. Scooped: One easy method, countless incredible ice creams. *Fine Cooking* 99:46–53, 2009.

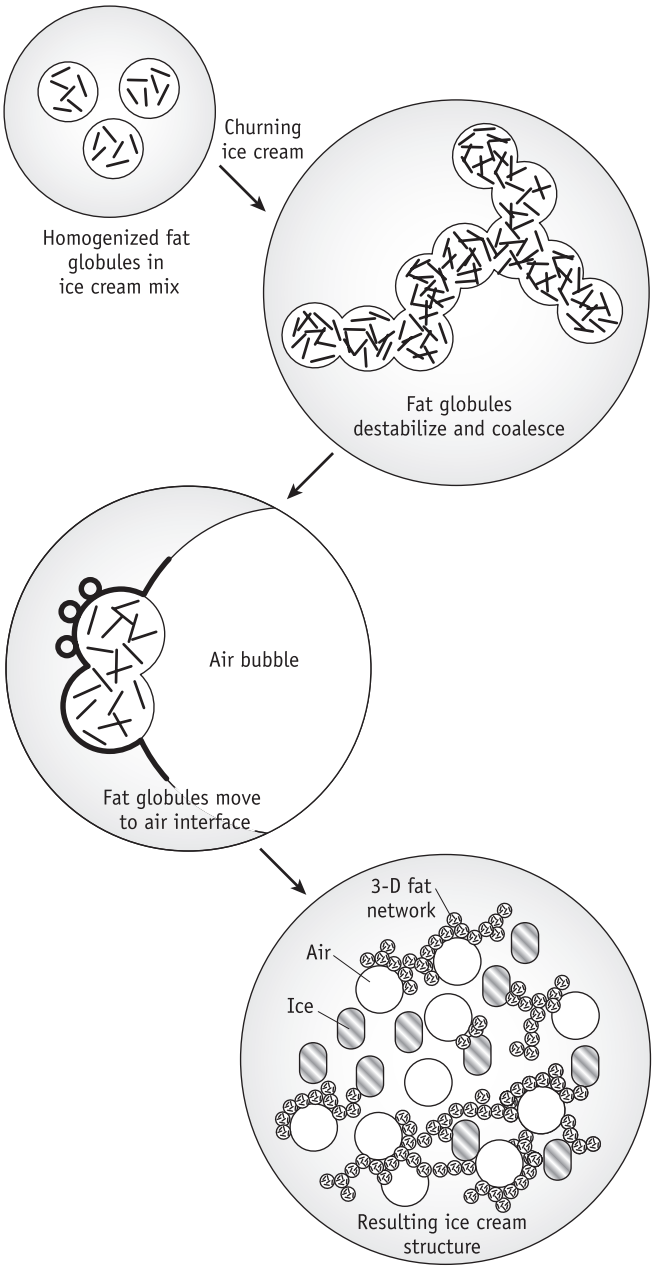
The two major noncommercial methods for mixing ice cream ingredients are the electric mixer method (ice cream machine) and the old-fashioned hand-cranking method. In both methods, the ice cream freezer canister is filled only two-thirds full to allow for the natural expansion that occurs with freezing (water expands when frozen) and the incorporation of air during churning. This container, equipped with a dasher for rotating the mixture, is traditionally surrounded with a combination of rock salt and crushed ice (1:4 to 1:6 ratio, with the ratio depending on the dessert) to promote freezing to temperatures below 32°F (0°C) during churning (Figure 26-9; Chemist's Corner 26-2). The dasher should be turning before the mixture is added. Some electric models use a canister with liquid inside that is frozen instead of using ice and salt.

It is best to fill the space around the canister half full with crushed ice and then add the salt to prevent it from aggregating at the bottom. The remaining salt and ice can be mixed together and then added, or layered alternately on top of the ice around the canister. Crushed rather than cubed ice is used because of its greater surface area, and rock salt is preferred over table salt, which tends to cake, is more expensive, and dissolves too quickly. To maintain the cooler temperatures, it is important not to discard the liquid that results from the salt melting the ice. The cooler temperature of the outside container necessitates the constant churning of the ice cream mixture to prevent large ice crystals from forming on the perimeter. The sharp edge of the revolving dasher moves ice crystals forming on the container's wall toward the center to promote uniformity of crystal size. It also helps to begin the churning process with everything cold by freezing the canister overnight and refrigerating the ice cream mixture until it's completely chilled (14).

Speed of Churning/Freezing

The number of revolutions per minute of the mixer is low at first, but it increases near the end to facilitate the formation of small crystals. This is based on the principle that slow freezing results in large crystals, whereas quick freezing creates tiny ice crystals (12). The speed of the dasher also determines how much air is

FIGURE 26-8 Restructuring of fat during ice cream churning.

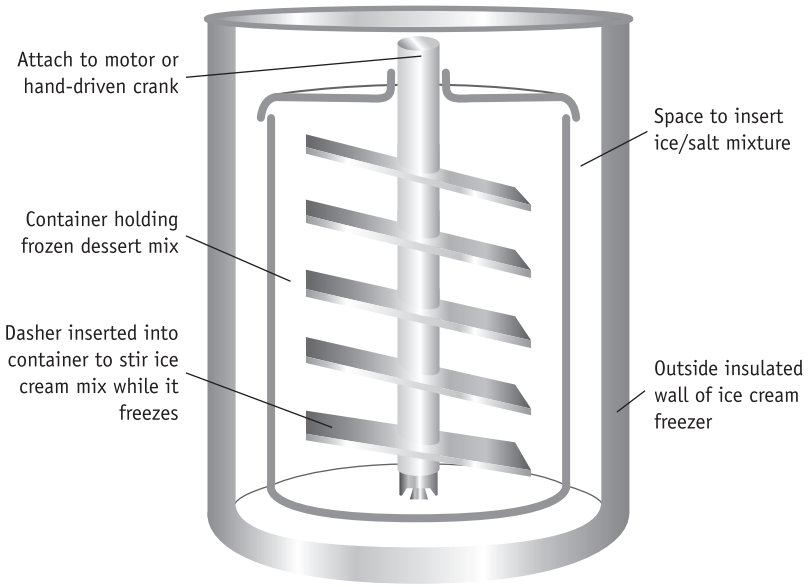


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FIGURE 26-9 Ice cream freezer.



CHEMIST'S CORNER 26-2

Salt's Effect on Freezing

The freezing point of water decreases 6.7°F (3.72°C) for each gram molecular weight (58 grams) of sodium chloride (NaCl) added to 1 liter of water. Melting each gram of ice requires 80 calories of energy, which is absorbed by the ice–salt mixture around the ice cream canister (26).

incorporated into the mixture. A faster dasher introduces more air, creating a lighter ice cream. Slowing down the dasher traps less air, yielding a denser ice cream (20). The ice cream is finished churning in about 20 minutes, when the dasher becomes difficult to rotate.

How & Why?

Why is rock salt added to ice cream machines?

Salting the ice surrounding a churning ice cream canister speeds the melting of the ice, which absorbs energy (heat) away from the contents of the canister. It keeps the canister and its contents cooler. The goal in adding an ice-and-salt mixture is to remove sufficient heat from the ingredients in the canister so that they start to freeze. The melting ice signals this absorption of heat.

Storing and Hardening

The dasher is then carefully removed, and the ice cream is packed down and put in the freezer for about 4 to 6 hours before serving. Ice cream may be served immediately after preparation, but its texture will be somewhat soft. If the ice cream is too grainy, a common fault, it may be because of any of several preparation errors: filling the container more than two-thirds full; using too much salt, which freezes the ingredients too rapidly and does not allow enough time for the formation of small crystals; and/or churning too rapidly. Freezing will also have an impact on the ice cream's texture. The initial churning freezes about 33 to 67% of the water, whereas the second freezing during storage, called the "hardening phase," freezes an additional 23 to 57% of the water (29).

Frozen Yogurt

An ice cream freezer is used to prepare frozen yogurt. The process is similar to that for making ice cream, except that the ingredients are yogurt based. Emulsifiers may also be added.

Sherbet

The procedure for preparing sherbet is again similar to preparing ice cream, but the ingredients are syrup based rather than milk based. No egg yolks are used. The sugar concentration is key to determining the final flavor of the sherbet. This can be fine-tuned either by tasting or by using an instrument that measures sugar concentration (Chemist's Corner 26-3).

Sorbet

Sorbets are relatively easy to prepare. A puree of either fresh or frozen fruits is combined with a sugar syrup and then frozen in an ice cream maker. Fruits that are beyond ripe, but not rotten, are best because they yield the most intense flavors. A sweet fruit should be the primary choice and may be balanced by one that is more tart, such as strawberries or plums (13). Herbs such as rosemary, thyme, or basil may also be added as a secondary flavor (17). If the fruit is less than ripe, it can be poached in the sugar syrup to soften the flesh and make it easier to puree. Poaching is always recommended for pineapple and kiwis, no matter how ripe, in order to destroy certain enzymes that will interfere with freezing.

Sorbet Syrup Preparation

The syrup of equal parts sugar and water is simmered prior to adding the fruit puree. It is best if the syrup is still warm when the puree is added in order to bring out the most flavors from the fruit. Chilling the mixture before churning speeds up the freezing process, but the mixture should first be tasted and any necessary flavor adjustments made because, once frozen, the flavors are less intense. In its liquid state, the sorbet mixture should have the desired flavor but be too potent to drink. Tart citrus flavors such as

CHEMIST'S CORNER 26-3

Measuring Sugar Concentration

A saccharometer, also known as a syrup-density meter, hydrometer, or Baumé hydrometer, measures the sugar concentration of a liquid. The calibration of the hollow glass tube ranges from 0° to 50° and is read as "degrees of Baumé." The recommended range for sherbets, sorbets, and ices is about 16° to 20° Baumé (17).

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lemon, grapefruit, or lime can be added if the mixture is too sweet.

Churning Sorbets

The final stage of sorbet preparation consists of placing the mixture in an ice cream freezer that incorporates air into the fruit syrup, creating a light, airy texture. After it thickens, the sorbet should be transferred to an airtight container and frozen for at least a couple of hours before consumption, although it may be consumed immediately. Sorbet made this way will keep for up to 2 weeks (13). The use of stabilizers such as gelatin and carrageenan (the two most popular) along with pectin, agar, or gum tragacanth improves the shelf life of sorbets by reducing the tendency of their frozen liquids to separate from the ice crystals (21).

Water Ices

Water ices are made by combining one part sugar with four parts liquid and flavoring. This flavored syrup is then placed in a mold, covered with aluminum foil, and frozen. Some frozen ices, such as granités, are stirred periodically during freezing to promote the formation of large ice crystals. Too much sugar will prevent the mixture from freezing, whereas too little results in an unappetizing hard-frozen mass.

Still-Frozen Desserts

Still-frozen desserts are frozen without stirring, usually in molds. The mixtures for these vary tremendously in their ingredients and preparation. Their light, airy texture and high volume are derived from whipped cream or egg-white foams that are folded into the other ingredients. The smoothness of still-frozen desserts often results from the addition of emulsifying agents that prevent the formation of large crystals during freezing. Such emulsifiers include eggs, gelatin, corn syrup, and/or cornstarch. It is best to remove still-frozen desserts from the freezer a half hour prior to serving, but care should be taken with regard to food safety because many contain eggs or cream.

Food Additives in Frozen Desserts

Food manufacturers of frozen desserts rely on several additives to maintain the quality, appearance, and flavor of their products. In contrast, the initial quality of homemade ice cream lasts only about 3 days. To combat the quality deterioration, commercial frozen dessert manufacturers incorporate a variety of food additives into their frozen desserts—sweeteners, stabilizers, emulsifiers, colorants, and flavorings (Table 26-4).

TABLE 26-4 Common Food Additives Used in Ice Cream

Food Additive	Function	Comments
Agar	Thickener	A seaweed derivative.
Alginate	Stabilizer	Seaweed derivatives that are used as stabilizers retain moisture, make foods creamier, and extend shelf life.
Carrageenan	Emulsifier, stabilizer, thickener	Type of seaweed (Irish moss) that stabilizes foods by making them gel.
Cellulose	Emulsifier, stabilizer, thickener	Component of all plants. Inert bulking agent in foods.
Citric acid	Preservative, antioxidant, pH control agent	Widely distributed in nature in both plants and animals.
Guar gum	Stabilizer, thickener, texturizer	Extracted from the seeds of the guar gum plant (legume grown in India).
Maltodextrin	Flavor enhancer, stabilizer	A carbohydrate produced from cornstarch that enhances stability and flavor.
Monoglycerides and diglycerides	Emulsifiers	Derived from lipids.
Xanthan gum	Stabilizer	Usually produced from cornstarch.

STORAGE OF FROZEN DESSERTS

Ice cream is best stored at temperatures of 0°F (–18°C) or below for a month or two. A thin, plastic film is sometimes used inside the carton to cover commercial ice cream. If this is absent, a sheet of wax paper can be pressed against the ice cream before resealing the carton, or the entire carton can be placed in an airtight plastic bag. This prevents absorption of other food odors in the freezer and exposure to moisture buildup, which can promote the formation of large crystals. Ice crystals do not remain the same size as when they formed, but slowly enlarge, so the consistency of frozen desserts rarely stays the same throughout their storage life.

Texture Changes

The gradual change in texture often observed in ice cream, lower-fat ice cream, and sherbet results from transportation from the store, repeated removal of the frozen dessert from the freezer, and/or freezer temperature fluctuations. During any one of these occasions, some of the ice crystals melt into water, which attaches to neighboring crystals and refreezes. Consequently, the crystals get larger and larger, creating a coarse texture (24). Over time, recrystallization occurs when the number of ice crystals decreases at the same time that the average ice crystal size increases. Thawing frozen desserts, even partially, and then refreezing them has a negative effect on their quality (Figure 26-10). It is best, therefore, to keep them at freezing temperatures and protect them as much as possible from changes in temperature.

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CAREER CORNER

Drs. Kristen and Jonathan Gray are food scientists, married to each other, and working for different food companies in Chicago, Illinois. Kristen's food science specialty is in the area of scientific and regulatory affairs. Jonathan is a flavor chemist studying ingredient interactions, evaluating new ingredients, and patenting new ingredients or technologies. Other types of chemists working in the food industry include flavor chemists or analytical chemists who often focus on quality control or nutrition labeling requirements.



Kristen M. Gray

Kristen M. Gray, PhD, Technical Regulatory Specialist—Wm. Wrigley Jr. Company

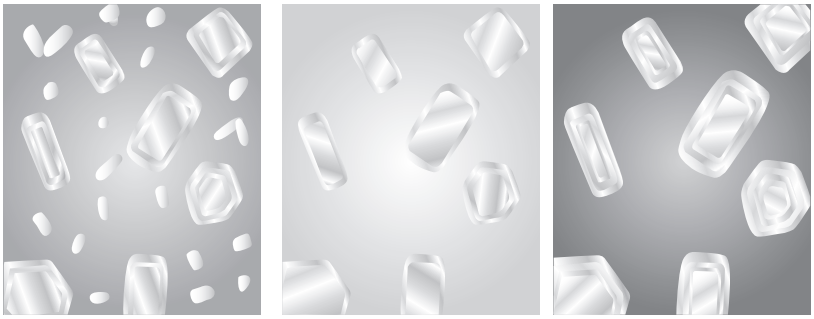


Jonathan Gray

Jonathan Gray, PhD, Food Chemist—Kraft Foods

Jonathan completed an internship at Procter & Gamble studying food ingredient interactions, and Kristen did a postdoc in industry. In academia, a postdoc is a university research position for students following their doctoral degree. In the food industry, as Kristen explains, "A postdoc allows corporations to hire you under contract without opening a new full-time position, and postdoc positions are listed as any other job. However, it's best to contact industry directly because they do not need to open an official position for a postdoc. All you need to do is send in a résumé and cover letter requesting a postdoctoral position." She prefers work that checks for regulatory compliance, handles consumer complaints, and ensures product safety. "For example, I do formula review (final product), ingredient safety, and ingredient review (raw materials). Label compliance is another important area," she adds, "and the rules to list ingredients and display food labels differ so much internationally, too. A lot of this job is keeping up with regulatory changes."

FIGURE 26-10 Ice cream quality is best when first purchased because numerous small crystals are present (left). Any increase in temperature causes the smallest crystals to melt (center). The extra water is taken up by the remaining crystals, making them larger and the ice cream more grainy (right).



Scooping Frozen Desserts

In spite of the hazard to its quality, slightly warmer ice cream is preferred during serving because it is easier to scoop and is more flavorful. A half-gallon can be easily sliced or scooped when left in the refrigerator for about 15 minutes. Scooping downward into the container to gather a compact ball of ice cream or sherbet results in fewer servings per tub than does skimming the dipper over the surface. Immersing the dipper in cool water before scooping also helps keep the ice cream from sticking to the dipper.

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PICTORIAL SUMMARY / 26: Frozen Desserts

Since AD 62, when Roman emperor Nero sent runners to the mountains to fetch ice to be flavored with nectar, fruit pulp, and honey for him and his court, frozen desserts have maintained their popularity. Today, commercially frozen treats are probably the most commonly consumed desserts in North America.

TYPES OF FROZEN DESSERTS

Federal and state regulations determine the minimum levels of fat and milk solids-not-fat (MSNF) for many frozen desserts.

What makes one frozen dessert different from another? The ingredients, ingredient proportions, and preparation methods.

Ice cream: Ice cream is prepared by simultaneously stirring and freezing a pasteurized mix of dairy (milk, cream, butterfat, etc.) and nondairy ingredients (sweeteners, stabilizers, emulsifiers, possibly egg, colors, and flavors). By law, regular ice cream must contain at least 10% milk fat and 20% MSNF, with premium ice creams containing at least 14% milk fat.

Lower-fat ice creams are compared to a referenced product (either an average of the leading brands, or the company's own brand):

- Reduced-fat ice cream: at least 25% less fat than the original product
- Light ice cream: 50% less fat or 33% fewer kcalories per serving than original product
- Low-fat ice cream: less than 3 grams of fat per half-cup serving
- Fat-free (nonfat) ice cream: less than 0.5 grams fat per serving

Imitation ice cream: Milk fat is replaced with other ingredients such as vegetable fat or corn oil. Other imitation ice cream products contain soy products.

Gelato: The Italian version of ice cream is made with less cream and more churning to yield a very smooth, creamy, intensely flavorful dessert.

Frozen yogurt: Full-fat frozen yogurt has almost as many kcalories as regular ice cream (about 280 kcal per 8 oz.), but nonfat yogurt averages only 180 kcal per 8 ounces plus 0 grams of fat.

Sherbet: Sherbets must contain less than 2% milk fat, and their creamy consistency often comes from egg whites and/or gelatin. More sugar is added so their kcalorie value is, in fact, very similar to that of regular ice cream.



Sorbet: Sorbets consist of pureed fruit or fruit flavoring and a sugar syrup. Sorbets have a harder consistency than ice cream or sherbet.

Water ices (glacés): Water ices, made from a base of sweetened water and fruit juice, lack both milk fat and MSNF. Examples: popsicles, granités, and frappés.

Still-frozen desserts: These desserts are not stirred while freezing. Examples include mousses, bombes, and parfaits. The use of whipped egg whites or whipped cream results in an airy, velvety texture without large ice crystals.

PREPARATION OF FROZEN DESSERTS

Combine the ingredients (may be cooked or uncooked), churn using an ice cream freezer until frozen (ice cream, sherbet, sorbet, frozen yogurt) or placed in a mold (water ices, still-frozen desserts, sorbet).



Flavor, texture, and body all contribute to the quality of frozen desserts. The texture of frozen desserts is based on their crystalline nature—the smaller and more evenly distributed these crystals are, the smoother the texture. Larger crystals yield a coarser texture. Other factors contributing to texture are fat, MSNF, air cells, emulsifiers, and processing. Body is defined as the product's combined firmness, richness, and viscosity.

The first step in preparing a frozen dessert is to combine the ingredients, which may or may not be cooked. Frozen dessert mixtures are then either churned using an ice cream freezer (electric or hand-cranked) until they are frozen (ice cream, sherbet, sorbet, frozen yogurt) or placed in a mold where they are allowed to freeze undisturbed (sorbet, water ices, still-frozen desserts).



Among the different flavors of ice cream . . .
. . . **vanilla** is the most popular.

STORAGE OF FROZEN DESSERTS

Ice cream is best stored at temperatures of 0°F (–18°C) or below for 1 to 2 months, and it is best if protected as much as possible from fluctuations in temperature.



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. By law, regular ice cream must contain at least ___ milk fat.
   a. 10%
   b. 20%
   c. 30%
   d. 40%

2. What characteristic(s) of ice cream is/are influenced by the milk solids-not-fat (MSNF) content?
   a. Flavor
   b. Body
   c. Texture
   d. All of the above

3. The freezing point for water _____ when salt (sodium chloride) is added.
   a. stays the same
   b. increases
   c. decreases
   d. varies

4. Sherbet is different from ice cream in that it is _____ based, not milk based.
   a. syrup
   b. yogurt
   c. sorbet
   d. ice

5. Why does commercial ice cream have more body than homemade ice cream?
   a. Larger batches are made.
   b. High-tech equipment is used.
   c. Secret recipes are used.
   d. Stabilizers are used.

6. Commercial ice creams often have _____ as a result of air pumped into the mixture during manufacture, which makes them softer, creamier, and more economical.
   a. overrun
   b. churning
   c. emulsifiers added
   d. milk solids-not-fat added

7. A frozen dairy dessert containing no fat is called _____.
   a. gelato
   b. sherbet
   c. mellorine
   d. sorbet

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe how the basic ingredients of the following frozen desserts differ: ice cream, low-fat ice cream, imitation ice cream, frozen yogurt, sherbet, sorbet, water ices, and still-frozen desserts.
2. Smooth texture is important to the majority of frozen desserts. Describe the factors that affect texture in the preparation of frozen desserts.
3. Explain how commercial ice cream manufacturers add body to their products.
4. Describe the basic steps for preparing ice cream.
5. How does the preparation of still-frozen desserts differ from that of most other frozen desserts?
6. For what purpose is commercial ice cream sometimes covered with a thin, plastic film for storage?
7. Describe how the thawing of frozen desserts reduces their quality.
8. What is the best technique for scooping ice cream with a dipper? Explain why.
9. Explain why salt is added to the crushed ice to facilitate the freezing of homemade ice cream.
10. What are the recommended storage temperatures and times for ice cream?

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27



Beverages

Water 518
Carbonated Soft Drinks . 520
Functional Beverages . . . 521
Coffee 523
Tea 528
Dairy Beverages 530
Alcoholic Beverages 530

All living organisms require water for survival. This essential nutrient can be absorbed by some organisms through cell membranes, cell walls, or the skin, and, in higher organisms, it is consumed in the form of foods and/or directly by drinking. Human bodies are approximately 65 to 70% water, so fluids must be consumed daily to maintain that supply. Helping to meet this need are foods such as fruits, vegetables, milk, meat, and eggs, which all contain approximately 70% water. Beverages, however, contribute a greater share to the human requirement for water, and they do this in sometimes mundane, sometimes delicious ways.

Classification There are several ways to categorize beverages used for obtaining fluids. According to the hospitality industry, most beverages can be classified using the following two sets of categories: nonalcoholic versus alcoholic and cold versus hot. The beverage industry may classify beverages as bottled waters, carbonated soft drinks, functional beverages (alternative drinks), juices and juice drinks (fruit or vegetable juices; see Chapter 14), hot beverages (coffee and tea), dairy (see Chapter 10), sport drinks and shots, or alcoholic beverages (beer, wine, and spirits) (18).

This chapter discusses these beverages—specifically their composition, processing, preparation, and storage.

WATER

Water provides no kcalories or vitamins, but it is so vital to human life that its availability determined where early humans lived—near streams, rivers, lakes, and springs. A person can survive up to 40 days without food, but only approximately 7 days without fluid. While the majority of the earth is covered with water, only 3% of it is suitable for drinking; the rest is salt water or unusable (69). About 70% of the population in the United States is served by community water systems that utilize surface water sources, and the remaining 30% is served by systems that utilize ground water (19).

Bottled Water

The FDA defines bottled water as a food, more specifically as "water intended for human consumption that is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents." Fluoride may be added within FDA limits. An increase in bottled water consumption that began as a trend has evolved into a permanent change in the beverage industry (37)—so much so that both Coca-Cola

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and PepsiCo have entered the bottled water market. In 2016, Americans drank more bottled water than soft drinks for the first time ever (44).

Bottled water is regulated by the Food and Drug Administration (FDA), specifically its standard of identity, standard of quality, and current good manufacturing practices (cGMP). The quality of tap water, also known as municipal or public drinking water, is the responsibility of the Environmental Protection Agency (EPA) (16). The EPA monitors water sources and sets safe levels of potentially dangerous compounds. Regulated contaminants include infectious organisms, disinfectants, inorganic and organic chemicals, and radionuclides (55). A list of EPA-regulated contaminants can be found at www.water.epa.gov/drink/contaminants/index.cfm.

This section discusses the different types of bottled water available on the market. See Chapter 3 for the background information on water's chemical composition, content in foods, specific heat, freezing point, melting point, boiling point, and altitude influences; soft versus hard water; and functions of water in food—heat transfer, solvent, chemical reactions, and food preservation.

Bottled water may be labeled with many different terms based on its source (artesian water, mineral water, spring water, well water), or the treatment processes applied to it (deionized water, distilled water, reverse osmosis water).

Sources of Water

Artesian Water

Artesian water is collected from a confined aquifer after it has risen to the surface on its own or by other means.

Mineral Water

Most untreated water naturally contains dissolved mineral salts, but mineral water is from an underground source that contains at least 250 parts per million (ppm) of total dissolved solids. The characteristic taste and odor of mineral water vary because of small amounts of salts of calcium, magnesium, and sodium (sodium bicarbonate, sodium carbonate, sodium chloride), and sometimes iron or hydrogen sulfide. No minerals may be added to this water.

The predominant mineral in most water is usually either calcium or sodium, varies according to region, and determines whether the water is hard or soft (see Chapter 3). In some locations, the water is so high in calcium that it serves as a significant dietary source of the mineral (56).

P.W.S.

This is public water source or tap water obtained from the municipal water supply.

Spring Water

Spring water comes from an underground source that flows naturally to the surface. The water must be collected at the spring or through a borehole tapping the underground source (must have the same mineral content as that flowing naturally to the surface).

Well Water

Well water is pumped from an aquifer, an underground source of water.

Water Treatment Methods

Purified Water

Tap water can be treated to create "purified water" through processes that remove minerals, chemicals, and/or flavors. Treatments include deionization, distillation, reverse osmosis, and other methods. Standards are established by the U.S. Pharmacopoeia.

Deionized Water

The deionization process removes all the mineral salts (via ion exchange), leaving only pure water. Deionized water may make beverages taste less flavorful.

Distilled Water

The purpose of distillation is to separate a liquid from other particles or liquids. Water is heated until it converts to steam, which is then condensed into a second, cooler container as a purified liquid. Dissolved particles and/or other liquids with higher boiling temperatures are left behind. This process not only removes dissolved minerals but also destroys pathogens. Sometimes normal concentrations of minerals are added back to the water (18).

Reverse Osmosis Water

In reverse osmosis treatment, water is forced through membranes to remove the minerals.

Soft Drinks Marketed as "Water"

Beverages labeled "sparkling water, soda water, tonic water, or club soda" are not defined by the FDA as bottled water (71). They are considered soft drinks (described in the following section). Carbon dioxide gas, which is available through commercial carbonation or naturally from underground sources, contributes the fizz and bubbles to these drinks (Figure 27-1). Club soda (soda water or plain soda) is somewhat different from carbonated water in that, in addition to having been filtered and carbonated, it has had mineral salts such as bicarbonates, citrates, and phosphates of sodium added. Until World War II, carbonated water was called *soda water* because sodium was added to reduce acidity

FIGURE 27-1 *Carbonated mineral spring water.*



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and duplicate the taste of mineral water. Today, club sodas may contain sodium (approximately 75 mg per 12 ounces) for the same reasons.

CARBONATED SOFT DRINKS

Carbonated soft drinks, sodas, or "pops" were the most widely consumed type of beverage in North America, but they have been surpassed by bottled water (44). Carbonated soft drink consumption has decreased in recent years (44), due in part to concerns about the high-fructose corn syrup and artificial sweeteners contained in sodas (5).

Among purchased soft drinks, cola drinks are the number one soft drink purchased, followed by lemon-lime and orange (12). Trade journals, such as *Beverage Digest* and *Beverage Industry*, provide the latest data on what and how much is selling (12). Beverages in *Beverage Digest* are categorized as carbonated, noncarbonated, and bottled water. What are people actually buying when they purchase soft drinks? About 90 to 98% is sparkling water, 10% is sugar (see Chapter 21), and the remainder consists of added flavors, colors, acids, and preservatives (Chemist's Corner 27-1). Some of these ingredients are unappealing to a growing number of consumers who are seeking more natural drinks (67).

Early Soft Drinks

The major ingredient in soft drinks, sparkling water, was created in 1772 by the chemist Joseph Priestley, who added carbon dioxide, a colorless, nontoxic gas, to water. One of the early methods of creating carbon dioxide consisted of acidifying baking soda (sodium bicarbonate). This is where the term *soda* originates. The word *soft* was originally used to distinguish these beverages from the so-called hard alcohol drinks (18). The carbonated bubbles increase the pressure in the can so that, when opened, it sounds like a "pop," another name given to soft drinks. In addition to providing sparkling bubbles, carbon dioxide provides a tingling mouthfeel, an effervescent appearance, and a preservative effect to the beverage.

CHEMIST'S CORNER 27-1

The Water in Soft Drinks

The water used in soft drinks is relatively chemically pure as compared to that obtained from municipal drinking water. Tap water cannot be used in soda production because the alkalinity is too high, causing it to neutralize the acids; minerals such as iron and manganese interfere with coloring and flavoring agents; and residual chlorine is detrimental to flavor. Bottling plants treat water to be used for sodas by deionization; chemically precipitating the minerals; using activated charcoal to remove undesirable flavors, odors, and chlorine; deaeration to remove oxygen; and a final filtration to remove any remaining compounds that passed through the carbon filter (58).

In the 1800s, another chemist, Benjamin Silliman, began selling carbonated soda water to the public (18). Flavored soda water became popular after 1830, and in the late nineteenth century, a druggist invented a flavored soda by adding an extract from the African kola nut. Coca-Cola was invented in 1886 by a pharmacist, John Pemberton, as a hangover remedy (40). The list of Coca-Cola ingredients has been guarded for more than 100 years, but one researcher claims the original Coca-Cola recipe included citrate, caffeine, extract of vanilla, seven flavoring oils, fluid extract of coca (cocaine), citric acid, lime juice, sugar, water, caramel, and alcohol (62). The use of cocaine became illegal in the 1930s. Another pharmacist who created a soft drink was Charles Hires, who added a unique extract to sparkling water and introduced root beer.

Soft Drink Processing

Numerous soft drink companies started with closely guarded formulas for flavored syrups. Water is added to the syrup, resulting in a mixture that is then carbonated by adding carbon dioxide gas. Today, soft drinks are carbonated by placing a syrup–water mixture in a pressurized carbon dioxide container known as a carbo-cooler. After interacting with the carbon dioxide and cooling off, the newly carbonated syrup water is pumped to a filler, which then allocates a set amount of the soft drink into a sterile container (31). Added sweeteners, usually in the form of corn syrup, sucrose, or monosaccharides, contribute flavor and increase density, viscosity, mouthfeel, and kcalorie content. Sucrose was originally used to sweeten soft drinks, but it was gradually replaced by the less expensive corn syrups. The fructose in corn syrup is sweeter than sucrose, so less is required.

Various acids also contribute to the flavor of soft drinks: citric acid from citrus fruits contributes tartness, usually to fruit drinks; phosphoric acid, usually used in cola drinks and root beers, is flat and sour; and malic acid from apples is used for its long-lasting flavor (30). Preservatives added to soft drinks usually consist of benzoic and sorbic acids and their calcium, potassium, and sodium salts (31).

Soft Drink Health Concerns

In recent years, news stories have brought to light the role that soft drinks may play in the obesity epidemic. The 2015–2020 *U.S. Dietary Guidelines* identify sugar-sweetened beverages as the number-one source of added sugars in the U.S. diet (70). Beverages are a significant source of dietary kcalories, primarily because of these added sugars. In fact, almost 20% of the energy intake among Americans comes from beverages (70). An American Heart Association report noted that Americans should "significantly reduce intake of foods containing added sugars and solid fats," especially in the form of sugar-sweetened beverages, "because these dietary components contribute excess calories and few, if any, nutrients" (74). As a result of these concerns over excess sugar intake, some have suggested that certain foods (soft drinks, fast foods, and snacks) be taxed as a preventive measure to curb consumption. Portion sizes are a contributing factor; the first popular soft drink was

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TABLE 27-1 Selected Food Additives in Soft Drinks

Acids	
Citric acid	Natural acid obtained from citrus fruits, strawberries, raspberries, and black currants.
Malic acid	Natural acid obtained from apples, cherries, peaches, and plums.
Phosphoric acid	A stronger acid usually used in cola drinks at low concentrations (it is caustic at high concentrations). Phosphorus is present in most animal and plant cells. Cola drinks contain about 13–19 mg/100 mL, as compared to 200–800 mg/100 g in cheese, eggs, meat, fish, bread, and nuts.
Preservatives	
Benzoic acid	Inhibits molds and yeasts.
Sorbic acid	Better at lower pH levels than benzoic acid.
Colors	
Natural	Derived from plant products—fruits, vegetables, herbs, nuts, spices, and oils.
Artificial	Synthetically manufactured.
Caramel	Made from sugar; provide the characteristic brown color of cola drinks.
Flavors	
Natural	Derived from plant products—fruits, vegetables, herbs, nuts, spices, and oils.
Artificial	Synthetically manufactured.

originally sold in a 6.5-ounce bottle that has now grown to 12 ounces (1½ cups) or more. Avoiding regular soft drinks may be necessary for weight management; one study found that reduction in liquid kcalorie intake had a greater effect on weight loss than reduction in solid kcalorie intake (13). Researchers have predicted that replacing 8 ounces of sugar-sweetened beverage with water in one's daily diet can result in a weight loss of 0.88 to 4.38 pounds over a 6- to 8-month period (17).

Some researchers have suggested that the exposure of tooth enamel to the low pH of some soft drinks increases the risk of erosion; in addition, prolonged contact with the sugar in these drinks is a risk factor for dental caries (8). These and other issues regarding the health risks of soft drinks remain open to debate.

Diet Soft Drinks

Diet soft drinks use alternative sweeteners such as aspartame, saccharin, acesulfame-K, or sucralose. The result is an increase in water content from 90 to 98% and the omission of sugars, which has a detrimental effect on mouthfeel (29). Bulking agents such as carboxymethylcellulose or pectin are often added to counter this side effect (58). Diet soft drinks were introduced in the 1950s and have steadily grown in popularity, with diet cola varieties among the top five most popular soft drinks on the market (29).

Food Additives in Soft Drinks

Additives in drinks commonly make up only 2 to 3% of the beverage weight, but they can have a large influence on taste. They are often used to add definition and character, to balance the acid or sugar content, to improve nutrition, and to act as a preservative (30).

Table 27-1 lists some of the acids, preservatives, colors, and flavors added to soft drinks.

FUNCTIONAL BEVERAGES

Functional beverages are the latest breakthrough in the manufacture and sale of beverages (78). An older term, "new age beverage," was coined in the mid-1990s and followed by "alternative" drinks. The newer term, "functional beverages," is more common because many of these beverages serve a function other than energy, essential nutrients, and simple hydration.

It is difficult to categorize these drinks, so the terminology remains fluid as new beverages emerge, often combining attributes of existing categories or creating new ones. A few, but not all, of these functional beverage categories are now discussed: nutraceutical, sports and performance, smart, and energy beverages (46).

Nutraceutical Beverages

Almost half a century ago, Japanese merchants were selling elixirs aimed at countering stress, fatigue, and the effects of alcohol (36). Today, functional beverages delivering health benefits are often described as *nutraceutical* beverages. Marketed as having beneficial health effects, these nutraceutical beverages often contain an added herb or dietary supplement. The ingredients are endless, but they include vitamins, minerals, bee pollen, chromium, carnitine, picolinate, selenium, and hydroxyl citric acid (claimed to improve brain function), to name a few (Table 27-2) (34). Other examples include green tea, antioxidants, soy, fiber, probiotics, phytochemicals, and even oxygen. Despite concerns about overblown health claims, these functional beverages continue to appear on the market at a rapid pace.

One of the oldest functional beverages is cranberry juice, recommended to reduce or treat urinary tract infections. Normally, the bladder is sterile, but bacteria such as *Escherichia coli* can cause an infection that can enter through the urinary tract, pass the bladder, and end up in the kidneys, where it can cause serious damage if not treated. The unique blend of organic acids in cranberry juice appears to have an inhibitory effect on potentially harmful bacteria.

Probiotic beverages that are fermented dairy or nondairy drinks are also being touted as benefiting health. A dairy example is lassi, a traditional yogurt-based drink from India made by blending yogurt, water, ice, salt, pepper, and Indian spices (66). Kombucha (kom-boo-cha) is a nondairy fermented beverage prepared from black tea and fermented kombucha mushrooms.

A growing market, especially in Japan, exists for desalinated deep seawater. Proponents claim that this seawater, pumped

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TABLE 27-2 Selected Herbs and Supplements in Functional (Nutraceutical) Beverages

Herb	Popular Claim in the Press
Echinacea	Boosts immune system (conflicting evidence)
Ginkgo biloba	Sharpens the mind (some evidence)
Ginseng	Boosts energy (conflicting evidence)
Guarana	Stimulant (due to caffeine)
Kava	Alleviates stress (evidence of liver toxicity if consumed in excess)
Saint John's wort	Herbal antidepressant (evidence for mild depression)
Supplement	
Carnitine	Muscle growth (minor evidence of minimal effect)
Glucuronolactone	Fights fatigue and improves well-being (no evidence); precursor of taurine
Inositol	Part of B-complex
Taurine	Amino acid used in combination with carnitine for muscle growth (no evidence)

from the depths of the ocean by pipes submerged more than 3,000 feet under the surface, is free of modern impurities and may benefit health.

Nutraceutical Trends

The latest focuses in the nutraceutical beverage line include digestive health, cancer (antioxidants), heart health, brain health, blood sugar management, and weight management. Ingredients such as glucosamine and chondroitin sulfate and methylsulfonylmethane (MSM) are being added to drinks to benefit joints (73). Lycopene, the red pigment from tomatoes, is being added as an antioxidant. Pomegranate and mangosteen juices are claimed to be high in fruit-based antioxidants. Heart-friendly ingredients include omega-3 fatty acids and fruit phytochemicals. Blueberries and a few other botanicals are suggested to aid memory, alertness, and cognitive function. Women's health nutrients include, but are not limited to, calcium, folic acid, soy isoflavones, and omega-3 fatty acid (docosahexaenoic acid). The plant compound inulin serves as the foundation of some nutraceutical drinks. This carbohydrate-based fiber (prebiotic) promotes the growth of beneficial bacteria in the large intestine, which is thought to reduce the risk of colon cancer. Weight-loss products are now focusing on fiber, resistant starches, oat beta-glucan, and protein (20). The low-carbohydrate product trend that peaked in 2004 is being replaced by interest in drinks with a low glycemic index. Other drinks that may aid with weight maintenance are those that are primarily water with a new flavor, process, or ingredient added primarily for increasing the water's palatability; most of these products are lightly flavored waters with fewer kcalories than sports/performance drinks.

Sports Beverages

Sports drinks have long been mainstream and have recently grown in popularity to the point of sometimes replacing soda/pop beverages. They were initially designed for and targeted toward sport and exercise enthusiasts to replace the fluid, electrolytes, and carbohydrates lost during intense exercise (Figure 27-2) (5). Physical performance is often enhanced by these sports, isotonic, or recovery beverages that prevent dehydration, replace important electrolytes, and provide extra energy in the form of carbohydrates. Carbohydrates are available in many forms but usually include sucrose, glucose, and maltodextrin. Adequate hydration, according to the American College of Sports Medicine, is achieved by most people if they drink at least 4 hours before exercise (about 5 to 7 mL for each kilogram of body weight; equals 1.4 to 2 cups for a 150-pound [68 kg] person) and during physical exertion to prevent excessive dehydration (>2% body weight loss from water deficit; equals 3 pounds for a 150-pound or 1.36 kg for a 68-kg person) (3). However, physical performance lasting under 1 hour does not benefit from the carbohydrates in isotonic drinks. Another benefit of sports or isotonic drinks is that they provide the electrolytes potassium and sodium in the form of monopotassium phosphate, potassium chloride, sodium chloride, and sodium citrate. They typically contain 14 to 15 grams of carbohydrates and at least 70 mg of sodium per 8-ounce serving. Specialized sports drinks designed for endurance events have an even higher sodium content—about 200 mg per 8 ounces (5).

Smart Beverages

Certain compounds claimed to boost brain power are added to beverages sold as "smart" drinks—despite the fact that there is very little to no research

FIGURE 27-2 Functional drinks are gaining in popularity over soft drinks.



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CALORIE CONTROL
Beverages

Although water is kcalorie free, many other ingredients added to water are not.

- **Drink water.** Plain water may not be as tasty as sugared and/or flavored beverages, but it meets the primary need of the body—hydration.
- **Choose lower-kcalorie flavored beverages.**
  - Bouillon (low-sodium) (0 kcalories)
  - Club soda (0 kcalories)
  - Coffee (0 kcalories without added sugar, milk, or cream)
  - Diet soda (0 kcalories)
  - Enhanced waters (0 to 100 kcalories each; read Nutrition Facts label)
  - Sugar-free drinks (liquids or mixes) (0 kcalories)
  - Tea (unsweetened) (0 kcalories)
  - Tomato or vegetable juices (70 kcalories for 12 ounces)
  - Tonic water (0 kcalories)
- **Note that there are 150 kcalories for each 12-ounce beverage.** A general rule of thumb is that the average 12-ounce beverage (usual soda can size) delivers approximately 150 kcalories. This adds up quickly: 300 kcalories for two cans, or 450 kcalories for three cans.
- **Beverages can contribute excess sugar.** Sugar or high-fructose corn syrup is often added to soft/soda drinks. In fact, the equivalent of **10 teaspoons** of sugar is added to a single 12-ounce regular beverage.
- **Fruit juice is nutritious, but it is sugary too.** Surprisingly, fruit juices pack a lot of kcalories, making high juice intake a possible hidden source of excess kcalories. Only **8 ounces (1 cup),** which is less volume than a soda, delivers **100 to 150 kcalories**.
  - Limit fruit juice to 2 cups daily.
  - **Dilute fruit juice** (1 cup fruit juice plus 1 cup water; add sweetener if needed).
  - Replace fruit juice with actual fruit.
- **Alcoholic beverages also deliver kcalories.** Although brands vary widely depending on the percent alcohol and other ingredients, alcoholic beverages deliver **approximately 100–150 calories each**.

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supporting such claims. Substances said to stimulate mental activities that are added to smart drinks include amino acids such as choline, L-cysteine, and taurine and antioxidants (76).

Energy Beverages and Shots

In the United States, energy drinks and energy shots are the fastest-growing portion of the beverage market and the most popular among adults 18 to 24 years of age. They may be high in kcalories (usually from carbohydrates) and often have added stimulants such as caffeine. Other possible ingredients include water-soluble (B) vitamins, herbs, amino acids, and/or other flavorings. Some energy drinks have been banned in certain European countries because of their high caffeine content (63). Excessive consumption may cause acute caffeine intoxication, resulting in tachycardia (increased heartbeat exceeding the normal range), vomiting, cardiac arrhythmias (abnormal heart rhythm), seizures, and death (77). According to researchers, excess caffeine intake may raise blood pressure, disrupt sleep patterns, exacerbate psychiatric disease, cause physiological dependence, and increase the risk of addiction. The FDA has investigated adverse events (illness, injury, and death) among people who consumed energy drinks or shots; however, other influencing factors, such as underlying health problems, may have played a role in these events (72). Liver failure due to excess niacin (a B vitamin in some energy drinks) ingestion was suggested in a healthy 23-year old woman who consumed 10 cans of energy drink a day (75). Another case involved a 16-year old boy drinking energy drinks who experienced two episodes of jaundice before needing a liver transplant (6). The taurine content of some energy drinks has been suspected in contributing to an autoimmune skin condition (erythema exsudativum multiforme) (7).

FIGURE 27-3 Coffee follows tea as one of the most common aromatic beverages.



Henrik Sorensen/Getty Images

COFFEE

Coffee is one of the two most common aromatic beverages, the other being tea (Figure 27-3). An *aromatic beverage* is defined as one generating a pleasant odor from plants or spices. Coffee consists primarily of water with some additional compounds extracted from coffee beans during brewing.

Legend suggests that coffee was probably discovered in Ethiopia around the third century AD, when an Arabian goatherd named Kaldi noticed that his goats became particularly frolicsome after eating certain berries. The berries, of course, turned out to be from the coffee plant. Although many varieties of this plant are grown, only two, *Coffea arabica* and *Coffea robusta,* constitute 99% of the commercial coffee crop. A third variety is *Coffea liberica* (18). Brazil and Colombia are the world's top coffee-producing countries, but other areas with tropical rain forest climates

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conducive to coffee production include Indonesia, Mexico, Central America, and several African countries. Knowing where a coffee is grown is important to coffee producers because the flavor and quality of coffee vary according to the region where the particular coffee plant is grown.

Coffee Processing

Coffee is made from beans that are picked, partially dried, processed to remove the hull, and either roasted and ground immediately or exported to a processing plant for roasting and grinding. A small percentage arrives on the market as whole beans. Most imported beans are shipped green because they can be stored in this state without loss of quality. Coffee beans can also be processed to remove the caffeine, and liquid coffee extract can be used to produce instant coffee.

Removing the Hull

Coffee plants, which are evergreens, generate numerous white flowers that yield a cherry-like fruit containing two seeds, the coffee "beans," enclosed in a tough skin. These coffee beans are usually handpicked and then subjected to one of two treatments to remove their hulls and free their greenish-blue berries. Countries with a limited water supply, such as those in the Middle East, historically have used the dry method, in which they sun-dry the beans. In the wet method, the berries are washed and then hulled by machine and partially fermented. Coffee processed by the wet method is more expensive, but experts agree that it has a better flavor than coffee processed by the dry method. Whichever method is used, the beans are then graded for size, type, and quality. It takes about 2,000 hulled coffee beans to produce 1 pound of coffee.

Roasting

Roasting develops the beans' flavor, aroma, and appearance (60). The beans' physical and chemical makeup changes during the process. Physically, the beans dehydrate, becoming lighter and more porous as their surface area is increased. The beans also darken from green to brown during roasting. Unroasted green coffee beans would have little, if any, flavor and aroma.

Roasting time determines whether a coffee is classified as a light, medium, or dark roast. The darkest roasts, in ascending order, are French (New Orleans), Spanish (Cuban), and Italian (espresso) roasts. Europeans prefer darker roasts, whereas Americans gravitate toward medium-roast coffees.

Grinding

Once roasted, the beans are ground to create more surface area from which the hot water can extract the compounds that contribute to flavor, aroma, and appearance. Grinding releases the beans' aroma and flavor, so it's best to brew immediately after grinding. The type of grind—fine, drip, or regular—depends on the equipment that will be used to brew the coffee. Coffee beans ground too fine for their equipment deliver a bitter cup of coffee, whereas coarse grinds produce a weak, flavorless coffee when the wrong equipment is used. Generally, fine grind is used for vacuum and pressure pots, drip grind for drip pots, and regular for percolators. Particle size does not differ very much among these three main grinds, although fine has a greater number of smaller particles, whereas regular has the largest particles.

Decaffeination

Approximately 10 to 20% of the coffee consumed in the United States is decaffeinated. Caffeine, a stimulant and natural pesticide, is usually removed by first soaking green coffee beans in steam or water to increase surface area and allow solvents to penetrate the beans. They are then washed with a solvent such as methylene chloride or ethyl acetate that extracts the caffeine (9). Either chemical will bond with the caffeine, which is then evaporated (the boiling point of methylene chloride is 104°F/40°C, and 171°F/77°C for ethyl acetate). The caffeine can then be used for other products (15). When used in large amounts, methylene chloride has been shown to cause cancer in laboratory animals, so the FDA limits its concentration to 10 parts per million. Ethyl acetate occurs naturally in fruits and vegetables. Some manufacturers choose nonchemical decaffeination methods, such as filtering the soaking water with activated charcoal. Such coffee is labeled as "water-processed" decaffeinated coffee. Regardless of which method is used, not all the caffeine is removed. Decaffeinated coffees need to be 97.5% caffeine free in order to be labeled "decaffeinated," but drinking numerous cups may provide enough caffeine to have an effect. Scientists are working to produce caffeine-free coffee beans through conventional breeding and genetic engineering (9).

? How & Why?

Why do roasted coffee beans have an oily coating?

The oily surface of roasted coffee beans results from the breakdown (hydrolysis) of fats (fatty acids released from triglycerides) that occurs during the heat of roasting.

Instant Coffee

There are two major methods for manufacturing instant coffee: spray drying and freeze drying. In the first method, a strong extract of coffee is sprayed through a jet of hot air, evaporating the water and leaving dried coffee particles. Freeze drying is accomplished by freezing coffee concentrate into a solid mass and breaking the mass into small particles, which are then heat-dried in a vacuum.

Composition of Coffee

Coffee's aroma, taste, and stimulating qualities are derived from substances extracted from the beans when hot water is poured over them. These substances are almost completely depleted from the ground coffee in this way, so the grounds should never be reused. There are more than eighteen classes of flavor compounds in ground coffee, but to simplify the discussion, only the volatile compounds, bitter substances, and methylxanthines will be reviewed.

Volatile Compounds

The roasting of green coffee beans creates many volatile substances, which give coffee its characteristic fragrance (53). Not all of the compounds responsible for the aroma of coffee have been deciphered, but more than 800 volatile compounds have been identified so far (61). Heat vaporizes these substances into

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How & Why?

Why does coffee lose its flavor as it cools or stands?

The instability of some of the volatile compounds causes the flavor of roasted coffee to deteriorate quickly as it cools. In addition, when coffee is kept hot too long, evaporation causes the loss of many of these compounds and their accompanying flavors.

the air, where they signal to the human nose that the coffee is ready.

Bitter Substances

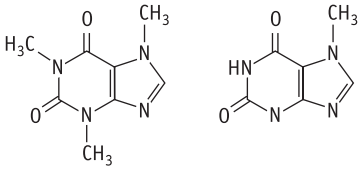
The bitter, slightly sour taste of coffee is partially due to its organic acids. Chlorogenic acid, which constitutes about 4% of roasted coffee beans, contributes to over half of the acid found in a cup of coffee. Two other components contributing to the bitter taste of coffee are the **polyphenol** compounds and caffeine. Coffee should never be boiled because temperatures at or above boiling increase the solubility of these compounds, resulting in coffee that has moved from pleasantly bitter to unpalatable.

Methylxanthines

Coffee contains two substances—caffeine and theobromine—that belong to a group of compounds called **methylxanthines** (Figure 27-4). Methylxanthines can have either positive or negative effects, depending on the individual. Possible side effects of caffeine, other than alertness and enhanced exercise performance, include temporarily increased heartbeat, metabolism, and stomach acid; sleep disturbance; and dilation and/or constriction of certain blood vessels. It also has diuretic effects, causing increased urination and increased loss of calcium through the urine. Caffeine withdrawal symptoms include headache, fatigue, moodiness, depression, and anxiety (42).

The amount of caffeine in a cup of coffee depends on which brewing method is used (52). Brewed drip coffees contain the most caffeine, about 132 to 180 mg per cup, whereas decaffeinated coffees contain the least, about 3 mg per cup. In comparison, tea contains about 40 mg of caffeine per cup.

FIGURE 27-4 Methylxanthines: Compounds found in certain foods and beverages that stimulate the central nervous system.



Caffeine Theobromine

The caffeine content of coffee and various other beverages can be found at www.caffeineinformer.com.

Types of Coffee

Selecting among the many different types of coffee beverages available can become confusing. Coffees vary depending on the beans from which they are produced, how the bean is processed (ground, instant, decaffeinated, or espresso), or what other ingredients are added (specialty coffees, imitation, café au lait, flavored, or iced). The following section describes each of these factors affecting coffee beverage quality.

Types of Beans

Coffea arabica produces the finest coffee, whereas *Coffea robusta* yields a strong but inferior-quality coffee. However, almost all coffee sold in the United States is blended and known by a brand name rather than by its variety.

Blended Coffees

Blending different varieties of beans allows the best characteristics of each to be fully expressed. Coffee beans found in nature rarely possess the taste, aroma, body, and consistency of blended varieties because the beans used for blends are chosen so that the best qualities of each type complement the others (18). Sometimes vegetable chicory is added to blends to reduce their cost, but it produces a heavier, more bitter, and darker cup of coffee.

Some desired qualities and the coffees that contribute them to a blend include the following:

- Richness/body (Sumatran, Java)
- Sweetness (Venezuelan, Haitian)
- Extra sweetness (Mature Java, Mysore)
- Flavor/aroma (Sumatran, Colombian, Celebes)
- Brightness/acidity (Costa Rican, Central American coffees)

Unblended Coffees

Lately, the demand for unblended coffees such as Mocha, Java, and Kona has increased. Many specialty coffee roasters are also offering popular "estate" coffees, or coffees grown in specific locations with certain characteristic flavors.

Types of Processing

Coffee quality changes depending on how the coffee beans are processed—ground (previously discussed), instant, decaffeinated, or espresso.

Instant Coffee

This coffee is convenient, is less expensive, and constitutes about one-fifth of all coffee sold. Its quality, unless it is decaffeinated, is inferior to that of freshly brewed coffee, which limits its use in restaurants.

Decaffeinated Coffees

The quality of these coffees varies, ranging from a detectable difference from regular coffee to no discernible difference.

Espresso Coffee

The word **espresso** is Italian for "pressed out," describing how high-pressure steam is used to force water through the ground coffee. This "express" pressing only takes 25 to 30 seconds (28). Espresso is usually served in small coffee cups because it is very dark and strong. The beans are roasted until they are almost black, and twice the normal amount of ground coffee is used to brew it (Table 27-3).

Polyphenol An organic compound with two or more phenols—carbon atoms structured into an aromatic ring with one or more hydroxyl (–OH) groups.

Methylxanthine A compound that stimulates the central nervous system.

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TABLE 27-3 Types of Espresso Coffee

Espresso	A very dark, very strong coffee that is usually served in small cups. It can also be used as the foundation for the espresso beverages listed below.
Caffè mocha	Espresso and hot chocolate (mocha) mixed together in a tall glass, possibly topped with whipped cream and sprinkled with cocoa powder.
Caffè latte	Primarily steamed milk with espresso poured into it (whereas cappuccino consists of espresso with foamed milk on top).
Cappuccino	Some steamed milk is added to espresso that is then topped with the creamy foam created from steamed milk. May be dusted with sweetened cocoa powder, cinnamon, or nutmeg.
Mocha	Espresso combined with hot chocolate and foamy steamed milk.

Types of Ingredients

Coffee can be combined with other ingredients to yield many different and flavorful products.

Specialty Coffees

Specialty coffees are blends of coffee flavored with chocolate, sugar, almonds, and even liquor. They are higher in price but preferred by certain coffee connoisseurs.

Café Brulot

The café brulot is classic Creole strong coffee made with brandy, citrus zest, and spices.

Irish Coffee

Irish coffee is a strong black coffee with added Irish whiskey, a little sugar, and regular or whipped cream.

Imitation Coffee

Imitation coffee is a cheaper version of coffee made from roasted and ground grains. Molasses is often added to cover the grainy taste and aroma.

Café au Lait, Caffè Latte, or Café con Leche

These coffee drinks are made with milk—usually a double-strength coffee mixed with an equal part of hot milk. Thai coffee is unique in that it uses condensed milk, making it much heavier and sweeter. It is also poured over ice to chill the beverage.

Flavored Coffees

These coffees contain flavored syrups made from sugar, water, natural flavor, and a preservative.

Iced Coffee

Iced coffee is a popular beverage in Japan and increasingly common in North America.

Preparation of Coffee

Many coffee-drinking consumers judge an establishment by its coffee. The key to making a good cup is to extract the compounds that contribute to good flavor and aroma, while simultaneously limiting the extraction of bitter substances. Three distinct layers form a cup of coffee—the bottom (first) layer called the shot, the middle section called the body, and the crema portion on top. Much of the flavor is derived from the oils that float to the top crema area. Preparing coffee requires focus on the various elements that go into an enjoyable cup, including the type of coffee selected (see earlier section), freshness, water-to-coffee ratio, water quality, temperature, brewing time, brewing equipment, and holding time. This section discusses how each of these factors influences the coffee beverage's final quality.

Coffee Freshness

Coffee flavor and aroma begin to deteriorate as soon as the coffee beans are roasted. Deterioration and staling become even more rapid after the coffee is ground, so it is usually packaged in vacuum-packed cans: the fresher the bean, the better the coffee. Also for this reason, many people buy whole beans and grind them on a daily basis for ultimate freshness. It is best to grind the coffee beans right before each brewing for optimal freshness and flavor, although there are different views on whether or not coffee should be refrigerated or frozen. Opened containers of ground beans should be discarded after 1 week. Coffee, whether ground or in bean form, is often stored in the freezer to maintain its freshness. Unopened, sealed packages of whole coffee beans store fairly well in a cool, dry place, but the freezer may be an option if they are stored in an airtight container to avoid absorption of other food odors and deterioration from oxygen.

Water-to-Coffee Ratio

The normal ratio of coffee to water ranges from 1 to 3 tablespoons of coffee (1 Tbsp = weak, 2 Tbsp = medium, 3 Tbsp = strong) for each 6-ounce cup, or about 1 pound of coffee for every 1¾ to 2 gallons of water. Measurements for coffee pots are based on an average 6-ounce coffee cup. Personal preferences and geographical locations dictate the most appropriate ratio.

Water Type

Coffee is 98% water, so the type of water selected to prepare it makes a difference. Fresh, cold, tap water is usually best for making coffee. Bottled water is preferred if the tap water has off-flavors or if a coffeemaker that may trap mineral buildup is used. Hot water has a tendency to produce a flat, stale cup of coffee. Deionized or distilled water tends to produce a sour cup of coffee. Water that is naturally soft is best, although chemically softened water is not recommended because it filters more slowly and the sodium ions may combine with the fatty acids of the beans to form soaps (68).

Water Temperature

The water to be used for coffee should not be boiled because the dissolved oxygen will escape, resulting in flat-tasting coffee. Boiling also causes a loss of volatile compounds responsible for flavor; thus, the aroma of boiling coffee smells good, but the coffee itself lacks flavor. It is best to warm the water to just below boiling temperatures (190 to 200°F [88 to 93°C]) in order to extract just the right amounts of substances from the coffee grounds. Another method to reach this temperature is to bring the water to a boil, remove from heat, and wait 30 seconds. At these temperatures, about 20% of the weight of the grounds is extracted, which makes the best cup of coffee. Lower temperatures do not extract sufficient flavor, whereas higher temperatures extract too many bitter compounds.

Brewing Time

Brewing time usually averages about 5 minutes, depending on the type of

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grind. A fine grind requires less time for extraction than a coarse grind. The fineness or coarseness of the grind selected is often determined by the brewing equipment used (Table 27-4).

Brewing Equipment

The basic styles of brewing equipment rely on filter, drip, percolator, vacuum, and steeping mechanisms. Different types of coffee-making equipment based on these systems are shown in Figure 27-5. Keurig brewing systems are the latest type of equipment that uses small "K-Cups" to brew individual cups of coffee. A K-Cup consists of a coffee filter placed inside a small plastic container along with ground coffee; numerous blends and flavors are available from the various coffee companies under license. The brewer machine punctures the foil lid cup top and plastic bottom, forcing hot water through under pressure (4). When preparing coffee, consult the coffee brewing appliance's manual for specific brewing instructions.

TABLE 27-4 Brewing Time Increases with Larger Grind Sizes

Grind	Brewing Time (Minutes)	Usual Equipment
Very fine	1–2	Espresso, filter
Pulverized	2–3	Turkish coffeepot
Fine	2–4	Vacuum
Drip	4–6	Drip pot
Regular	6–8	Percolator/steeped
Coarse	6–8	Percolators with aluminum filters

Materials used to make coffee equipment should be stainless steel, glass, earthenware, or enamelware; uncoated metals leave an undesirable aftertaste. After use, the equipment must be washed to remove the natural oils that accumulate and may become rancid. Thorough rinsing removes any soap residue. Mineral deposits in the drip spout can be prevented by pouring through it a combination of 1 cup of hot water and 1 cup of white vinegar once every 3 months.

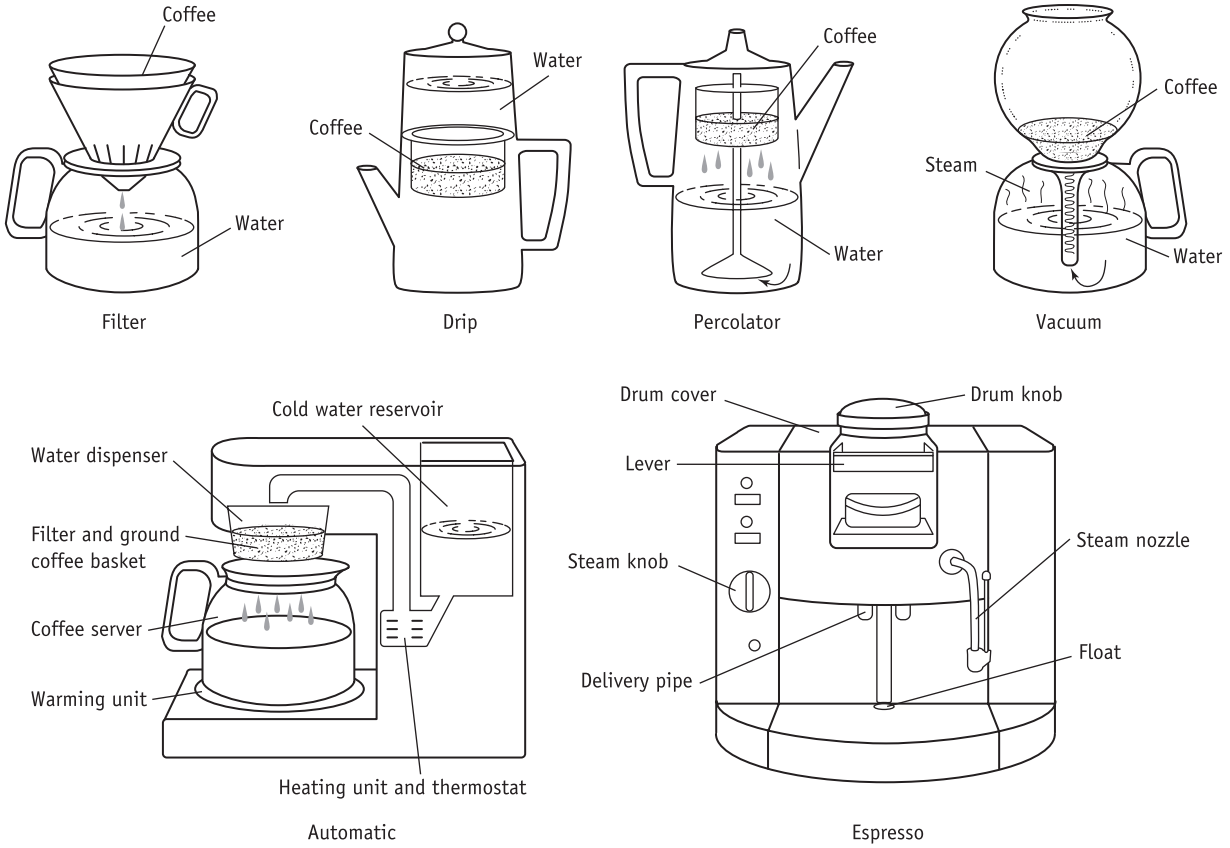
Holding Time

For the best flavor, piping hot coffee should sit for 3 to 5 minutes before being sipped to allow the flavor to mellow. Coffee can be held at 185 to 195°F (85 to 88°C), but the longer it is held, the more the flavor deteriorates. Coffee should never be held for over an hour or the loss of flavor will be substantial. Higher temperatures will also negatively affect the quality of the coffee. Reheating is not recommended because it causes coffee to lose much of its flavor and aroma as volatile compounds are lost, destroyed, or altered.

Storage of Coffee

Whole, roasted coffee beans should be transferred from their paper bag to a tightly sealed glass or metal container and stored in the refrigerator, freezer, or other cool, dry place. Properly stored, they will retain their freshness for up to 3 weeks. Whole coffee beans can be frozen for several months, and there is no need to thaw the beans before grinding. For the freshest taste and aroma, they

FIGURE 27-5 Coffee-brewing equipment.



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should be ground just before brewing. Coffee beans contain sufficient fat to make them good candidates for rancidity with improper or overly long storage; this will also cause them to lose volatile essential oils. Most ground coffee on the market is vacuum-packaged, but once opened, it starts to lose its freshness. For maximum keeping time, ground coffee should be protected against any exposure to air or moisture by being stored in an airtight container in the refrigerator or freezer.

TEA

The origins of tea, one of the world's most popular beverages, can be traced to ancient China. Legend has it that around 2737 BC, Chinese emperor Shen Nung was boiling water when some wild tea leaves fell into the pot. The aroma was so pleasant that he tasted the brew and declared it good (39). The plant from which the leaves fell was an evergreen shrub, the *Camellia sinensis*. It is believed to have been first grown in India. In the sixteenth century, traders from Europe carried tea leaves and the knowledge of how to make the brew home from the Far East, and by the eighteenth century, it had become the national drink of England. A tea tax that increased the cost of tea imported by American colonists is said to have triggered the Boston Tea Party of 1773 and the start of the American Revolutionary War (18).

Tea comes from many regions throughout the world. The United States imports most of its tea from Sri Lanka and India, but other main tea-producing countries include China, Indonesia, and Japan. As with coffee, the country of origin and its climate influence the flavor characteristics of each tea variety, but the method of processing is even more important.

Tea Processing

Only the smallest and most tender leaves are picked, which includes the bud and the top two leaves (Figure 27-6). About 1,000 leaves are needed to make 1 pound of manufactured tea. Processing consists of withering, rolling, oxidizing, and firing (54).

Withering

Tea leaves are withered by spreading them out in thin layers to expose them to warm air for 6 to 18 hours to reduce their moisture content by approximately 55 to 65%.

Rolling

Cell structure within the tea leaves is disrupted by rolling that allows oxidation to occur. Also incorrectly called *fermenting,* rolling is the process whereby the natural enzymes in the leaves, released by rolling, cause the leaves to become darker and develop the tea flavor.

Oxidizing

The polyphenol oxidase in the leaves catalyzes the oxidation of the polyphenols (see Chapter 3).

Firing

Firing dries the leaves by passing them through a hot dryer for 20 minutes, inactivating the enzymes and decreasing their leaf moisture (58).

Types of Tea

The three major categories of tea that result from different processing techniques are black (fully fermented), green (unfermented), and oolong (partially fermented) (33, 54) (Figure 27-7). The majority, about 77%, of commercially produced tea is black tea, the predominant choice in North America, Great Britain, Europe, and some Asian countries. People in China, Japan, Korea, and India prefer green tea, which accounts for 21% of the tea produced. Oolong tea, which is consumed primarily in southeastern China, accounts for the remaining 2% of tea production (1). These teas may be further distinguished by added flavorings. In addition, white tea and various herbal teas are available on the market.

Black Tea

The leaves are allowed to wither and dry under hot blown air (80 to 200°F [27 to 93°C]) before being rolled to break the membranes between the cells. Enzymes that occur naturally in the leaves then oxidize the polyphenolic compounds in the cells and create changes in color, taste, and aroma.

Green Tea

For green tea, the leaves are not oxidized but rather are heated and steamed before being rolled. The heat prevents "fermentation" by inactivating the enzymes (14). The lack of oxidation results in the "green" tea that is lighter (greener) than black tea. Matcha is a particular type of green tea created by grinding the entire leaf and dissolving it in water, as opposed to steeping the leaves in a bag or strainer (39).

Oolong Tea

Oolong tea is processed to be somewhere between black and green tea. It

FIGURE 27-6 Harvesting tea leaves.



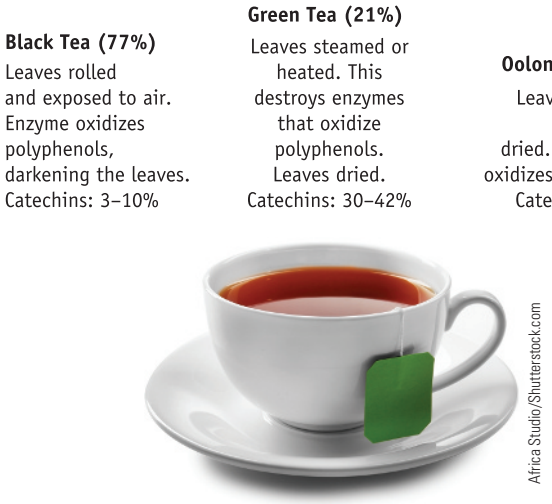
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FIGURE 27-7 Three major types of tea based on processing technique.



is only partially oxidized and is often perfumed and flavored with jasmine flowers.

White Teas

These teas are produced from the tip buds of a special tea plant produced in only one province of China (23).

Flavored Teas

These are teas flavored with natural oils, spices, and dried flowers or fruits. Almond, orange peel, cinnamon, and lemon peel are a few such teas.

Herbal Teas

Beverages derived from plants other than *Camellia sinensis* may be called *herbal teas* (23). In Europe, herbal teas are referred to as "herbal tisane" (45). Technically, these are not teas because they do not contain tea leaves; rather, they are called "teas" because they are brewed in a similar fashion. A wide variety of leaves, flowers, barks, and/or fruits of plants other than the tea plant are used to make herbal teas, which are sometimes called *infusions*. Examples of herbal teas include chamomile, ginseng, spearmint, rose hip, and raspberry. Health and therapeutic benefits are often claimed for these and other herbal teas, but research is still inconclusive. On the other hand, it has been reported that sassafras tea contains the carcinogen safrole; that comfrey in large amounts causes liver damage; that lobelia can cause vomiting; and that woodruff, tonka beans, and melilot are anticoagulants that can result in bleeding (22).

Specialty Teas

This term may be used to refer to teas that are exotic and sometimes flavored with added ingredients (45). The term *premium* is often used interchangeably with *specialty* in the U.S. tea market.

Grades of Tea

The grade of a tea is based primarily on leaf size. The leaves are separated by screens with different hole sizes. Quality decreases as the size of the leaf increases. The largest leaves are generally packaged as loose tea and are named orange pekoe (pee-koh), pekoe, and pekoe souchong. Smaller or broken leaves are usually used in tea bags and called "broken orange pekoe," "broken orange pekoe fannings," and "fannings" (18). Tea bags became popular when an American merchant sent tea leaf samples wrapped in silk bags to customers, who took advantage of this to brew individual cups of tea. The leaves in tea bags are usually blended to yield a characteristic flavor associated with a given brand.

Composition of Tea

More than 300 compounds have been found in black tea, and about 30 in green tea. Some of the major constituents, other than water, in a cup of tea are polyphenolic compounds (such as **catechins** and flavonols), methylxanthines, and volatile compounds. Catechins tend to be found in higher concentrations in young tea leaves than in older leaves (41). The concentration of polyphenols also varies depending on whether the tea is black, green, or oolong. Polyphenolic compounds and/or their oxidative products are largely responsible for the flavor and strong astringency of tea. Green tea has the greatest amount, which gives this tea its metallic taste. Phenolic compounds are believed to have possible antioxidant and anticarcinogenic properties. On the other hand, polyphenols bind iron and prevent some of it from being absorbed by the intestine if tea is consumed with a meal containing iron. Methylxanthines, such as caffeine and theobromine, are found in tea, but in smaller quantities than are found in brewed coffee. Green tea is an excellent source of fluoride, and a moderate source of folate, a B vitamin. Other compounds in tea, theaflavins, help decrease the bitterness of the caffeine, whereas **tannins** contribute to its astringency and characteristic reddish-brown color. Very few nutrients, other than water, fluoride, and folate (B vitamin), are found in tea.

Health Benefits of Tea

Tea, particularly green tea, has grown in popularity because of its purported health benefits. Its cancer-preventing effects are supported by in vitro, animal, and epidemiologic studies (33). The debate over whether green tea reduces the risk of cancer continues. In 2006, the FDA reviewed 105 articles and other publications and determined that there was insufficient evidence to date to allow a claim that green tea reduces the risk of heart disease.

Preparation of Tea

The goal in making tea, as in coffee making, is to extract the compounds responsible for good flavor and aroma, while limiting the extraction or development of bitter substances. Fresh tea may be consumed hot or iced, but the brewing process is the same for both.

Catechins Flavonoid pigments that are a subgroup of the flavonol pigments.

Tannins Polymers of various flavonoid compounds; some of the larger ones yield reddish and brown pigments.

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How & Why?

Why do some people add milk to tea?

The addition of milk decreases the bitterness of tea because milk proteins bind the astringent tannic acids (35).

Brewing Tea

Tea is easy to prepare. Distilled water is best because it is free of minerals and chlorination, which interfere with the tea's flavor. Water is heated to just below the boiling point (212°F/100°C), poured over a tea bag or 1 teaspoon of loose black tea per 6-ounce cup, and allowed to steep for 3 to 5 minutes. Then the tea or bag is removed, and the beverage is served hot or with ice (31). In any case, it is important to avoid boiling the water or steeping the leaves too long, both of which will extract more of the bitter compounds, increase the degree of astringency, and elevate the caffeine concentration. The caffeine content of tea can be reduced by 50 to 75% if the tea bags are soaked in cold water overnight. If the opposite is preferred, stronger teas can be prepared by increasing the amount of tea leaves rather than the brewing time because the longer the tea steeps, the more bitter it will become. Using glass, pottery, china, or stainless steel teapots will keep metallic tastes to a minimum. In addition, the teapot should always be covered to prevent the escape of volatile compounds.

Iced Tea

The story goes that a vendor selling hot tea on a blistering, humid day at the 1904 World's Fair in St. Louis, Missouri, was not having much luck until he dropped a couple of ice cubes into the brew. Iced tea now accounts for more than three fourths of the tea consumed in the United States. It starts out hot, prepared with double the amount of tea leaves used to brew tea to be consumed hot, and it can be poured over ice cubes immediately or allowed to cool before the ice is added.

Sun tea is a popular form of iced tea made by placing eight to ten regular-size tea bags in a 1-gallon jar of cold water and setting it out in the sun for 2 to 4 hours. The bags are then removed and the brew refrigerated. Overnight tea can be made by placing six regular-size tea bags in 1 quart of cold water, covering the brew, and placing it in the refrigerator for at least 8 hours.

Fruit-flavored and herbal teas also make good iced teas. Flavored ice cubes made of citrus, cranberry, or other fruit juice add a special taste to iced teas. Sugar and lemon are often added to iced tea; mint is added less often. Lemon combats the astringency and lightens the tea by bleaching the tannins. It also prevents the tea from clouding by creating an acidic environment, which inhibits the precipitation of compounds formed by caffeine and the tannins. Cooling the tea too quickly can cause the tannins to settle out; this can be avoided by leaving it at room temperature for a while. Cloudy iced tea may also be caused by hard water; this can be avoided by using distilled water. "Ready-to-drink" teas are actually a beverage category introduced in 1991 and available unsweetened or sweetened, in green and white tea varieties, and flavored. These teas arrive already brewed and packaged for immediate use. New tea lines continue to be produced, offering consumers a variety of flavors, decaffeinated options, and herbal blends marketed as having a medicinal value.

Instant Tea

Instant iced tea can be made by mixing soluble tea powders with water and ice. Instant tea powder is manufactured by dehydrating a strong concentration of tea and sometimes mixing it with sugar and other flavorings.

Microwaving

A single serving of tea can be made in the microwave oven by placing one tea bag in a 6-ounce microwave-safe cup filled with cold water, microwaving on high for 30 seconds without boiling, and letting it stand for 30 seconds before removing the tea bag. Iced tea can be made the same way using a 12-ounce glass and ½ cup of cold water. It is allowed to cool a few minutes before adding ice.

Storage of Tea

Proper storage is important in maintaining the quality of tea. It keeps longer than coffee, but when it is stored improperly, it is susceptible to oxidation as well as to the loss of volatile compounds. Tea should be stored in airtight containers at temperatures below 85°F (30°C).

DAIRY BEVERAGES

Milk-based beverages contain more nutrients, in the form of protein, calcium, and B vitamins, than most other beverages. The choices are many, beginning with whole milk (3.5% fat) and moving to reduced-fat (2%), low-fat (1%), fat-free (nonfat), and reconstituted nonfat dried milk (NFDM). Any of these can be used to make hot chocolate, milk shakes, and chocolate or other flavored milk drinks. Some drinks formulated to enhance dietary intake, known as *nutritional beverages,* may be made with a milk base. Fermented or cultured dairy beverages such as kefir, acidophilus milk, and buttermilk are also available. These and a variety of other dairy products are explained more fully in Chapters 10 (on milk) and 26 (on frozen desserts).

Cocoa Beverages

Cocoa powder serves as the basis for either cold or hot cocoa beverages (see Chapter 25 on candy for more information on chocolate). Commercial dry cocoa beverage mixes are available, but noncommercial cocoa beverages can be prepared by either the syrup or paste method. In the syrup method, a syrup is made by briefly boiling either cocoa or chocolate in sugared water. Hot milk is then added to the syrup base. The paste method relies on boiling the same ingredients with some cornstarch before adding the milk. The cornstarch gel creates a more full-bodied hot chocolate beverage. Beverages made by the paste method also have less of a tendency to settle out than do syrup-based cocoa beverages.

ALCOHOLIC BEVERAGES

Alcoholic beverages fall into three major categories: beer, wine, and spirits. Figure 27-8 shows that, although serving sizes for these drinks differ in volume, each contains the same amount of

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FIGURE 27-8 All these drinks contain the same amount of alcohol—1 ounce.



One 1.5-oz glass of liquor | One 5-oz glass of wine | One 12-oz beer

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CALORIE CONTROL
Alcoholic Beverages

Alcohol provides **7 kcalories per gram**; however, lower-kcalorie alcoholic drinks are appearing on the market as weight-conscious consumers become a growing segment of the population. Mild vodkas and whiskeys, with half the alcohol, are available in Europe. In North America, it is more common to find "lite" beers and wine coolers. The term lite refers to lower-kcalorie beer. The word light is used to refer to beer that is lighter in color than the dark beers, so some confusion is possible between the two terms.

- Beer averages about **150 kcalories per 12 ounces**.
- **Lite beers** contain about **100 kcalories**.
- A martini made with vodka or gin averages 150 kcalories.
- **Gimlets** can run as high as **350 kcalories per serving**.
- Dealcoholized beverages have fewer kcalories than their original counterparts.

© 2010 Amy Brown

alcohol—1 ounce. The type of alcohol in drinks is ethanol (C_2H_5OH), which is formed by fermentation of the pyruvate found in plants with a high carbohydrate content (58). When a person drinks any type of alcohol beverage, the ethanol is absorbed into the bloodstream, where it reaches its maximal concentration (blood alcohol concentration [BAC]) within about 45 to 75 minutes.

The most common plants used in alcohol production include barley, wheat, corn, and grapes. The differences among alcoholic beverages stem from how they are manufactured. Beers are fermented by the action of yeast on grain, primarily barley, whereas wines are produced by fermentation of the sugars derived from fruit, primarily grapes. Hard alcohols contain more alcohol and are called *spirits* because they contain (via distillation) the "spirit or soul" of fermented grain or fruit mixtures. More than 50 years ago, apple cider was considered an alcoholic beverage, but the term, for which there is no legal definition, is now used to describe fresh-pressed apple juice with a darker color and less clarity than regular apple juice because of its suspended solids (65). However, the term *hard cider* is often used to describe an alcoholic beverage.

Beer

Baere is the German word for "barley" and the root of the word *beer*. Barley is the principal grain used in the production of beer, although other grains can serve as a source of carbohydrates, which are eventually fermented by yeast to alcohol. Different types of beer result from the different grains and processing techniques used by brewers. This section describes the steps in beer production—malting, brewing, fermenting, lagering, and either filtering or pasteurizing—as well as the types of beer and best practices for serving and storing beer.

Beer Production

Malting

Malting, the first step of beer production, is the process of converting grain to malt. Regardless of the grain used, its starch cannot be utilized by yeast unless it is first converted to simple sugars. This extract of the grain's sugars (maltose, maltotriose, and glucose), known as malt, is the compound that gives beer its characteristic color and flavor: the darker the malt, the darker the beer.

Malting begins with the natural process of germination that activates the starch-breaking enzymes that supply sugars, such as malt, to the growing seedlings. To produce malt, beer manufacturers must first allow the barley to germinate by soaking the grain in water, a production step known as *steeping* (47). Germination is then halted by drying the grain, a process called *kilning,* which results in malt. Timing is important; the germination process must be stopped after the enzymes such as α- and β-amylases are released, but before they have converted the starch naturally present in barley to sugar. Steeping generally occurs for several days, followed by 5 days of kilning at about 60°F (16°C) (10). After germination, the malt is crushed to separate the kernels from the husk.

The barley malt, called *grist,* is made further available to the yeasts by the next step, called *mashing,* in which malted barley is mixed with water and heated to gelatinize its starches. Mashing converts the nonfermentable starches into simpler sugars, mostly in the form of maltose (10). As a result, the liquid fraction resulting from

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How & Why?

Why are hops important to beer brewing?

Hops contribute several substances to beer flavor: essential oils (responsible for aroma and flavor), bitter resins, and the tannins that contribute to color and astringency. The bitterness of hops is lost during storage when the resins are broken down (oxidized and polymerized) (2).

mashing, called "wort," is very high in sugars capable of being fermented by yeast (58). The separation of this liquid fraction is called *lautering* (10).

Brewing

The next stage in beer production, *brewing,* is such a critical step that the entire process of manufacturing beer is often referred to as brewing. Extracting plant materials by pouring hot water over them describes the brewing of coffee, tea, and beer. Beer brewing further consists of adding **hops** to the wort and boiling the mixture. Brewing also concentrates and sanitizes the wort, inactivates enzymes, precipitates proteins contributing to haze, and caramelizes the sugars.

The hops added during brewing are from the hemp family of plants, *Cannabaceae*. Different hops can be used to achieve different flavors, aromas, and bitterness in the brew (10). Hops also have the effect of inhibiting the growth of certain types of bacteria that cause beer to spoil. After hops are added, the mixture is then transferred to a *whirlpool,* where it is cooled and clarified (10).

Fermenting

After cooling, this mixture is ready to be inoculated with *Saccharomyces carlsbergensis* yeast. This ferments for approximately 9 days to produce a beverage containing about 4.6% alcohol by volume (38), though the alcohol content of beer can range from 2% to 8% (18). Yeast converts the sugar in the brew to alcohol and produces carbon dioxide (10). Yeast is also an important factor in developing the dryness or sweetness of beers. The degree to which sugar is converted to alcohol is termed *attenuation,* and high attenuation yields dry (nonsweet) beers, whereas low attenuation produces sweet beers. To stop the production of alcohol from yeast, the temperature is quickly lowered to 32°F (0°C), and the beer is filtered to remove the yeast and other suspended particles.

Hops The dried fruit of the *Humulus lupulus* plant, which grows in the Pacific Northwest of the United States.

Lagering

The next step, called *lagering,* involves storing the beer in tanks for several weeks to months, allowing the development of flavor and body and the settling of particles. The particles, traces of degraded proteins and tannins, will cause an unsightly haze in chilled beer, so they are filtered out to give the beer a clear appearance (11). Enzymes may be added to further degrade the proteins, or earths or clays may be used to adsorb these materials (32).

Filtering or Pasteurizing

The yeast in a bottle of beer brought back to room temperature will continue to ferment up to a certain concentration of alcohol, creating undesirable pressure within the sealed bottle. To avoid this, most beer is either cold filtered (draft) or pasteurized to completely halt fermentation. Filtering removes the yeast, whereas pasteurization kills it. Some of the off-flavors in canned and bottled beer result from the heat of pasteurization. Draft beer is filtered, packaged in kegs, and refrigerated, resulting in a better flavor than that of pasteurized beer. Beer that has been filtered and then refrigerated is identified as having undergone cold pasteurization.

Classifications of Beer

The two main categories of beer are ales and lagers (10).

Ales

Ales go back to when beers were first produced, and they are made with yeasts that form clumps, or flocculate, at the *top* of the fermentation tank and prefer temperatures around 60 to 70°F (16 to 21°C). Ales are aged for several weeks at about 50°F (10°C) and are characteristically complex and flavorful (24). They are usually served at room temperature.

Lagers

These beers have a lighter, cleaner taste than ales and are usually served chilled. Lagers have only been around for the past several hundred years and are produced with yeasts that flocculate at the *bottom* of the tank and prefer cooler temperatures (approximately 50°F/10°C). They are aged for weeks or months at temperatures of 32 to 45°F (0 to 7°C).

Specialty Beers

In addition to differing in whether they have been cold filtered (draft) or pasteurized, beers differ in where they have been produced—by a large commercial brewer, a small brewer, or home brewing. Brew pubs and small brewers produce much of the regional and specialty beers: ales, pale and bitter, light and dark; porter; bock; stout; and flavored beers.

Serving Beer

Beer is best served chilled but not too cold. Light lagers should be served at 38 to 52°F (3 to 1°C), light ales at 54 to 58°F (12 to 14°C), and rich ales and lagers at 57 to 65°F (14 to 18°C) (24). While beer can be consumed straight from the bottle, pouring it into a glass releases aromatics that enhance the flavor. The "correct" pouring technique is to hold the glass at a 45-degree angle and pour the beer in evenly and slowly, while slowly straightening the glass to its upright position. This should result in about one inch of foam on top.

Storing Beer

Beer flavor begins to deteriorate the minute it is packaged. Exposing the beer to oxygen contributes to oxidation and the production of substances (i.e., carbonyl compounds) that taste "pasty, papery, or like cardboard" (80). Beer is best stored in a dry, dark location free of temperature fluctuations. The best storage temperature is 55 to 60°F (13 to 16°C).

Wine

Wines are made from the fermented juice of fruits, usually grapes (*Vitis vinifera*). The grapes used in winemaking are carefully cultivated (10). Compared

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How & Why?

Why are wines described as sweet or dry?

The degree to which sugars are fermented to alcohol determines whether the wine is sweet or dry. Sweet wines contain higher concentrations of unfermented sugars than do dry wines; almost all of the carbohydrate in dry wines has been converted to alcohol.

to table grapes, wine grapes are smaller, have thinner skins, and have a higher sugar content. Wine grapes are harvested when their sugar content is highest because yeast will convert the sugar to alcohol. In contrast, table or eating grapes are usually harvested when their sugar content is at its lowest.

Wine Production

After the yeast ferments the sugar content, the wine is usually racked and aged. These three major steps of wine production are briefly explained here.

Fermentation

Wine production involves the growth of grapes, their harvesting, the extraction of their juices, and finally fermentation (Figure 27-9). The sugar in grapes contributes to yeast fermentation, whereas their acidic concentration (pH 3) discourages the growth of most other microorganisms. Yeasts produce many of the flavors found in wine, so selecting a particular wine yeast strain is very important. Yeasts produce certain compounds (higher alcohols, acids, and esters) that all contribute to flavor quality (51). Fermentation results in the conversion of grape juice to ethyl alcohol (ethanol) (10).

The sweetness and/or dryness of a wine does not always correspond to the alcohol content resulting from fermentation. A dry wine containing 14% alcohol can be made sweeter by adding juice or sugar. Sweet wines are not always lower in alcohol because distilled spirits may have been added. In general, wines average 11% alcohol.

Racking

After fermentation, the wines undergo *racking,* during which they are allowed to stand to settle out the yeast cells and finely suspended material. The wine is then drawn out, leaving behind the sediment or *lees*. Racking was classically done in large 50- to 1,000-gallon barrels, but it is now often achieved with large tanks.

Aging

The next step is aging, in which the wine is stored in casks (often made of oak) or tanks for several months or years to allow the remaining traces of sugar to ferment and to allow the further development of flavor (Figure 27-10). Most of the wines with a final alcohol concentration under 17% are filtered (cold pasteurized) or heat pasteurized just before bottling (Chemist's Corner 27-2). The exception is sparkling wine, in which the carbon dioxide content acts as a partial preservative. Sulfur dioxide (SO_2) is sometimes added to wines to inhibit microbial growth and the enzymatic browning that occurs when the phenolic compounds found in grapes are oxidized by phenolase enzymes (58).

Evaluating Wines

Appearance or clarity, mouthfeel, taste, and aroma are characteristics used to judge various wines. In terms of appearance, wine may be clouded by bacteria or trace metals. The wine's astringency and body (viscosity) contribute to the mouthfeel. Body is the weight of the wine in the mouth—light, medium, or heavy bodied: the more alcohol, the fuller the body (27). Another way to gauge alcohol content is to swirl the wine in a glass and

FIGURE 27-9 Grapes arrive at the winery in gondolas from the vineyard, ready to be crushed into juice for fermentation. Gondolas are usually pulled by a tractor through the vineyard, where grapes are picked either by hand or by mechanical harvester.



Howard Sayer/Shutterstock.com

CHEMIST'S CORNER 27-2

Filtering Wines

Tartrates naturally found in grape juice tend to crystallize as salts of tartaric acid. If these salts are not removed from wine by ion-exchange treatments or a combination of chilling and filtering, the salts will slowly appear as glass-like crystals in the bottom of stored wine bottles (58).

How & Why?

What are congeners?

Congeners (amines, amides, acetones, histamine, polyphenols, and methanol) are produced during alcohol fermentation or added during production. Alcohol beverages high in congeners include red wine, cognac, tequila, and whiskey (59).

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FIGURE 27-10 Fifty-gallon oak barrels age wine and impart flavor and complexity. Wine may be aged in oak barrels for an average of 1 to 3 years. Many fine wines benefit from further aging in the bottle.



iStock.com/alvarez

watch how the liquid streams back down the sides. Thicker rivulets, also called *legs* or *tears,* often indicate a higher alcohol level (27). The major taste difference in wines is their balance between sourness and sweetness. The longer the taste remains in the mouth after being swallowed, the longer the finish and the better the wine will be. Aroma, also known as bouquet or nose, comes from more than 200 volatile compounds, among them **congeners**, which contribute to aroma as well as to hangovers (50). Aromatic wines such as vermouth are flavored with the flowers, leaves, roots, or bark of plants. The aromas and tastes of wine are more easily detected if the wine is aerated with oxygen by swirling it in the glass. To detect any sediment or cloudy, brownish hues indicating spoilage, a wineglass is held up to the light. A dry, crumbly cork means that the wine was improperly stored (27).

Selecting a Wine

Choosing a wine can be confusing because more than 10,000 different strains of *Vitis vinifera* exist, and the names of vineyards or regions on the labels of wines are unfamiliar to most consumers. If a particular growing year results in an especially good wine, it is known as a **vintage** year.

Congener An alcohol by-product such as methanol or wood alcohol.

Vintage The year in which a wine was bottled; especially an exceptionally fine wine from a year with a good crop.

Types of Wines

Table 27-5 lists common types of wines. Some of these wines are named after their grape of origin—such as Cabernet Sauvignon, Concord, Muscatel, Pinot, Riesling, and Zinfandel. Others are named for their region of origin (more common with French wines)—Bordeaux, Burgundy, Chablis, Madeira, Moselle, Port, Rhine, and Sauterne. Wines may also be classified based on certain characteristics, such as sweetness or dryness, carbonation, or color. As a result, wines are sometimes categorized as appetizer wines, sweet dessert wines, sparkling wines, and red or white table wines. Champagne, named after a region in France, is a wine that has been carbonated—either naturally in the bottle, a method known as the champagne method, or mechanically by adding carbon dioxide to the wine. Only sparkling wines made in the Champagne region of France can be called Champagne. Champagne flutes are designed so that their shapes help the bubbles last longer.

The Colors of Wine

Wines may be white, red, or pink. White wines can be made from lightly colored (white or green) grapes, or they can be made from red grapes by one of two methods (Chemist's Corner 27-3). The first method is to remove the skins, pulp, and seeds from the red grapes prior to pressing, and the second is to gently press the red grapes and collect the juice early enough so that the pigments from the skin have not had time to release. Red wines are produced by leaving the skins, pulp, and seeds in the juice. Pink wines are made by adding a small amount of red wine to white wine (58). The traditional guideline has been that red wine goes with red meat, white wine goes with white meat, and a dessert wine is served after dinner/supper, but actually the decision should be made entirely on the basis of which wine one prefers (26).

CHEMIST'S CORNER 27-3

White Wine from Red Grapes

If white wines are made with red grapes, any remaining pigments can be removed with ion exchange, anthocyanase enzymes, or activated charcoal treatments (58).

How & Why?

Why are wines decanted?

A wine decanter can be used to separate the sediment from the wine and improve its flavor. Decanting is simply pouring the wine into a glass container, such as a decanter or carafe (25). Decanting allows young wines to aerate, which improves their flavor and increases the temperature for optimal drinking. Older wines are decanted to remove any sediment that develops over time. Decant wines by letting the unopened bottle stand for 12 hours (30 minutes for young wines), removing the cork as gently as possible without disturbing the sediment, wiping the top and inside neck of the bottle with a cloth to remove any dust or mold resulting from the aging process, and pouring the wine slowly in one continuous pour to prevent the sediment from mixing with the wine (25).

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TABLE 27-5 Wines

Product	Description	Uses
Apple wine (hard cider)	Apple cider or juice that has been allowed to ferment.	Served cold or hot as a beverage. Distilled to make apple brandies such as applejack (an American product) or Calvados (from Normandy, France).
Aromatic wine	A fortified wine flavored with one or more aromatic plant parts such as bark, flowers, leaves, roots, etc. Vermouth is one of the best-known types of aromatic wines.	An aperitif (drink served before a meal to stimulate the appetite) that is best when poured over ice. Mixer for cocktails and similar drinks.
Bordeaux	A wine produced in the Bordeaux region of France.	During meals or with the dessert. Good when chilled slightly and served in elongated Bordeaux glasses.
Brandy	Distillate from a wine (hence, the characteristics of each product stem from those of the original wine, the type of distillation, and the aging process).	After-dinner drink. In desserts and other dishes.
Burgundy	A wine produced in the Burgundy region of France. May be red, white, or sparkling.	During meals or with the dessert. Good when chilled slightly.
Cabernet	Wine made from the Cabernet Sauvignon grape, which was brought from Bordeaux, France, to California.	With or after a meal. Pairs well with steak but not spicy foods.
Chablis	An excellent dry white wine (with a green-gold tint) from the French town of Chablis. However, the name is sometimes applied to similar dry, white wines made elsewhere.	The best wine for serving with oysters. Also good with fish, hors d'oeuvres, seafood, and shellfish.
Champagne	A sparkling wine that is made by allowing wine from Pinot grapes to undergo a second fermentation after a small amount of sugar has been added to the bottle. In France, the name Champagne is limited to the sparkling wines produced in the province of Champagne.	An aperitif that is served chilled. However, it may also be served at any time during any meal. A tulip-shaped glass helps to retain the bubbles.
Chianti	Red wine from the Tuscany region of Italy that is often sold in a round-bottom flask placed in a straw basket. However, the best wine comes in tall bottles that can be binned for aging.	With meals, particularly when Italian meat or pasta dishes are served.
Claret	A dry, red Bordeaux wine made from Cabernet Sauvignon grapes.	With or after a meal.
Cognac	Brandy that is double-distilled from wine made in the Charente district of France.	After-dinner drink. In desserts and other dishes.
Dry wines	Wines that are not sweet or sweetened. (In other words, all or most of the natural sugar content has been converted to alcohol.)	With or after a meal.
Fortified wines	Wines that have had their natural alcohol content increased by the addition of a brandy.	With dessert or after dinner. Should be served in small, narrow glasses.
Honey wine (mead)	An ancient type of wine that was made from fermented honey flavored with herbs.	With meals.
Light wines	Wines that have a low alcohol content.	With meals.
Madeira	One of the wines made on the island of Madeira. Madeira wines are the longest-lived (they keep for many years without deterioration) of any of the wines.	Depending on the type of wine, it may be served at various parts of the meal.
May wine	A light, white Rhine wine that is flavored with the herb woodruff.	Served chilled in a punch bowl with pieces of fresh fruit floating on top.
Moselle wines	Light wines (the alcohol content is usually about 10% or less) made in the valley of the Moselle River in Germany, which lies to the west of the Rhine.	With lunch or dinner.
Mulled wines	Heated, sweetened, spiced wines served in a cup.	Served during the winter holidays.
Muscatel	A sweet, fortified wine made from Muscat grapes.	Served with dessert.
Perry (pear wine)	Light wine made from pear juice.	With meals.

(*continued*)

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TABLE 27-5 Wines (*Continued*)

Product	Description	Uses
Pinot	Wine made from Pinot grapes.	Starting material for making champagne. Served with meals.
Port	The type of fortified wine that originated in the town of Oporto in Portugal.	With dessert or after dinner.
Pulque	Fermented juice of the agave plant that grows in Mexico and in the southwestern United States. A common drink in Mexico.	Used to make a distilled liquor, or used shortly after its preparation because it does not keep well.
Red wines	Wines produced from dark-colored grapes that are fermented together with their skins (which contain most of the color pigments).	Served at meals featuring beef or lamb dishes, other than stews flavored with wine. (In the latter cases, wine is served after the meal.)
Resinated (Greek) wines	Greek wines containing a resin that imparts a pine-like flavor.	Best served with mild-flavored main dishes made from fish, pork, or poultry.
Rice wine (sake)	A Japanese wine made from fermented white rice. Although made from grain and sometimes referred to as beer, sake's alcohol content is similar to that of wine.	With meals at Japanese restaurants. May be served hot.
Riesling	White wine made from the Riesling grape, which is considered to be the finest wine grape grown in Germany.	With meals.
Rhine wines	Wines from grapes grown in the Rhine River Valley of Germany. (The wines range from dry and light to rich and sweet.)	Depends on the characteristics of the wine.
Rosé wines	Rose-colored wines produced by fermenting dark-colored grapes. The best rosé wines are made from Grenache grapes.	With cold foods and light meals, or when either a red or white wine may be used.
Sauternes	Wines made in the Sauterne district of Bordeaux, France, from grapes withered somewhat by a Botrytis mold that is also called "noble rot."	Should be served cold at the end of a meal, preferably one at which no other wine has been served. Serve in small, narrow glasses.
Sherry	A fortified wine made by a process similar to the one developed in Jerez de la Frontera, Spain. (Sherries range from pale-colored dry wines to rich, sweet ones.)	Depends on the characteristics of the particular wine.
Sparkling wines	Wines that are bubbly with carbon dioxide gas by virtue of having undergone a second fermentation initiated by the addition of a small amount of sugar.	Accompaniments to any part of a meal.
Sweet wines	Fortified wines that contain considerable amounts of unfermented sugars. (The addition of extra alcohol prevents the fermentation of the sugars that are present.)	Served as dessert. Should be served in a small, narrow glass.
Table wines	Unfortified wines of low to moderate alcohol content. (They usually contain 14% or less alcohol.)	Served with meals.
Tokay	A rich white dessert wine made in Hungary that comes in dry and sweet varieties.	At meals or with desserts, depending on whether the dry or sweet variety is served.
Vermouth	A fortified wine that is flavored with a variety of aromatic herbs and comes in dry and sweet varieties.	Preparation of martinis or other cocktails. Sweet Italian vermouth is often served on ice as an aperitif.
White wines	Made by fermenting grapes separated from their skins in order to keep the content of colored pigments low.	Served at meals featuring fish, pork, poultry, seafood, shellfish, or other bland-flavored items.
Zinfandel	A red wine made from Zinfandel grapes grown in California.	At meals featuring beef or lamb dishes other than stews that contain wines.

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TABLE 27-6 Spirits

Types of Liquor	Production
Brandy	Brandies are distilled from either a wine or a fermented mash of fruit. They are often aged for 2 or more years to mellow the harshly flavored constituents common to distilled liquors.
Gin	A fermented grain mixture is distilled to yield a strong alcohol mixture, which is then either redistilled or mixed with flavoring derived from juniper berries or other botanical substances.
Liqueur or cordial	A distilled liquor is either mixed or redistilled with one or more flavoring materials such as fruits, fruit peels, herbs, spices, flowers, cocoa, coffee, or roots. Liqueurs may contain from 2½% (minimum) to 35% added sugar.
Rum	Rum is distilled from a fermented sugarcane product. The stronger-flavored rums are usually aged for 3 or more years. Sometimes the distillation residue is added to subsequent rums to produce a strongly flavored product.
Vodka	Produced from starchy materials such as potatoes and/or grains (the starch is converted to sugar by enzymes). The distillation process used for vodka yields a product high in alcohol and low in congeners. The distillate is usually run through charcoal to remove any unwanted components.
Whiskey: All types	Produced from malted and unmalted grains. The enzymes in the former convert the starch in the latter to sugar. Distillation of the fermented grain mash is conducted to yield a product rich in congeners. The newly distilled liquor is usually aged in wooden barrels. Various whiskeys are often blended.
Bourbon	Made from either malted or unmalted grain, mainly corn. The distillation mixture is a sour mash containing about ¼ old mash (previously fermented) and ¾ new mash. Aging is done in charred barrels.
Canadian	Produced in Canada from malted barley and unmalted corn, rye, and wheat. It is distilled as other whiskeys, and then aged for 3 or more years. Usually, Canadian whiskeys with different characteristics are blended.
Irish	Malted barley and unmalted barley, corn, oats, rye, and wheat. Product of either the Republic of Ireland or Northern Ireland. The fermented mash, made from barley and other grains, is distilled in three stages. (Hence, it is "triple distilled.") Irish whiskeys are aged for at least 4 years. Many are blended.
Rye	Produced from rye and other grains, distilled to yield a high content of congeners, and then aged in charred barrels.
Scotch	Produced in Scotland from mainly malted barley. The fermented mash is distilled in two stages. (Hence, it is "double distilled.") Newly distilled Scotch whiskey is aged from 3 to 4 years in barrels previously used for whiskey or wine, and then blended with other whiskeys.

Food Additives in Wines

Sulfites are usually added to red wines (not white) to maintain their red or pink colors. People who are sensitive to sulfites can avoid these additives by reading the beverage's ingredient label (64).

Spirits

As mentioned earlier, distilled beverages are often called "spirits" because they embody the *spirit* of the fermented mixture. They are also often referred to as *hard* because they contain more alcohol than beer or wine. The boiling point of alcohol (173°F/78°C) is almost 40 degrees lower than that of water, so alcohol can be easily vaporized, cooled, condensed, and collected. Without this distillation, the alcohol concentration of most alcohol drinks would not exceed 15% because that is the highest alcohol concentration that yeast can tolerate.

Spirits, or liquors, include whisky, rum, vodka, brandy, and gin, among others (10). Liquors have no added sugar and are at least 35% alcohol by volume. Liqueurs, on the other hand, are distilled beverages sweetened and flavored with various compounds, including fruits, herbs, spices, or nuts.

Liquor is created via distillation of a mash that begins with boiling fermented fruit or grains (10). Alcohol separates from the water as steam, which is collected in a cooling tube and then recooled so it returns to a liquid state. Alcohol that is repeatedly distilled can result in 95% pure ethanol.

While wine and beer continue to age and develop flavor after bottling, liquor does not. It is best to store liquor in a cool, dry location.

Proof

The amount of alcohol in spirits is called its **proof**. An 80-proof liquor contains 40% alcohol by volume. Most liquors are 80 proof or 100 proof (40% or 50% alcohol, respectively), but some concentrated forms of whiskey and rum are 150 proof (75% alcohol), and grain alcohol can be up to 190 proof (95% alcohol). Liquor has a much higher proof than beer or wine. Beer is generally 8 to 12 proof, corresponding to an alcohol content of 4% to 6%. Wine is 14 to 28 proof, or 7 to 14% alcohol (10).

Common Spirits

Table 27-6 lists some of the common distilled spirits. Gin and most whiskeys are derived from fermented grains. Vodka is made from either grains or potatoes. Liqueurs, which are sweet, syrupy, flavored liquors, are produced by steeping herbs or fruits in strong spirits before distillation. Rum is made from products of sugar cane. Tequila, a less common liquor, comes from the fermented sap of the Mexican-grown mescal plant. Spirits can also be produced by distilling the alcohol in wines. This process results in such beverages as brandy, which is distilled wine; cognac, which is double-distilled brandy; and fortified wines, to which brandy is added to double the alcohol content.

Proof Alcohol strength indicated by a number that is twice the percent by volume of alcohol present.

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PICTORIAL SUMMARY / 27: Beverages

Most beverages fall into one of the following seven categories: water, carbonated, fruit/vegetable, functional, aromatic (coffee and tea), dairy, and alcohol.

WATER

Water contains zero kcalories and vitamins, and its mineral content varies according to region. Water is an essential nutrient required for the very existence of life. Plain water, the simplest of all beverages, from surface or underground sources, is either hard or soft. Bottled water is regulated by the FDA and can be classified by its source (artesian water, mineral water, spring water, well water) or treatment (deionized water, distilled water, reverse osmosis water).

CARBONATED SOFT DRINKS

Adding sweetener, flavors, colors, acids, and preservatives to sparkling water creates a limitless number of carbonated drinks, known as soft drinks, sodas, or pops. Soft drinks are usually 10% sugars. Using alternative sweeteners increases the water content from 90% to 98% while eliminating the sugar.



FUNCTIONAL BEVERAGES

Functional beverages represent all beverages that do not fit into the traditional categorization of drinks, including beverages identified as sports drinks (low-carbohydrate, high-electrolytes), nutraceuticals (health benefit), smart beverages (alleged brain stimulators), and energy beverages and shots (high-carbohydrate and/or high-caffeine).

COFFEE

Coffee is made from beans that are processed by hull removal, roasting, and grinding. Making a good cup of coffee requires extracting enough of the compounds contributing to good flavor and aroma while limiting the extraction of bitter substances.



These factors influence the quality of coffee:

- Types of coffee
- Coffee quality
- Coffee freshness
- Water-to-coffee ratio
- Water type
- Water temperature
- Brewing time
- Brewing equipment



Once roasted, coffee beans will stay fresh for 2 to 3 weeks, whereas the freshness of ground coffee lasts only a few days.

TEA



Tea is one of the most popular drinks in the world and can be served hot or iced. The three basic categories of tea—black, green, and oolong—depend on the type of processing, which consists of withering, rolling, fermenting (for black and oolong), and firing. Tea grade is based primarily on leaf size. Tea keeps best in airtight containers placed in a dry atmosphere.

DAIRY BEVERAGES

Milk-based beverages are high in protein, calcium, and B vitamins. Examples of dairy beverages include fluid whole, reduced-fat (2%), low-fat (1%), fat-free (nonfat), and dried milks. These milks can be incorporated into other beverages such as hot chocolate, milk shakes, and chocolate or other flavored milk drinks.



ALCOHOLIC BEVERAGES

Alcoholic beverages fall into three major categories: beer, wine, and spirits (hard liquor).

Beers and wines are fermented with the action of yeast on barley and grapes, respectively.

Spirits contain the distilled alcohol derived from fermented grain or fruit mixtures.

BEER **WINE** **SPIRITS**



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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Deionized water is basically purified water without _____.
   a. color
   b. minerals
   c. carbonation
   d. steam

2. The fizz or bubbles in sparkling water are attributed to _____.
   a. oxygen bromide
   b. carbon carbonate
   c. carbon dioxide

3. Coffee is classified as a light, medium, or dark roast based on _____.
   a. grind
   b. roasting time
   c. roasting temperature
   d. caffeine content

4. What chemical compounds found in green tea act as antioxidants and may have anticarcinogenic properties?
   a. Phenolic compounds
   b. Phospholipids
   c. Pyrroles
   d. Phosphates

5. The principal grain used in beer production is _____.
   a. wheat
   b. hops
   c. malt
   d. barley

6. _____ is/are added to some nutraceutical beverages for joint health.
   a. Glucosamine and chondroitin sulfate
   b. Omega-3 fatty acids
   c. Chromium
   d. Mangosteen juice

7. Sulfites are often added to red wines to maintain their ___.
   a. flavor
   b. yeast fermentation
   c. color
   d. alcohol content

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Describe how the following types of water differ: mineral, deionized, distilled, and sparkling.
2. Describe the general ingredients in soft drinks and their functions.
3. Define the following types of functional beverages: *sport, nutraceutical, energy,* and *smart*.
4. What is the purpose of roasting, and how does it affect the quality of coffee?
5. After roasting, why are the coffee beans ground? How does the size of the bean influence the type of equipment that will be used?
6. What compounds are responsible for the bitter, slightly sour taste of coffee? What preparation mistake causes a higher concentration of these compounds to be present?
7. Describe the differences among the following types of coffee beverages: espresso, caffè mocha, caffè latte, and café au lait.
8. How should roasted coffee beans be stored to retain their freshness?
9. Explain the differences among black, green, and oolong teas.
10. Describe how each of the following types of alcohol beverages is produced: beer, wine, and spirits.

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28



Food Preservation

Food Spoilage 540
Food Preservation Methods 542
Cold Preservation 546
Heat Preservation 548
Other Preservation Methods 548
Nutrient Retention 552

The U.S. Department of Agriculture (USDA) estimates that approximately 20% of all food is lost to food spoilage (8). Spoilage contributes to the average North American family discarding about one-fourth of the food it purchases (77). Some of the biological, chemical, and physical changes that lead to spoilage are preventable. This chapter explains why food spoils and the preservation methods to prevent spoilage.

Yeast A single-celled fungus (a plant that lacks chlorophyll) that is able to ferment sugars and that is used for producing food products such as bread and alcohol.

FOOD SPOILAGE

The foods we eat are all derived from living matter and thus subject to the natural process of decomposition. Food not only decomposes but is consumed by creatures other than humans—rats, mice, flies, and microorganisms. Food spoilage is obvious and detectable because of changes in appearance, taste, texture, and/or odor that all affect eating quality (67). In contrast, food contamination, which can also occur with food spoilage, is often undetectable (see Chapter 4 on food safety).

Not all foods spoil at the same rate. Foods are classified as perishable, semiperishable, or nonperishable, depending on their susceptibility to spoilage. The most perishable foods are those with large concentrations of protein and/or water, which accelerate the microbial and chemical processes of decomposition. For example, fish, seafood, meat, eggs, and dairy products, which all have high protein and water contents, are very perishable. Watery fruits and vegetables such as tomatoes, peaches, berries, and leafy vegetables are also highly perishable. Semi-perishable foods contain less water and protein and include those that remain edible for several months if stored under the proper conditions. Selected examples include potatoes, carrots, beets, turnips, onions, and apples. Processed nuts, cereals, dried tea leaves, pastas, and dried beans and peas are nonperishable because they contain very little water and protein, and they will keep for many months with little loss of quality.

The biological, chemical, and physical changes in food that contribute to spoilage are briefly discussed in this section of the chapter.

Biological Changes

The prime biological factors involved in food spoilage are microorganisms such as bacteria, **yeasts**, and molds. Just

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like people, these tiny organisms need nutrients to survive, so food is a natural target for them. The most common foods spoiled by bacteria include meat, eggs, milk, and opened canned goods. Foodborne illnesses caused by bacteria are discussed in Chapter 4.

Yeasts prefer high-sugar foods, such as fruits, vegetables, and fruit preserves, and can cause unwanted **fermentation** of fruits and fruit juices in the presence of the proper amounts of oxygen, moisture, and acidity (pH). The naturally occurring yeasts found in the air normally pose no threat. The moisture in foods, however, can encourage their growth to a point that becomes unacceptable. Any method that keeps the moisture content low will be successful in controlling yeasts.

Molds and their toxins are discussed in Chapter 4. These microorganisms, like yeasts, prefer high-sugar foods but are particularly drawn to cheese and bread. The appearance of their bloom on foods indicates that spoilage has begun. Molds are easily spread through the air, are very resistant to drying, and can be difficult to control by the means used for bacteria and yeasts. Commercial food enterprises employ vacuum pumps to remove oxygen from containers because molds cannot grow in its absence.

The many weapons in the arsenal used to fight spoilage resulting from microbial action include boiling, refrigeration, drying, and curing with high concentrations of sugar or salt. These methods, which destroy or inhibit the growth of microorganisms, are discussed later in this chapter in the section on "Food Preservation Methods."

FIGURE 28-1 Edible biosensor stickers on foods can be scanned by a smartphone to detect spoilage.



Fiorenzo Omenetto

CHEMIST'S CORNER 28-1

Proteinases

Also known as "proteases," "proteolytic enzymes," and "peptidases," these enzymes split proteins into smaller peptide fractions, such as peptones and proteoses, which are then broken down into polypeptides and peptides. The latter are then split by peptidases into amino acids. The various protein enzymes break protein down into a liquefied mass because the amino acids are water soluble (62). The entire process is called proteolysis.

Chemical Changes

Chemical reactions or changes also contribute to food deterioration. Enzymes play a significant role in catalyzing these reactions and can be categorized by the substance on which they act (substrate) or their mode of action (71). Proteases, also called "proteolytic enzymes," split proteins into smaller compounds (Chemist's Corner 28-1). Fish has many more active proteases than meat, which is one of the reasons fish deteriorates so quickly. Lobsters are also prone to proteolytic breakdown, which begins the minute they expire. Unless lobsters are kept alive until the very last second, the proteases cause the lower abdomen to partially liquefy, with the result that the tail meat becomes crumbly when cooked (47).

Lipids are broken down by enzymes called "lipases," which degrade the triglycerides of fat into glycerol and fatty acids. Further degradation leads to rancidity, or off-odors and off-tastes.

Enzymes that decompose carbohydrates are carbohydrases, each named after the particular sugar on which it acts. Another group of enzymes that oxidize compounds includes ascorbic acid oxidase, peroxidase, tyrosinase, and polyphenolase. The last two of these enzymes are involved in enzymatic browning, which leads to unappetizing brown discoloration in some fruits and vegetables. Hydrolysis may also contribute to the deterioration of foods. See Chapter 3 for a more detailed discussion of these chemical reactions.

The chemical changes that occur in spoiling food can be detected. This principle was applied by researchers to develop an edible alert sensor that can be scanned by a smartphone to determine whether or not the food is spoiled (Figure 28-1). The sensor stickers can be placed on food to detect subtle changes that trigger the emission of an electromagnetic signal (9).

Physical Changes

Physical changes, unlike chemical changes, do not result in the formation of new compounds. Common physical changes that occur in foods as they spoil are evaporation, drip loss, and separation. Water evaporates out of improperly stored foods, creating an unattractive, dried-out appearance and possibly undesirable flavor changes. Water can also be lost (syneresis) out of foods such as gelatins, yogurt, and sour cream as they age. Separation of water

Fermentation The conversion of carbohydrates to carbon dioxide and alcohol by yeast or bacteria.

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How & Why?

How is nanotechnology used in foods?

Nano is the prefix that represents *billion*. Nanotechnology deals with materials that are 1 to 100 nanometers—that is, billionths of a meter—in diameter. As a reference point, a sheet of paper is 100,000 nanometers thick, and a DNA molecule is 2.5 nanometers wide. Nano foods are produced when nanoparticles or nanotechnology techniques are used during their cultivation, production, processing, or packing. Few such products exist, but they are being researched. Practical applications include biosensors for detecting contaminants (chemicals or foodborne pathogens) in food and barriers to gases or moisture in packaging, as well as food additives that enhance the product's stability or quality or increase the availability of its nutrients during digestion and absorption (57).

and oil occurs in foods such as nonhomogenized milk, mayonnaise, salad dressings, and high-moisture cheeses when they are stored too long or are frozen and later thawed.

FOOD PRESERVATION METHODS

For more than 5,000 years, humans have been preserving foods by drying, salting, and fermentation. Ironically, the demands of war have triggered monumental developments in food preservation techniques. Napoleon's need for a safe and portable food supply for his armies in the late 1700s and early 1800s led to the discovery of canning (18). World War II led to the development of **dehydrated** foods such as instant potatoes and eggs. The American Red Cross provided irradiated milk in the food packages given to prisoners of war (58). The Vietnam War spurred the refinement of the process of **freeze-drying**, which allowed for the development of complete, lightweight foods that could be carried into the field easily and transformed into ready-to-eat meals by adding water.

Because of newer preservation techniques and advances in refrigeration and transportation, people now enjoy a wide variety of foods from all over the globe, including out-of-season and exotic foods. Dried fruits and vegetables are widely used by the confectionary, baking, and processed food industries (34). Dried fruits or vegetables are used in cereals, energy bars, dietary supplements, puddings, soups, and as powdered flavorings and colorants.

Chemical protection prevents changes in food composition typically due to exposure to gases, moisture, or light (40). Glass and metal provide an absolute barrier to these agents, while plastic is more permeable and only provides partial protection (39). Biological protection is the prevention of contact with microorganisms, rodents, insects, and other animals. Physical protection focuses on preventing mechanical damage (40).

This section discusses the various methods of drying, curing, fermentation, pickling, and canning; cold, hot, and other preservation methods; and nutrient retention during preservation.

Dehydrate To remove at least 95% of the water from food through exposure to high temperatures.

Freeze-dry To remove water from food when it is in a frozen state, usually in a vacuum.

Drying

Drying is the removal of the food's water, which effectively inhibits the growth of microorganisms and simultaneously makes the food lighter to transport (11). Bacteria and molds need approximately a 15% moisture level to survive, whereas yeast needs at least a 20% moisture content. As mentioned in Chapter 3, the water activity of a food (a_w) is the measurement of its water content (17). The a_w required for preservation varies by food but is generally a value below 0.6. Once dried, the food can be eaten as is, or, unlike microorganisms, be rehydrated (have water added), which changes its size, color, flavor, and texture (17).

Sun-Drying

Many early cultures subsisted throughout the year on naturally dry foods such as nuts, grains, and dried legumes. The discovery that fruits, vegetables, and meats could be dried in the sun was a natural extension of this practice (77). The sun provided the heat for evaporation for many centuries, and it continues to do so in various countries around the world.

Commercial Drying

Because sun-drying takes a long time and exposes foods to the weather and to the action of insects, most foods are now dried by various commercial processes, although raisins are still sun-dried.

The most important types of commercial drying are conventional (heat), vacuum (pulls the water out), osmotic (water drawn out by osmosis), and freeze-drying (ice crystals vaporize), microwaving, and any necessary pretreatments.

Conventional Drying

Conventional drying uses heat to evaporate the water. In one method, the food is spread on a slatted floor or on shelves within kilns or drying rooms. A blower then passes hot air from a heater over and through the food. In tunnel drying, food is placed on trays or "cars," which are moved through a tunnel of carefully controlled hot air. Liquids can be dried by either spray drying or drum drying.

Spray Drying

A fine spray of the liquid is dried very quickly in midair. Common foods that are spray dried include nonfat dried milk, coffee creamers, instant coffee, fruit juice powders, and dried whey (16).

Drum Drying

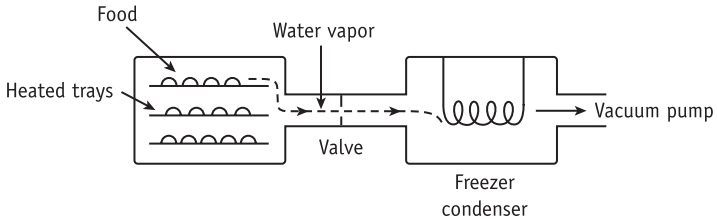
Liquid is poured over the very hot surface of a drum dryer, an apparatus resembling a large barrel, to dry the food that is then peeled off like tissue paper, ground into flakes, and packaged. Some foods that are drum dried include mashed-potato flakes and quick-cooking hot cereals.

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FIGURE 28-2 Typical freeze-drying process.



Vacuum Drying

Vacuum drying dehydrates foods to very low moisture levels (1 to 3%) through the use of a vacuum. Milk, tomato paste, orange juice, and coffee are often concentrated by vacuum drying. The food is placed in a chamber and the surrounding pressure is reduced below atmospheric pressure, which lowers water's boiling point. The water is then more easily boiled off at this lower boiling temperature.

Osmotic Drying

Osmotic drying is not often used commercially. It relies on the reuse of a strong syrup with a high sugar concentration that osmotically draws water from the object being dried. Ocean Spray's Craisins are cranberries dried through osmotic drying (61).

Freeze-Drying

Freeze-drying consists of first freezing the food and then placing it in a vacuum, where the ice **sublimates** to a vapor (Figure 28-2). This process of sublimation is the most effective method for drying foods because it does not subject the food to high heat, which alters a food's flavor, color, and structure. Freeze-dried products exhibit the highest quality, store indefinitely, and can be reconstituted easily. However, the process is more costly than conventional drying. Coffee is the most commonly freeze-dried food, but others include tea, fruits, herbs, and meats and vegetables used in instant meals for military, camping, or astronaut rations (Figure 28-3) (21).

FIGURE 28-3 Apples being checked after coming out of a freeze dryer.



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Microwave Drying

Drying time, and the energy used for drying, is significantly reduced through rapid microwave drying (33). Foods dried this way include but are not limited to herbs, potatoes, mushrooms, carrots, asparagus, raisins, apples, kiwifruits, pears, and bananas.

Pretreatments

Some fruits are pretreated prior to drying. Plums have their skins *checked* before being dried into prunes by dipping them in lye or very hot water. This process cracks the skin, thereby improving skin texture and shortening the drying time by exposing more surface area to drying. Another pretreatment consists of blanching certain vegetables, such as potatoes or carrots, prior to drying to prevent enzymatic browning. The heat from dipping the food briefly into boiling water (and then into cold water to stop the cooking) disrupts the enzymes responsible for browning and inhibits discoloration. Some fruits, such as apricots and peaches, are dipped in a sulfite solution or exposed to sulfur dioxide gas.

Curing

High concentrations of salt bind to the water in food, making it vunavailable to microorganisms. The earliest recorded use of salt as a preservative dates back to 3000 BC, when salt was used to **cure** fish. One of the earliest methods of preservation was to rub the surface of meats and fish with salt. Native Americans used salt to preserve some of their foods; the Hopi people traveled long distances to the salt mines within the Grand Canyon to obtain salt for this purpose.

Corned beef is a cured meat, and it was a provision on the early British navy fleets for more than 200 years. The word *corn* refers to the Latin word for "grain," which in this case means grains of salt (30). Today, the most commonly cured meats include ham, sausages, hot dogs, bacon, and bologna.

Smoking Cured Meats

Cured meats sometimes undergo the optional treatment of smoking for added flavor. Smoking is one of the oldest methods of preserving meat and fish (38). Meats are placed in smokers,

How & Why?

Why is sulfur dioxide often listed as an ingredient in dried fruits?

To preserve their natural color and prevent spoilage, some foods, such as apricots and peaches, are dipped in a sulfite solution or exposed to sulfur dioxide gas prior to drying. Sulfur protects against enzymatic browning and the loss of vitamins A and C. However, it destroys thiamin (vitamin B_1), and in certain sensitive individuals, it may cause headaches or allergic reactions and even coma and death.

Sublimation The process in which a solid changes directly into a vapor without passing through the liquid phase.

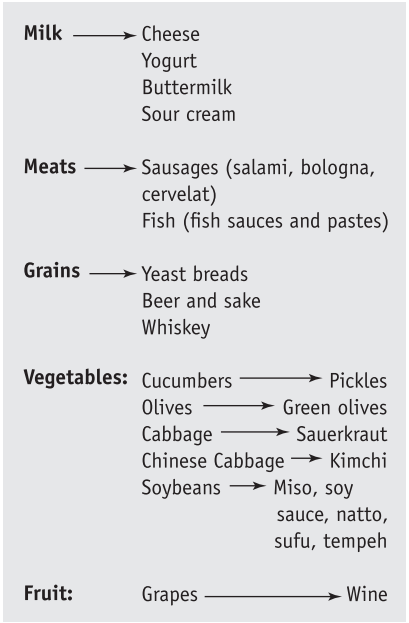
Cure To preserve food through the use of salt and drying. Sugar, spices, or nitrates may also be added.

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FIGURE 28-4 Selected food products produced by fermentation.



where they are exposed to the smoke of burning wood. The type of wood selected (sawdust, mesquite, hickory, oak, and various combinations of these woods) determines the resulting flavor of the meat (38). There are some health concerns with smoked foods, however, as they have been linked to cancer in laboratory animals and possibly humans.

Fermentation

For thousands of years, fermentation has been used for both the production and preservation of various foods (Figure 28-4). In the third century BC, laborers building the Great Wall of China were fed fermented vegetables as part of their rations. Vegetables are still commonly fermented throughout Asia; kim chee, for example, is a popular Korean condiment made from cabbage with added chili peppers, garlic, salt, and perhaps some vinegar. In many Southeast Asian cuisines, fish sauce is made from fish that have been salted and allowed to ferment (31). In North America, the foods most often preserved by fermentation are cucumbers, olives, and cabbage (sauerkraut).

The chemical and biochemical changes that occur during fermentation primarily depend on the (1) raw material, (2) selected microorganisms, and (3) various processing steps (44). For example, using different grains or starter cultures will result in entirely different types of alcohol beverages. The process of fermentation itself relies on microorganisms (bacteria, yeast, and molds) to transform the food into an easily preserved form while simultaneously creating desired changes in flavor, color, and texture. One of the most common types of bacteria used in fermentation, especially of dairy products, is the species that produce lactic acid. The lactic acid lowers the food's pH, alters the flavor, and inhibits microorganisms that are pathogenic or that might cause spoilage. Yeast also contributes to fermentation, with *Saccharomyces cerevisiae* used in bread and beer production to metabolize carbohydrates into carbon dioxide gas (CO_2) and ethanol (which evaporates during baking). Various salt-resistant bacteria are used to create dried sausages. Dry-curing of minced meats occurs when very small pieces of meat and fat are mixed with flavorings (salt, nitrates and/or nitrites, sugar, and spices), stuffed into casings, fermented, dried, and possibly smoked. The longer the fermentation period is, the drier the sausage (36).

Pickling

Pickling preserves food by acidification—acid and/or fermentation is used to acidify foods (14). Vinegar is often used because its acidity keeps many microorganisms in check. In the Middle East, vinegar was used as early as 1000 BC to preserve foods such as fruits, onions, and walnuts. The food was simply covered with vinegar, boiled, and sealed in a container. It was then allowed to stand for at least 3 weeks to give the vinegar enough time to penetrate all parts of the food.

The acid created by fermentation of natural sugars in most pickled foods is lactic acid (14). Salt is often added to draw liquid out of the vegetable being pickled and to inhibit microbial growth. *Clostridium botulinum* is one important food contaminant inhibited by acidification because it cannot grow below a pH of 4.6.

Most people associate pickles with those made from cucumbers, but pickled foods include beets, cauliflower pieces, green tomatoes, green beans, chilies, bell peppers, and sliced Jerusalem artichokes (Figure 28-5). These foods are preserved in vinegar and salt, with spices often added to enhance their flavor. For example, pickling changes the texture, color, and flavor of cucumbers to create pickles (14). The pickle's flavor profile—sweet, salty, sour, or spicy—depends on the combination of ingredients. Although pickling is supposed to preserve foods, those that need to be stored long term are canned for safety reasons. They are also sometimes pasteurized to reduce microbial growth and preserve acidification (14).

The Food and Drug Administration (FDA) regulates acidified foods, which requires electronic filing of the preservation process (14).

Weak Organic Acids

Pickling relies on vinegar, which contains acetic acid as a main component. An inexpensive and effective method to reduce bacterial populations on

FIGURE 28-5 Cucumbers are converted into pickles through the pickling preservation process.



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How & Why?

How are pickles made?

Cucumbers can be manufactured into sweet, sour, dill, kosher dill, and other pickles by one of two methods: the longer process of fermentation, which yields brined pickles (with acid produced from the bacteria); and pickling (as discussed earlier), in which acid is added in the form of vinegar, resulting in quick pickles. During the process of fermentation, a 10% salt solution serves as the liquid in which the cucumbers are submerged and allowed to ferment for several weeks. In this fermentation period, bacteria normally found on vegetables break down the sugar in the cucumbers. The salt penetrates the cucumbers, and the brine concentration is increased to 15%, except in the processing of dill pickles. Once fermented, pickles (whole or sliced) are placed in warm water; packed in glass jars; covered with a combination of vinegar, sugar, spices, and garlic; and pasteurized. It is this canning process, rather than fermentation, that preserves the pickles.

food is through the application of weak organic acids. Lactic, citric, and acetic acids (1.5 to 2.5% concentrations) have already been approved to reduce microbial pathogens on meat carcasses (59). Depending on the food product, acidic solutions are applied by either spraying or dipping the food.

Edible Coatings

A unique food preservation method is to surround the food with an **edible coating**. Edible coatings serve four purposes (63):

1. Increase shelf life by acting as a barrier to moisture, oxygen, carbon dioxide, volatile aromas, and other compounds (72).
2. Impart improved handling characteristics, such as the ability to bend more easily without breaking.
3. Improve appearance through increased gloss and color.
4. Serve as a vehicle for added ingredients such as flavors, antioxidants, antimicrobials, and so on.

Composition of Edible Coatings

Edible coatings can be produced from carbohydrate, protein, or lipid materials. The most common edible coatings are lipid-based (beeswax, candelilla wax, carnauba wax, rice bran wax); oils (paraffin oil, mineral oil, vegetable oils); and petroleum-based waxes (paraffin, polyethylene wax) (7). Carbohydrate coatings include starches, cellulose, seaweed extracts (carrageenan, alginates), pectinates, and chitosan. Previously, sugar was used to coat foods to prevent decay and moisture loss (e.g., sugar-coated nuts). Protein films can be made from foods through the use of gelatin, collagen, whey protein, corn zein, soy protein, and wheat gluten (7).

Commonly Coated Foods

Edible coatings are commonly used on vegetables and fruits such as cucumbers, tomatoes, peppers, eggplants, pumpkins, summer squash, apples, bananas, guavas, mangoes, papaya, melons, nectarines, and citrus fruits. They are also used to coat candy, cheese, nuts, dried fruit (prevents stickiness, especially in raisins and dates), eggs in their shell (as a moisture and bacterial barrier), and processed meats (especially sausages), poultry, and fish (35).

Micro-encapsulation

Tiny particles or droplets can also be coated or micro-encapsulated. Most flavors are fat-soluble oils that do not mix readily with other water-soluble ingredients, so they need to be encapsulated with starches or other carriers. This preservation method allows them to mix with dried baking mixes or sprays used on flavored chips or other baked products (46).

Canning

Canning is a two-step process. First, the food is prepared by being packed into containers, which are then sealed. Then the containers are *canned,* or heated to ensure that all microorganisms are destroyed.

As previously mentioned, during the Napoleonic wars, Napoleon was having difficulty feeding his troops. He offered a prize to the person who could discover a new method of preserving food. The winner was Nicolas Appert, who invented the canning process in the late 1790s. Food was placed in glass jars or canisters (cans), boiled, and then sealed shut. The jars were then boiled a final time, creating a vacuum. Many people believed that lack of oxygen in the cans preserved the foods. Almost a hundred years later, Louis Pasteur discovered that the real reason canning was successful was because the high boiling temperatures destroyed harmful bacteria. The heat processing also destroyed the enzymes responsible for the deterioration of foods, thereby protecting canned food from both harmful microorganisms and natural spoilage (55).

Preparing Food for Canning

Fruits, vegetables, and meats are the most frequently canned foods. All are prepared prior to canning by either *hot* or *cold* packing. Hot-pack canned foods are heated to at least 170°F (77°C) in syrup, juice, or water prior to being poured into **sterilized** jars. This initial heating drives out much of the air, allows the food to be packed tightly in the jar, gives a translucent appearance to fruit, and reduces the heating time. In the cold-pack method, food is placed directly into the sterilized jars. The jars are then filled with boiling liquid. In both cases, some space is left at the top of the jar (the amount of space depending on the product and canning method). Air bubbles are removed by gently sliding a rubber spatula or knife between the jar's side and the food, and a small amount of air, known as the headspace, is left

Edible coating A thin layer of edible material, such as natural wax, oil, or petroleum-based wax, that serves as a barrier to gas and moisture.

Sterilization The elimination of all microorganisms through extended boiling, heating to temperatures much higher than boiling, or using certain chemicals.

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at the top of the jar (77). This headspace is required for pulling a vacuum and ensuring a seal. Jars with nicks or cracks should not be used for canning because they are not guaranteed to provide a reliable seal.

Two Methods of Canning

The two major techniques for canning foods are boiling water processing and pressure canning (boiling at higher temperatures under pressure). The method chosen depends primarily on the pH of the food. A potentially deadly bacterium, *Clostridium botulinum,* cannot survive in an acidic environment, so boiling temperatures are sufficient to process most fruits and tomatoes whose pH falls below 4.6. Lemon juice is sometimes added to varieties of tomatoes that are less acidic to avoid the possibility of food poisoning. For foods above pH 4.6, the U.S. Department of Agriculture (USDA) states, "To prevent the risk of botulism, low-acid and tomato foods [not canned according to USDA recommendations] should be boiled 10 minutes at altitudes below 1,000 feet. For altitudes at and above 1,000 feet, add 1 additional minute per each 1,000 feet." Another way to heat foods with pHs above 4.6 (meats and vegetables) is to use a special piece of equipment known as a pressure canner that allows higher temperatures to be reached.

The majority of *C. botulinum* food poisoning cases in the United States are traced back to errors in home canning. In an effort to discourage home canning, the USDA no longer provides information booklets showing how to can foods at home.

COLD PRESERVATION

Refrigeration

Refrigeration slows down the biological, chemical, and physical reactions that shorten the shelf life of food. Prior to the 1900s, refrigeration consisted of iceboxes filled with ice cut from lakes. In the 1850s, beer brewers began using mechanical refrigeration. Later, in the 1880s, meat packers started using refrigerated railroad cars to ship carcasses rather than live animals. However, home refrigeration was not widespread in the United States until the 1940s.

Refrigerating Food

Not all foods have to be refrigerated, but all perishable foods should be refrigerated as soon as possible, preferably during transport, to prevent bacteria from multiplying. Placing produce in the crisper section of the refrigerator limits the amount of oxygen available to the foods, which slows their metabolism and prolongs their life and quality. Vegetables and fruits often continue to ripen and exchange gases with the environment after harvesting, even though they are cut off from their roots or leaves. When the fruit's or vegetable's stored nutrient supply is finally depleted, the cells slowly die, and spoilage occurs as enzymes that break down, soften, and brown the tissue are released.

Plastic bags used to store vegetables or fruits should have holes in them to let in a small amount of oxygen to prevent tissue death but not enough to speed up deterioration. Trapping these gases within a closed bag at room temperature speeds ripening and eventual deterioration.

Refrigeration Temperatures and Times

For safety purposes, refrigerators should be kept between just above freezing and no more than 40°F (4°C). Researchers studying domestic refrigeration practices found that only 37% of survey respondents ensured that their refrigerators were at this temperature (37).

Refrigerator storage times vary according to the food (see back inside cover of this book). Hot foods can be cooled down by placing them in shallow containers and setting the containers in cold water. Stirring during cooling distributes the heat and speeds the cooling process (77).

Freezing

In the past, people used environmental snow and ice to preserve foods during the winter in colder climates. Serendipity played a part in the discovery that foods could be frozen commercially. Clarence Birdseye was ice fishing when he noticed that a fish he pulled out of the water froze in midair. He experimented and found that fish frozen immediately after being caught tasted fresh when thawed and prepared weeks later. In the early 1920s, Birdseye started the frozen food industry (80).

It is now known that freezing foods at 0°F (–18°C) or below is the least damaging to the food's original flavor, nutrient content, and texture as compared with most other preservation methods. Freezing makes water unavailable to microorganisms. In addition, chemical and physical reactions leading to deterioration are slowed by freezing. Some oxygen is still present, however, allowing these reactions to continue, with the result that frozen foods have a shorter shelf life than canned foods. Shelf life is extended further for most supermarket products that are flash frozen in a very cold industrial freezer (26). The faster the food freezes, the less the food is damaged in the process.

Foods Suitable for Freezing

The food's composition determines whether, and for how long, it can be stored in the freezer. Certain fruits, vegetables, and liquid dairy products do not freeze well. The plant tissues of unblanched fruits and vegetables are irreversibly damaged during freezing. Dairy products may lose quality when their original distribution of fat and water is permanently altered. The higher a food's fat content, the shorter its life span in the freezer because fat can become **rancid** even when frozen. Conversely, foods containing very little water, such as dried fruits and beans, grains, nuts, and coffee, can have their useful life span doubled if they are frozen (Chemist's Corner 28-2).

Freezer Storage Times

Specific maximum freezer storage times for various foods are listed on this book's back inside cover, but in general, foods can be kept frozen for 2 to 12 months. The "first in, first out" rule should be followed: foods should be stored so that those most recently bought or frozen are the farthest back

Rancidity The breakdown of the polyunsaturated fatty acids in fats that results in disagreeable odors and flavors.

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CHEMIST'S CORNER 28-2

Glass Transition Temperature

The shelf life of frozen products is extended if their water movement is limited. Deterioration results when water migrates during storage, resulting in large ice crystal formation. One way to avoid this is to raise the food's glass transition temperature (Tg), the temperature at which the food is said to be in a glassy state. This glassy stage is reached when the food's pure water freezes and leaves behind a very viscous concentration of solutes that trap the remaining water. The trapped water cannot crystallize. Food components that significantly raise Tg are higher-molecular-weight compounds such as protein, polydextrose, and gums (50).

in the freezer, thereby moving food into a more easily accessible position as the freezer time increases.

Four Problems with Frozen Food

Despite its effectiveness as a food preservation method, freezing has several potential disadvantages: freezer burn, cell rupturing, fluid loss, and recrystallization.

Freezer Burn

Freezer burn occurs when frozen food has been improperly packaged or frozen too long, resulting in a dried-out surface that looks "burned" (Figure 28-6) (65). It alters the texture, color, and flavor of foods and is due to a loss of moisture that occurs when air spaces are left in a package, the package is torn, or moisture-proof paper is not used. Moisture loss occurs through sublimation, which is the transition from ice directly to vapor. After the food is thawed, the texture of freezer-burned food is spongy, and its color and flavor are irreversibly altered to the point that most people would discard it (21). Frost-free freezers and the use of individually frozen products increase the risk of freezer burn (65).

FIGURE 28-6 Freezer burn on cut string beans.



iStock.com/SpaulN

The best way to prevent freezer burn is to wrap foods properly in airtight, vapor-resistant material, tape the package tightly, date it, and use the food before the optimal storage time has passed. An effective method for meats is to triple-wrap them, first with plastic wrap, then aluminum foil, and finally freezer paper secured with freezer tape. Masking tape should not be used because the adhesive is not made to withstand freezing temperatures. The practice of keeping an up-to-date inventory on the freezer door showing the date on which each food was frozen avoids the costly waste of freezer-burned food. For commercially frozen foods, the use of vacuum packaging has almost eliminated the problem of freezer burn.

Cell Rupturing

Water expands when it freezes, and the resulting ice crystals pierce the food's cell walls, rupturing them and causing the food to take on an inferior texture. For this reason, some foods with a very high water content, such as lettuce, milk, tomatoes, and cottage cheese, should not be frozen. One way to minimize this problem is with rapid freezing, which results in smaller ice crystals, less cell rupturing, and a higher quality (25). Rapid freezing is accomplished commercially by the use of liquid nitrogen (–320°F/–196°C), which freezes foods in a few minutes rather than the 6 or more hours needed in a home freezer. Several other commercial methods of freezing that overcome the cell-rupturing problem include the following (1):

- **Air-blast freezing.** Frigid air is blown on foods as they pass on a conveyor belt.
- **Plate or contact freezing.** Foods are placed between two plates of metal while being cooled by refrigerants.
- **Immersion freezing.** Foods are submerged in a low-temperature brine.
- **Impingement freezing.** High-velocity air jets gently cool the outer layer of meat and then slowly freeze the entire cut.
- **Cryogenic freezing.** Very low temperatures (–140°F/–60°C) are used with liquid nitrogen, liquid carbon dioxide, or their vapors.

Fluid Loss

Most frozen meats lose fluid when thawed. This is known as *drip,* and although red, it is not blood but actually water being lost from the cells. If too much fluid is lost, the meat's texture will be dryer when cooked than the fresh product would have been.

Recrystallization

Another problem with freezing is recrystallization, which occurs with longer storage times and temperature fluctuations caused by opening and closing the freezer door. Numerous small ice crystals melt and then combine on refreezing to form larger crystals, thus affecting the texture and quality of foods such as ice cream. During a lengthy power failure, the freezer door should be kept shut, and dry ice (solidified carbon dioxide) should be placed in the freezer and/or refrigerator as soon as possible. The addition of 25 pounds of dry ice will keep a 10-cubic-foot freezer below freezing for

Freezer burn White or grayish patches on frozen food caused by water evaporating into the package's air spaces and possibly recrystallizing as ice on the food's surface.

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2 to 3 days. A much smaller amount is required for the refrigerator and refrigerator freezer. When the power returns, any thawed foods can be refrozen as long as the temperature has stayed below 40°F (4°C).

HEAT PRESERVATION

Heat in its various forms can be used as a preservation method because many of the microorganisms responsible for food spoilage or foodborne illnesses are susceptible to heat. Heating methods include boiling, pasteurization, and ohmic heating.

Boiling

Boiling is the simplest heat preservation method and has been used for centuries. Ten minutes of boiling renders most foods free from microorganisms, but to remain that way, they must not be allowed to touch any unsterile object or be exposed to the air. Boiling temperatures can be exceeded by using pressure canners, autoclaves, and other instruments.

Pasteurization

Another method of preserving liquids and extending their shelf life through heat is **pasteurization**. It destroys non-spore-forming pathogenic microorganisms and many organisms that cause spoilage. Milk is the most common beverage treated by pasteurization (discussed in more detail in Chapter 10), but fruit juices and other beverages can also be pasteurized. Nutrient losses during pasteurization are small, with flavor changes being the most significant alteration (2). The USDA has approved the use of steam pasteurization for meat, in which whole beef carcasses are sprayed with a blast of steam, killing microorganisms on the surface (9). Steam-pasteurized meat is not considered kosher (see Chapter 1) because there is no rabbinical supervision, and the necessary temperatures required for kosher acceptance are not reached, as such temperatures would cook the edges of the carcass meat.

High-Temperature Pasteurization

Using temperatures higher than those used for conventional pasteurization is described as high-temperature short-time (HTST) or ultrahigh temperature (UHT) pasteurization (see Table 10-5 in Chapter 10). HTST temperatures and times start at 161°F (72°C) for 15 seconds, whereas UHT temperatures are above 280°F (138°C). Shorter times mean that there is minimal degradation of the products (45).

Sous-vide

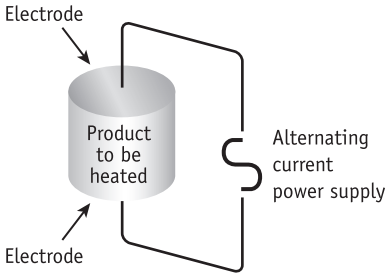
Food can be preserved by the sous-vide technique: cooking it in sealed, airtight plastic bags in a water bath at lower temperatures but for longer times. Overcooking is avoided because the food never gets hotter than the water bath. As a result, cell walls do not burst, and the tough collagen in the connective tissue of meats is hydrolyzed to yield foods with better texture and flavor and increased juiciness. One drawback is that the browning from the Maillard reaction and crust and flavor development associated with high and/or dry heat do not occur. Nevertheless, the unique flavors that result make the sous-vide method popular among gourmet restaurants. Removing the oxygen from the bags allows the food product to be safely stored for a longer period, which appeals to the catering and transportation industries.

Pasteurization A food preservation process in which liquids (milk, beer, soups, or juices) are heated to a specified temperature for a certain period of time to destroy most microorganisms (bacteria, yeasts, and molds) that could cause disease, spoilage, or undesired fermentation.

Ohmic heating A food preservation process in which an electrical current is passed through food, generating enough heat to destroy microorganisms.

Irradiation A food preservation process in which foods are treated with low doses of gamma rays, X-rays, or electrons.

FIGURE 28-7 Ohmic heating.



Ohmic Heating

A more recently developed heat preservation technique is **ohmic heating**, also known as "resistance heating," "joule heating," or "electro conductive heating" (Figure 28-7) (78). Not all foods can be subjected to this type of preservation as they need to be in a semi-suspended state, such as a sauce (81). The benefit of ohmic heating is that it reduces the need for excess heat, resulting in a higher-quality food (78). Foods currently preserved with ohmic heating include liquid eggs, orange juice, and other fruit juices (12).

OTHER PRESERVATION METHODS

Irradiation (Cold Pasteurization)

Irradiation, also called "cold pasteurization" (56), is a relatively recent food preservation method that has been used for a variety of applications. Food irradiation was being experimented on as early in 1895 (56). The FDA approved it as a food additive in 1958, and it was used to control insects in wheat and wheat flour in 1963 and to inhibit sprouts in white potatoes in 1964. The Army Medical Department had been studying the safety of irradiated foods starting in 1955, and the process was adopted in the early 1970s for foods consumed by astronauts (69). In 2002, the concern with school-related foodborne illness outbreaks led the USDA to approve the use of irradiated meat for the school lunch program, but this practice was not adopted until later (52).

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TABLE 28-1 Foods Approved for Irradiation in the United States

- Wheat flour
- White potatoes
- Certain fruits and vegetables
- Seeds for sprouting
- Herbs and spices
- Red meats
- Shellfish
- Raw poultry
- Fresh shell eggs
- Dry enzyme preparations
- Dry spices or seasonings

The main benefits of food irradiation are as follows (70):

- Inhibit sprouting of vegetables (onions, potatoes)
- Prevent insect infestations
- Prevent food spoilage by reducing microorganisms
- Prevent foodborne illness by reducing microorganisms
- Delay certain fruits from ripening
- Extend food shelf-life

Irradiation of foods has expanded rapidly since it was first approved, as shown in Table 28-1 (22, 56). Not all foods can be irradiated as it may affect the texture of certain plant foods (Chemist's Corner 28-3). Other uses of irradiation include the following:

- Sterilization of medical equipment (instruments, surgical gloves, alcohol wipes, sutures, etc.)
- Sterilization of consumer products (adhesive bandages, contact lens cleaning solutions, cosmetics, etc.)
- Preparation of foods for immunocompromised hospital patients (e.g., patients with AIDS or cancer or those who have undergone transplantation)
- Preservation of spices and seasonings used in products such as sausage and certain baked goods

The Irradiation Process

Common types of irradiation in the environment include visible light, radio waves, infrared light, ultraviolet light, and microwaves (22). The three sources of irradiation approved for use in foods are gamma rays, X-rays, and electron beams. These are stronger forms of irradiation called "ionizing" radiation because they produce ions, or electrically charged particles.

CHEMIST'S CORNER 28-3

Irradiation and Softening of Food

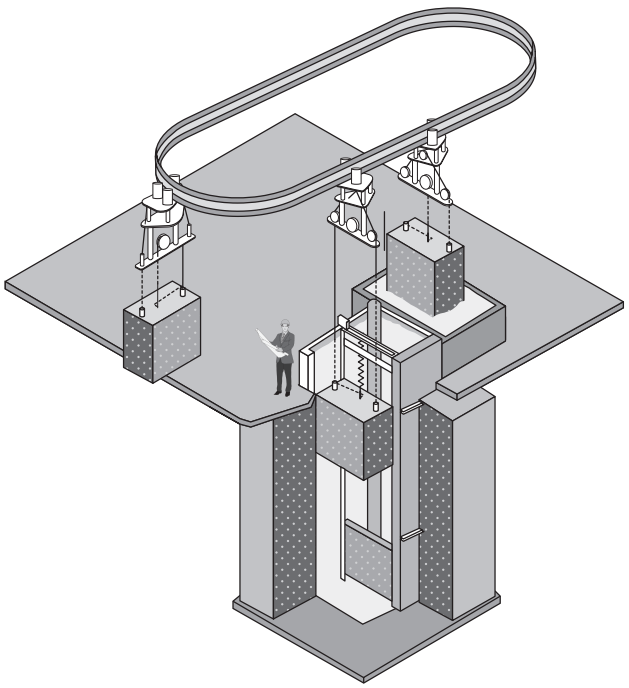
Irradiation induces a loss of firmness, or softening, in some types of fruits and vegetables. This occurs because irradiation causes depolymerization of cell wall polysaccharides, cellulose, and pectin in the produce (22). Also contributing are irradiation's effects on the activity of the enzymes pectin methylesterase and polygalacturonase, found in the cell wall.

Food is irradiated by passing it through an irradiator, an enclosed chamber in which it is exposed to an ionizing energy source. Figure 28-8 shows one type of irradiator in which the food is lowered into the ground, eliminating the need for heavy above ground cement shielding. A number of ionizing energy sources may be used (gamma rays, X-rays, or electrons), but gamma rays are the most common (Chemist's Corner 28-4). Irradiation causes free radicals, or highly reactive charged molecules, to be created from water (22). These free radicals act to disrupt DNA and other components of microorganisms and prevent them from multiplying (56). Thus, irradiation works by breaking down the chemical bonds within the DNA and other molecules in the cells. The treated food does not become radioactive itself, any more than a briefcase does after passing through an airport security check. The energy of the radiation used is not high enough to induce the changes in atomic nuclei that result in radioactivity (51). It also does not create significant radioactive waste. Cobalt-60, one of the radioactive metals used to produce gamma rays, decays by 50% in 5 years and can then be recharged and reused. However, cesium-137 requires 30 years to decay by 50% (56).

Effects of Irradiation on Foods

Treating foods with gamma radiation renders them less susceptible to deterioration and destroys many, but not all, microorganisms. For example, although it destroys bacteria, yeasts, and molds, the dosage used on foods for pasteurization is too low to eradicate *C. botulinum* spores, and it may not eliminate smaller viruses (48).

FIGURE 28-8 An irradiator in which the product is lowered below the ground so that heavy cement shielding is not required.



Source: Gray*Star Inc.s website at http://www.graystarinc.com/genesis.html.

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FIGURE 28-9 Irradiation inhibits mold formation in strawberries refrigerated for 17 days.



Irradiated (1 kGy) Nonirradiated

Cordelia Molloy/Science Source

CHEMIST'S CORNER 28-4

Irradiation Dosages

Gamma radiation uses the radioactive form of cobalt (^{60}Co) and possibly cesium (^{137}Cs) to produce gamma rays (51). The amount of radiation energy absorbed from these gamma rays is expressed in kilograys (kGy). For example, one kilogray equals 1,000 grays, and 1 gray equals 1 joule per kilogram. Irradiation dosages from low (under 1 kGy) to medium (1 to 10 kGy) kill insects, larvae, and pathogenic bacteria in wheat and wheat flour; inhibit sprouting in potatoes; and slow ripening and spoilage in fruits. Higher dosages (10 to 50 kGy) are enough to sterilize foods for use by astronauts or immunocompromised hospital patients (53). The FDA limits the amount of radiation used on different types of food (see 74). Examples of specific limits include 1 kGy for fresh foods, 4.5 kGy for raw poultry, 6 kGy for crustaceans, 30 kGy for dry or dehydrated spices, and the highest level of 44 kGy for frozen packaged meats used solely by NASA (76).

Irradiation reduces spoilage, lengthens shelf life, sterilizes or kills insects, and can protect the public from many bacterial foodborne diseases (Figure 28-9) (75). Meat can keep longer in the refrigerator when it is irradiated (60), and irradiation does not change the aroma, taste, or texture of ground beef (48). Research has demonstrated that irradiated fresh fruit retained desirable quality for up to 16 days, as compared to nonirradiated fruit, which spoiled within 6 days.

Not all produce can be irradiated successfully. Many fruits and vegetables become mushy, discolored, and actually spoil faster with irradiation (3). In fact, irradiation extends shelf life for only about ten different fruits. Irradiation causes other fruits and vegetables to lose firmness; this effect can be reduced in tomatoes and apples by dipping them in a calcium solution prior to irradiation and by storing them in modified-atmosphere packaging (22). Irradiation is not thought to affect the trans-fatty acid content of foods (23). Irradiation can reduce vitamin C levels by converting ascorbic acid to dehydroascorbic acid, but this effect is insignificant (22).

The FDA investigated the possibility that furan, a carcinogen, was produced during food irradiation (22). Studies showed that 5 kGy irradiation did not induce detectable furan production in most fresh fruits and vegetables.

Irradiation Pros and Cons

Despite official approval from many organizations (FDA, USDA, WHO, NASA, and others), food irradiation has aroused considerable controversy and is the subject of extensive studies (51). Consumer concerns include possible nutrient loss and the environmental hazards arising from the use of radioactive materials in irradiation facilities. Concerns about the free radicals produced by irradiation have been expressed, but the FDA counters that these are generated by other heating methods. Proponents argue that irradiation eliminates the need for some chemical fumigants and preservatives, reduces spoilage losses, and increases food safety by destroying harmful microorganisms, especially *Escherichia coli* and *Salmonella* (51, 75).

Consumer acceptance of irradiation may actually be higher than is indicated by media coverage. In fact, studies have shown that educating consumers about food irradiation can change their attitudes and increase acceptance (66). The major consideration for consumers is that irradiated food be clearly labeled so that they can make the choice for themselves. The FDA requires that irradiated food include the Radura symbol, the words "*treated with radiation*" or "*treated by irradiation,*" or the word "*irradiated*" as part of the ingredients list on the label (Figure 28-10) (76). In 2007, the FDA proposed a change to irradiation labeling, recommending that only foods in which irradiation caused a "material change" in the food

FIGURE 28-10 The green Radura symbol identifies irradiated food.



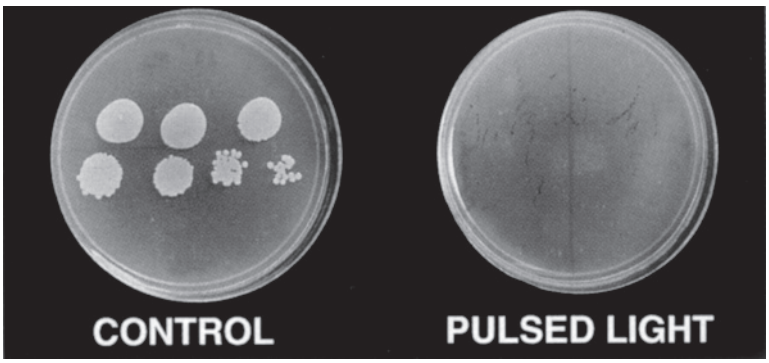
Jack-O'Keen/Shutterstock.com

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FIGURE 28-11 The effect of pulsed light on *Staphylococcus aureus.*



Adapted by permission, from J. Dunn, A. Bushnell, T. Ott, and W. Clark, 1997, Pulsed White Light Food Processing, Cereal Foods World 42:510-515, © AACC International

Staphylococcus aureus: Each dish inoculated with 7 one-cm^2 drops containing serially decreasing CFUs.
Source: Food Technology.

should be required to include the Radura logo and the statements concerning irradiation (22). Material changes include any nutritional (especially vitamins C and E), functional, or organoleptic modifications to the food.

Radio Frequency

Selected electromagnetic waves (13.56, 27.12, and 40.68 MHz allowed in the United States) are converted into heat to increase food temperatures. This type of heating is suited for dried ingredients such as flour, spices, seeds, cereal grains, protein supplements, and pet foods (43). It is also used in the thawing of frozen meat and in meat processing.

Pulsed Light

Another FDA-approved preservation technique uses the visible spectrum of radiation and is called "pulsed light" (PureBright) (54). This method works by exposing the food to intense, very brief flashes of light, which disrupt the cell membranes of bacterial cells but not those of the surrounding food (Figure 28-11) (54). Pulsed light also kills fungi, spores, viruses, protozoa, and cysts (54).

High-Pressure Processing

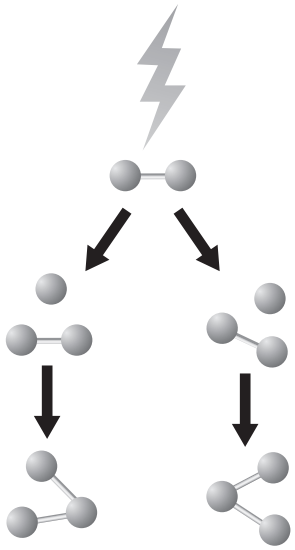
High-pressure processing is sometimes referred to as high-hydrostatic pressure (HHP) or ultrahigh pressure (UHP) processing (79) or as **pascalization**—after Blaise Pascal, a seventeenth-century French scientist who described how contained fluids are affected by pressure. Although discovered in 1899, treating foods with high pressure is a relatively new method of preservation, and one still under development. The pressure to which pascalized foods enclosed in flexible packaging are exposed in the pressure chamber filled with water is tremendous. A normal car tire holds about 30 pounds of pressure per square inch, whereas the pressure applied to foods in pascalization is at least 50,000 pounds per square inch, applied for 15 minutes. High pressure may preserve foods by inactivating the cells of bacteria or yeast. HHP is currently used for the processing of guacamole, fruit juices (especially raw or unpasteurized), sauces, smoothies, jams, ready-to-eat meats, and shellfish, especially in the shucking of oysters that open to the pressure, and the list continues to grow (13, 41).

How & Why?

How does pascalization work?

Hydrostatic pressure deactivates various microorganisms and numerous enzymes responsible for food deterioration. The high pressure of pascalization kills many bacteria, yeasts, and molds (79). However, bacterial spores remain resistant and must be treated with acid to block their ability to germinate. Thus, naturally acidic foods such as yogurt, tomato products, and sliced fruit are best suited for pascalization. The process also denatures proteins and disrupts noncovalent bonds without interfering with the food's overall structure.

FIGURE 28-12 Lightning or high-energy ultraviolet rays trigger ozone formation in the atmosphere. They do so by rupturing oxygen molecules, which produce fragments that then combine with other oxygen molecules to form ozone (O_3).



Source: Food Technology.

Ozonation

The fresh, clean, invigorating smell in the air after a thunderstorm is due to lightning forming ozone (Figure 28-12). Ozone (an oxidizing agent) is commercially produced by exposing oxygen to an electrical current (4). The oxygen molecules (O_2) are broken apart, creating numerous oxygen fragments that reunite with other oxygen molecules to yield ozone (O_3).

It has been known for decades that ozone is an effective disinfectant and sanitizer for many food products, but it was not until 1997 that ozone was granted Generally Recognized as Safe (GRAS) status, and approved as a food sanitizing agent in 2001 by the FDA (28). Ozone effectively kills viruses, molds, and bacteria and controls the growth of microbial organisms,

Pascalization A food preservation process utilizing ultrahigh pressures to inhibit the chemical processes of food deterioration.

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including *E. coli* and *Salmonella,* in packaged foods (42). Its antimicrobial effects are due to its ability to disrupt the cell walls of bacteria and viruses.

The FDA has allowed ozone to be used in the treatment of bottled drinking water, in meat aging coolers where frozen beef carcasses are stored (49), and, since 1997, of food. In Europe, especially Germany and France, ozone is the principal means of sanitizing the public water supply, rather than chlorine, which is used in the United States (27).

Aseptic Packaging

Aseptic packaging has been used for many years. Food that is *aseptically packaged* is sterilized, packed, and sealed in a sterilized container under sterile conditions (5). Common foods that are aseptically processed include juice boxes, lunch kits, puddings, cheese sauces, soups, tomato paste, baby foods, and UHT milk (15). They can be seen on store shelves stored at room temperature.

Modified-Atmosphere Packaging (MAP)

Aseptically treated foods are sometimes stored within modified-atmosphere packaging (MAP) (64). This type of packaging changes the composition of the air around the food to prolong its shelf life—specifically, by reducing oxygen and increasing carbon dioxide. The gas atmosphere is *modified* by (1) direct injection of gases (carbon dioxide or nitrogen) into a package; (2) removal of oxygen from the package; or (3) the natural respiration of fresh fruits or vegetables, which results in increased carbon dioxide and decreased oxygen levels (64). Fruits and vegetables are often packaged with MAP because it reduces their respiration (29). Cured cheese is commonly packaged with MAP from which the carbon dioxide has been removed to increase shelf life by 50 to 150% (32). Most meat, poultry, fresh cut vegetables, berry shipments, and fresh pasta are packaged using MAP (Figure 28-13) (6), and the number of applications for bakery products continues to grow.

FIGURE 28-13 Aseptic and modified atmosphere packaging.



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Controlled-Atmosphere Packaging (CAP)

The terms MAP and CAP are often used interchangeably; however, a defined mixture of gases is *controlled* in CAP. For example, the concentrations of oxygen, carbon dioxide, and nitrogen in shipping containers containing fruits or vegetables can be mechanically controlled. An oxygen-absorbing sachet inside a container can also help control oxygen levels through a chemical reaction. Mold growth on grapes during long shipments can be controlled by using sulfur dioxide–producing pads.

Vacuum Packaging

Food in pouch packaging (potato chips, pretzels, candy, etc.) will last longer if the air in the bag is removed. The oxygen is "vacuumed" out, which automatically increases the carbon dioxide concentration. The high impermeable bag is heat sealed to maintain the concentration of gases for as long as possible. After opening the bag, the contents will not get as stale quickly if as much air is removed from the bag before closing and clamping it closed.

NUTRIENT RETENTION

Foods and beverages may retain their nutrients longer than most people realize (20). The macronutrients—carbohydrates, fats, and proteins—are relatively unaffected by processing. The same is true for fat-soluble vitamins and minerals; however, both are susceptible to liquid losses that occur through boiling or meat juice drippings. The nutrients most sensitive to loss are the water-soluble vitamins. These include vitamin C (ascorbic acid) and the B vitamins (especially folate). Boiling or cooking food in liquids may reduce these nutrients, but approximately 75% or more of the nutrients are usually retained.

Only very limited information on nutrient retention is available. One reason is that measuring vitamins and minerals in the laboratory is costly and time-consuming. As a result, available data usually concern vitamin C and usually center on only one preservation technique. Even the gold standard of nutrient retention data, the USDA Table of Nutrient Retention Factors (2007; available at www.ars.usda.gov/ARSUserFiles/80400525/Data/retn/retn06.pdf), states that "Nutrient data are frequently lacking for cooked foods." This resource lists nutrient retention for only selected foods prepared with a few standard techniques (frying, boiling, grilling, etc.). It does not include nutrient loss data for any of the preservation processes discussed in this chapter.

The lack of research notwithstanding, it is known that even unprocessed fresh-cut produce loses vitamin C over time. For example, researchers reported the following vitamin C losses in fresh-cut produce after 6 days (24):

- 5% in mangos, strawberries, and watermelon
- 10% in pineapple
- 12% in kiwi
- 25% in cantaloupe

About 10 to 20% of the ascorbic acid was reported to be lost from fresh-cut potatoes stored under various types of MAP (73). A few limited studies concerning vitamin C retention in foods that have been canned, irradiated, pasteurized, or high-pressure processed have been conducted.

Freezing green vegetables results in less folate loss (approximately 30%) if they are first blanched, but losses approximate 80% without this step (19).

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PICTORIAL SUMMARY / 28: Food Preservation

The WHO estimates that about 20% of the world's food supply is lost to spoilage. The average North American family discards about one-fourth of the food it purchases because of spoilage. Understanding the biological, chemical, and physical changes that contribute to food spoilage can help prevent food waste.

FOOD SPOILAGE

Foods are organic in nature and are subject to spoilage. Food deterioration decreases both the quality and safety of food through a combination of changes:

- Biological: Microorganisms are responsible for some of the biological reactions in foods that contribute to their deterioration.
- Chemical: Chemical reactions that contribute to spoilage often involve enzymes.
- Physical: Physical reactions include evaporation, water drip, and separation.

Some of these changes are preventable, some can be alleviated, and others will occur to some degree despite current preservation methods.

FOOD PRESERVATION METHODS

Keeping spoilage to a minimum is the objective of both food manufacturers and consumers. Food preservation methods include the following:

- Drying
- Curing
- Fermentation
- Pickling
- Weak organic acids
- Canning
- Edible coatings
- Heat preservation
- Cold preservation
- Irradiation
- Pulsed light
- Ozonation
- Pascalization
- Aseptic packaging, MAP, CAP



COLD PRESERVATION

One-half of the foods consumed in the United States are refrigerated or frozen. Refrigeration slows down the biological, chemical, and physical reactions that shorten the shelf life of food. For safety purposes, refrigerators should be kept between just above freezing and no more than 40°F (4°C), and foods should be frozen at 0°F (–18°C) or below, for the least damage to the food's original flavor, nutrient content, and texture.



HEAT PRESERVATION

Heat in its various forms can be used as a preservation method because many of the microorganisms responsible for food spoilage or foodborne illnesses are susceptible to heat. Heating methods include boiling, pasteurization, and ohmic heating.



OTHER PRESERVATION METHODS

Irradiation: Food is passed through an enclosed chamber, where it is exposed to an ionizing energy source such as gamma rays, X-rays, or electrons, which renders it less susceptible to deterioration and destroys many, but not all, microorganisms. This method is controversial and under study.

Pulsed light: This FDA-approved method exposes food to intense, very brief flashes of light, which disrupts bacterial cell membranes but not the surrounding food.

Ozonation: This is an effective disinfectant and sanitizer for many food products because it kills viruses, molds, and bacteria. Ozone is the principal means of sanitizing the public water supply in Germany and France.

Pascalization: A relatively new method, pascalization subjects food to very high pressure, a process that kills many bacteria, yeasts, and molds, although bacterial spores remain. Acidic foods are best suited for this method because the acid will prevent the spores from germinating.

Aseptic, modified-atmosphere, and controlled-atmosphere packaging: Aseptically packaged food is sanitized, packed under sanitized conditions, and stored on shelves at room temperature. Modified-atmosphere packaging (MAP) modifies the air around the food by decreasing oxygen and increasing carbon dioxide levels. Controlled-atmosphere packaging (CAP) regulates the concentration of gases within the package.



NUTRIENT RETENTION

Foods and beverages retain many of their nutrients. Length of storage may have a greater impact on nutrient loss than the type of processing. Carbohydrates, fats, protein, fat-soluble vitamins, and minerals are relatively unaffected by processing. The nutrients most sensitive to loss are the water-soluble vitamins—vitamin C and the B vitamins (especially folate).

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. During fermentation, yeast or bacteria convert _____ to carbon dioxide and alcohol.
   a. fat
   b. water
   c. protein
   d. carbohydrates

2. Which form of food preservation uses vinegar to increase acidity and keep microorganisms in check?
   a. Pickling
   b. Fermentation
   c. Freeze-drying
   d. Vacuum drying

3. The ideal temperature for refrigeration is between 32°F (0°C) and _____.
   a. 40°F (4°C)
   b. 45°F (7°C)
   c. 55°F (13°C)
   d. 60°F (16°C)

4. Which heating preservation method passes an electrical current through the food?
   a. Steaming
   b. Ohmic heating
   c. Boiling
   d. Pasteurization

5. Irradiation is effective for eliminating bacteria, yeasts, and molds, but it may not eradicate which specific organism?
   a. *E. coli*
   b. *Salmonella*
   c. *C. botulinum* spores
   d. Insects

6. Modified-atmosphere packaging (MAP) operates by reducing _____ and increasing _____ in the air around the food.
   a. acid; alkalinity
   b. oxygen; carbon dioxide
   c. oxygen; ozone
   d. humidity; carbon dioxide

7. White or grayish patches on frozen food are due to _____.
   a. rancidity
   b. humidity
   c. freezer burn
   d. irradiation

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

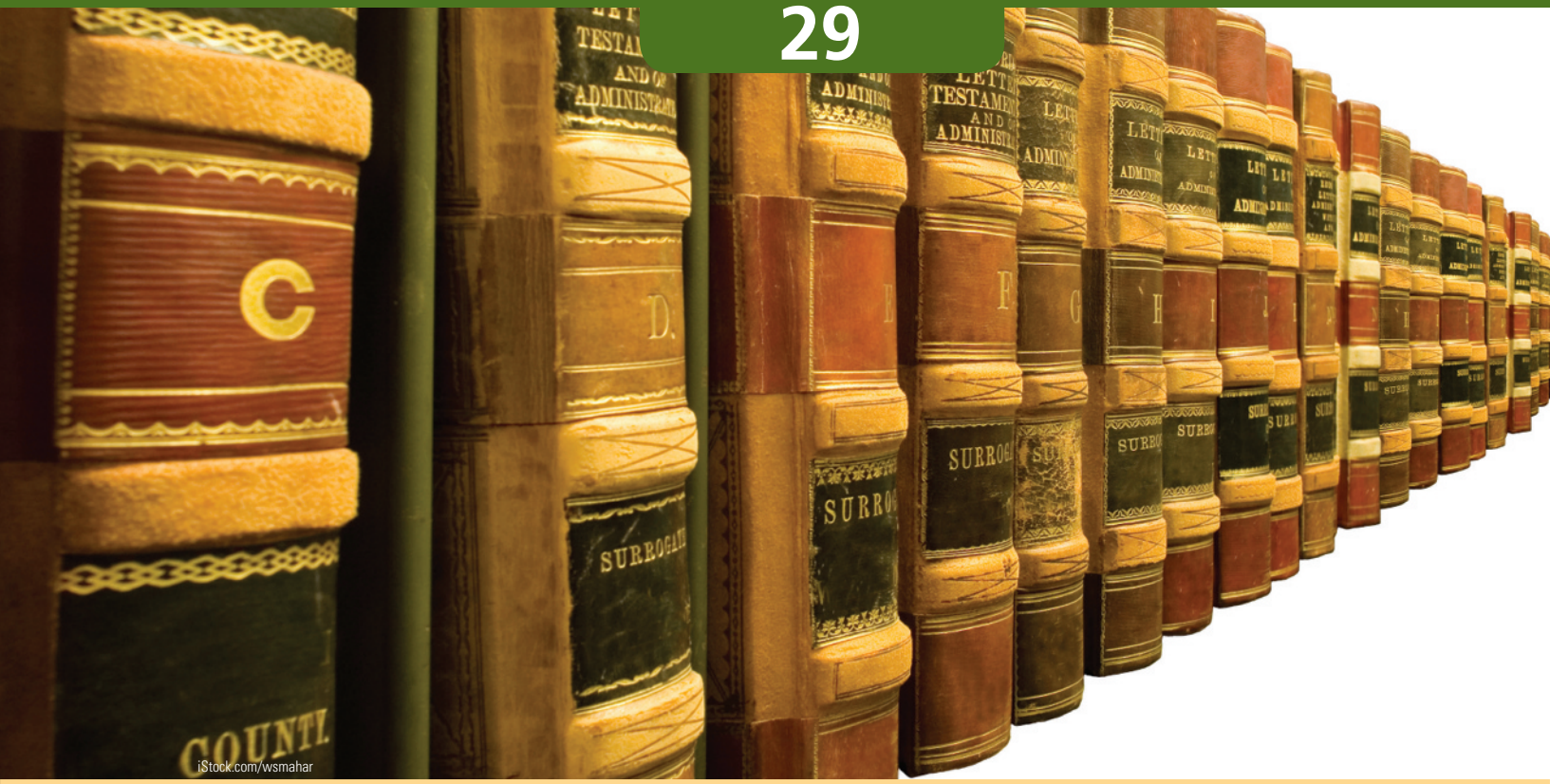
1. Give examples of foods that are perishable, semi-perishable, and nonperishable.
2. Describe the biological, chemical, and physical changes that can occur in foods.
3. Briefly explain the following food preservation methods: curing, fermentation, and pickling.
4. Briefly define the following terms: *dehydrated, freeze-drying,* and *sublimates.*
5. Explain the difference between boiling water processing and pressure canning.
6. What is the recommended refrigeration temperature?
7. Describe the four potential disadvantages of freezing foods: freezer burn, cell rupturing, fluid loss, and recrystallization.
8. Discuss four heating methods used to preserve foods.
9. Define *irradiation,* and list its pros and cons.
10. Describe the processes of aseptic and modified-atmosphere packaging (MAP).

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29



Government Food Regulations

Federal Food Laws 555
Food and Drug Administration 557
U.S. Department of Agriculture 564
Environmental Protection Agency 566
Centers for Disease Control and Prevention 566
Other Regulatory Agencies 567
International Agencies . . 567

Food laws and regulations date back to ancient Greece and Rome. One of the first recorded food laws made it illegal to dilute wine with water (16). Later, during the Middle Ages, trade guilds policed themselves to ensure that teas and spices were pure. This protected them against people taking unfair trade advantage by selling inferior, cheaper products. Yet problems continued, even in the New World. In 1630, a colonist of the Massachusetts Bay Colony was whipped for selling "a water of no worth" as a cure for scurvy (34).

In the United States, the public's demand for laws to protect consumers against contaminated foods helps to make this country's food supply one of the safest in the world (29). The government has responded at all levels—federal, state, and local—with laws and regulations to protect the foods and beverages consumed by the public (16). Companies may have to recall products, be temporarily shut down until they comply with the regulations, or in rare instances be put out of business (17). Despite these threats, most companies voluntarily comply with regulations in order to maintain consumer confidence in their products.

This chapter provides an overview of the U.S. government's food regulations. The various federal (not state) agencies involved include the Food and Drug Administration, the U.S. Department of Agriculture, the Environmental Protection Agency, the Centers for Disease Control and Prevention, and other regulatory agencies (Figure 29-1). Also discussed are the two major international agencies that develop global food standards: the Food and Agriculture Organization and the World Health Organization of the United Nations.

FEDERAL FOOD LAWS

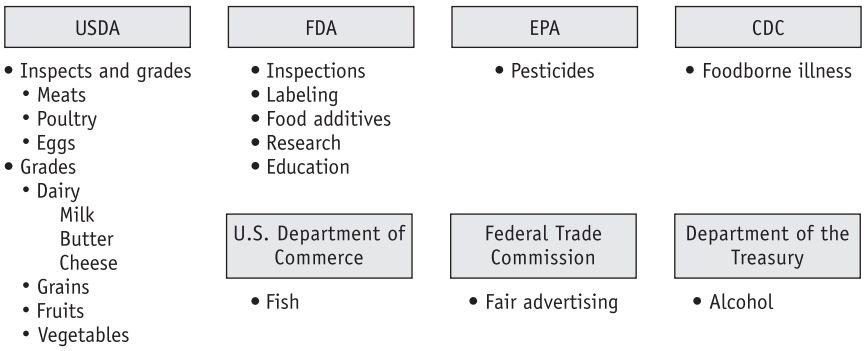
There was a time in the United States and other countries when laws related to the food supply did not exist. Serious problems stimulated the formation of new laws, and agencies were given the responsibility of recommending and/or enforcing these regulations. A brief review of the major laws passed in the United States is now discussed.

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FIGURE 29-1 Major U.S. federal agencies involved in food regulation.



Pure Food and Drug Act (1906)

The federal Pure Food and Drug Act of 1906, sometimes referred to as the Pure Food Law, was the beginning of the government's involvement in food regulation. This followed a series of nationally publicized blunders by manufacturers, including reports following the 1898 Spanish–American War that many soldiers had become ill after being fed spoiled canned meat and contaminated flour. Around the same time, it was found that some dairies were using formaldehyde as a milk preservative. One notorious incident during the early 1900s involved storeowners who substituted poisonous mushrooms for edible varieties.

Upton Sinclair's novel *The Jungle,* published in 1905 and very widely read, exposed the filthy conditions in Chicago's meatpacking plants. Animals that had died of disease were sometimes processed into meat products, and it was not uncommon to find foods contaminated with filth, including the hairs, urine, and feces of rats and mice; insects; maggots; larvae; parasitic worms; and excrement from humans and animals. Sausage meat often contained ground rats, other vermin, and even human fingers.

Sinclair's book added to the public groundswell of demand for the government to take action. The passage of the 1906 Pure Food and Drug Act followed, but the list of injurious foods and manufacturing processes continued to grow, resulting eventually in the need for modifications to the original bill.

Federal Food, Drug, and Cosmetic Act (1938)

The food laws were rewritten, and, in 1938, the Federal Food, Drug, and Cosmetic Act was passed. This was brought on, in part, by the deaths of 100 people who ingested a poisonous "Elixir of Sulfanilamide" (which contained a highly toxic chemical analog of antifreeze) (16). Several federal agencies were established to ensure consumer food safety. Unfortunately, the result was a fragmented and overlapping system of regulations that, to some extent, still exists today (44).

Numerous Government Agencies

Numerous laws regulating food were introduced, passed, and enforced over the years (the updated list of FDA Milestones can be viewed at www.fda.gov/AboutFDA/WhatWeDo/History/Milestones/default.htm) (Figure 29-2). However, there was no systematic application from a single government agency (16). To assist in correcting this problem, the U.S. Congress passed the Safe Food Act

FIGURE 29-2 Time line of selected congressional acts and amendments legislating the U.S. government's role in regulating the food supply

1906	Pure Food and Drug Act (FDA)
1906	Federal Meat Inspection Act (USDA)
1914	Federal Trade Commision Act (FTC)
1935	Federal Alcohol Administrative Act (U.S. Dept. of the Treasury)
1938	Federal Food, Drug, and Cosmetic Act (FDA)
1944	Public Health Services Act (USDA)
1946	Agricultural Marketing Act (USDA)
1947	Federal Insecticide, Fungicide, and Rodenticide Act (EPA)
1954	Pesticide Residue Amendment to 1938 (EPA)
1956	Fish and Wildlife Act (U.S. Dept. of Commerce)
1957	Poultry Products Inspection Act (USDA)
1958	Food Additives Amendment to 1938
1960	Color Additives Amendment to 1938
1966	Fair Packaging and Labeling Act (FDA)
1967	Wholesome Meat Act (USDA)
1970	Egg Products Inspection Act (USDA)
1972	Federal Environmental Pesticide Control Act (EPA)
1974	Safe Drinking Water Act (EPA)
1977	Saccharin Study and Labeling Act
1990	Nutrition Labeling and Education Act (FDA)
1994	Dietary Supplement Health and Education Act (DSHEA)
1996	Food Quality Protection Act
1996	Pathogen Reduction Hazard Analysis and Critical Control Points (HACCP) Systems Final Rule
1997	Pathogen Reduction Act
1997	Safe Food Act
2002	Farm Security and Investment Act—includes Country of Origin Labeling (or COOL) requirements
2002	Bioterrorism Preparedness Act
2004	Project BioShield Act
2004	Food Allergy Labeling and Consumer Protection Act
2011	FDA Food Safety Modernization Act (FSMA)

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of 1997. The purpose of this legislation was to create a single independent agency to oversee food safety (27). The most sweeping reforms in food safety laws in more than 70 years began in 2011, with the signing of the FDA Food Safety Modernization Act (FSMA), which shifted the focus from responding to food contamination to preventing it (13). As of this date, however, four federal agencies are primarily responsible for ensuring the safety of the food supply: the FDA, the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Centers for Disease Control and Prevention (CDC). Other agencies involved in monitoring food safety include the Department of Commerce, the Federal Trade Commission, the Public Health Service, the Consumer Product Safety Commission, and the Department of the Treasury (16). These latter agencies have jurisdiction over food that travels across state lines. The responsibilities of these agencies are now discussed.

FOOD AND DRUG ADMINISTRATION

The U.S. Food and Drug Administration (FDA) is a division of the Department of Health and Human Services, and its job is to enforce the Federal Food, Drug, and Cosmetic Act of 1938. This act ensures that the food, drugs, and cosmetics purchased by consumers are safe, wholesome, and produced under sanitary conditions. As a result, the FDA has jurisdiction over the production of all foods that pass across state lines. The major exceptions are the meat, poultry, and egg industries, which are regulated by the USDA. The main duties of the FDA are to inspect facilities and manufacturing processes, set standards, oversee food labeling, and regulate **food additives**.

Research/Education

Two other main functions of the FDA that are not as well known are (1) to conduct research and (2) to educate the public about food and nutrition. One of the reasons that these two duties are part of the FDA's mission is that the FDA's first chief was a university professor. In 1883, Dr. Harvey W. Wiley was a chemistry professor who left Purdue University to become chief of the Bureau of Chemistry (later named the FDA). During the early FDA days when Dr. Wiley was in charge, there were no laws about how companies could use chemical preservatives in foods and beverages (16). To remedy this situation, Dr. Wiley tried to introduce new legislation. However, this required hard data, so in an attempt to generate support for his food safety laws, Dr. Wiley recruited scientists. They studied the safety of foods in the marketplace and took the findings to the public. Scientific research remains an important function of the FDA, which reports its findings in two major publications: (1) *FDA Consumer* and (2) *FDA Drug Bulletin.*

The Code of Federal Regulations

Dr. Wiley, known as the "crusading chemist," worked with his staff to have many food laws passed at a national level. The specific regulations enforced by the FDA can be found in the Code of Federal Regulations (CFR), Title 21 (a new edition is published annually every April 1) (45). Any changes that are made during the year can be viewed in the Federal Register online at www.fda.gov/AboutFDA/WhatWeDo/default.htm#responsibilities. CFR, Title 21, covers food, drugs, and cosmetics; the publication focusing only on food is the FDA's **Food Code**. The Food Code is used as a reference for food safety guidelines in food establishments to promote safe practices and uniformity across the country (38).

FDA Inspections

One of the ways that the FDA ensures compliance with its laws is to conduct inspections. These unannounced onsite inspections of food manufacturers and processors are possible because the Food, Drug, and Cosmetic Act prohibits the sale of adulterated products. Such foods are defined as "defective, unsafe, contaminated with filth, or produced under unsanitary conditions."

The FDA, based in Rockville, Maryland, has about 1,700 inspectors to cover more than 90,000 FDA-regulated businesses (33). These inspectors are located in regional, district, and local offices spread throughout 157 cities across the country. Although they cannot visit every site, they do inspect more than 20,000 facilities a year to determine whether products are being prepared, processed, and packaged under sanitary conditions.

Companies comply with FDA laws through the use of Good Manufacturing Practice (GMP) regulations. These regulations set the requirements for quality controls such as sanitation inspection (37).

FDA Enforcement of Its Laws

Prior to the 1906 passage of the Pure Food Law, judges had no authority to stop rampant food adulteration. For example, a company could sell "fruit jam" made of water, sugar, grass seed, and artificial color. This kind of unethical practice not only cheated the consumer but also gave the offending manufacturer a higher profit margin than that of a legitimate competitor. The FDA now has the legal power to enforce the sanitation standards set by law. If a shipment is found to be unfit for consumers, for example, it is either detained in order to determine whether it should be destroyed, or the shipment is conditionally released back to the manufacturer until it is brought into compliance with the law. Another tool of the FDA is **product recall**. When a product is recalled, the manufacturer has three alternatives:

- Allow the FDA to dispose of the food product.

Food additive A substance added intentionally or unintentionally to food that becomes part of the food and affects its character.

Food Code An FDA publication updated every 2 years that explains how food-service organizations can prevent foodborne illness while preparing food. Available at www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/ucm2006808.htm.

Product recall Civil court action to seize or confiscate a product that is defective, unsafe, filthy, or produced under unsanitary conditions.

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- Contest the government's charges in court.
- Request permission of the court to bring the product into compliance under the law.

More than 3,000 products are withdrawn from the marketplace every year by either recall or court-ordered seizure. There are three levels of FDA recall: Class I—dangerous or defective products that could cause serious health problems or death; Class II—products that cause a temporary health problem or pose a slight threat of a serious nature; and Class III—products that are unlikely to cause any adverse health reaction but violate FDA labeling or manufacturing regulations. The number-one reason for the FDA to recall foods is microbial contamination (49). A list of current products being recalled is available at www.recalls.gov/food.html.

Food Fraud

Inspectors are also on the alert for catching **food fraud**, which is using deception for economic gain involving food (32). Examples of food fraud are listed in Table 29-1. Food fraud reports are submitted through the U.S. Pharmacopeial Convention's Food Fraud Database at www.foodfraud.org.

Allowable Contaminants

Eliminating all food contaminants is an unattainable goal. The FDA responded to this reality by setting "acceptable levels of filth" in certain foods. For example, it is extremely difficult, if not impossible, to ensure that all flour is free of insect parts, or that spinach does not contain a single aphid. As a result, a 1956 decision was passed stating that insect and worm parts fall under the legal principle of *de minimis non curat lex,* Latin for "the law does not concern itself with trifles" (34). Some of these official "trifles" are listed in Table 29-2.

Food fraud Deliberate substitution, addition, tampering, or misrepresentation of food, ingredients, packaging, or statements made about a product for economic gain. Also known as Economically Motivated Adulteration (EMA).

Standards of Identity Requirements for the type and amount of ingredients a food should contain in order to be labeled as that food.

Standards of Minimum Quality Minimum quality requirements for tenderness, color, and freedom from defects in canned fruits and vegetables.

TABLE 29-1 Leading Examples of Food Fraud

Olive oil	Cheaper vegetable oils substituted for olive oil
Fish and seafood	Less expensive fish sold in place of more expensive fish
Milk	Cow milk mixed with milk from other animals
Honey or maple syrup	Other syrups and sugars being used, or cheaper commercial honey substituted for "local" honey
Fruit juices	A cheaper juice (apple, grape, etc.) substituted for more expensive juices (pomegranate)
Coffee and tea	Instant coffee diluted with chicory, starch, cereals, figs, and/or other ingredients
Spices	More expensive spices such as saffron substituted with sandalwood dust, starch, and other ingredients
Organic foods	Nonorganic foods sold as organic to justify a higher price

Source: Leading Examples of Food Fraud" adapted from Mermelstein NH. Fighting food fraud. Food Technology 69(3):67–73, 2015.

TABLE 29-2 What the FDA Allows in Selected Foods

The following list represents what the FDA considers an acceptable level of contaminants in the foods listed.*

Food	Acceptable Levels of Filth
Chocolate	Fewer than one rodent hair/100 g
Coffee beans	Less than 10% insect-infested
Fig paste	Fewer than 13 insect heads/100 g
Fish (fresh frozen)	Less than 5% "definite odor of decomposition"
Mushrooms (canned)	Fewer than 20 maggots of any size/100 g (drained)
Peanut butter	Fewer than 30 insect fragments/100 g
Popcorn	Less than one rodent pellet/sample or one rodent hair/2 samples
Spinach	Fewer than 50 aphids, thrips, or mites/100 g
Tomato paste	Fewer than 30 fly eggs/100 g

Source: *Adapted from data provided by the FDA at www.fda.gov/Food/GuidanceRegulation/GuidanceDocuments-Regulatorynformation/SanitationTransportation/ucm056174.htm.

FDA Standards

In addition to addressing "filth" and ensuring that the correct ingredients are used in foods, the FDA is responsible for making sure that canned goods are filled to their capacity and foods in general are accurately labeled for sale. To combat unfair manufacturing practices, the FDA established three "content" standards: (1) Standards of Identity, (2) Standards of Minimum Quality, and (3) Standards of Fill.

Standards of Identity

Standards of Identity define a food's composition—the specific ingredients (and their proportions) it must contain in order to be labeled by its common name. For example, raisin bread cannot be called "raisin bread" unless the raisins equal 50% of the flour's weight. Fruit jam cannot be sold as "fruit jam" unless it consists of at least 45% fruit (45). Beef stew must contain at least 25% beef. Foods for which a Standard of Identity has been defined include ketchup, cheese, ice cream, frankfurters, bread, mayonnaise, salad dressings, soups, and jams (Figure 29-3) (46).

Standards of Minimum Quality

Standards of Minimum Quality ensure that foods sold meet a minimum level of quality. For instance, string beans cannot be too "stringy," peas cannot be too hard, and cream-style corn

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FIGURE 29-3 FDA Standards of Identity.

Food manufacturers have to list the ingredients in 300+ standardized foods, which include the following 20 product categories:

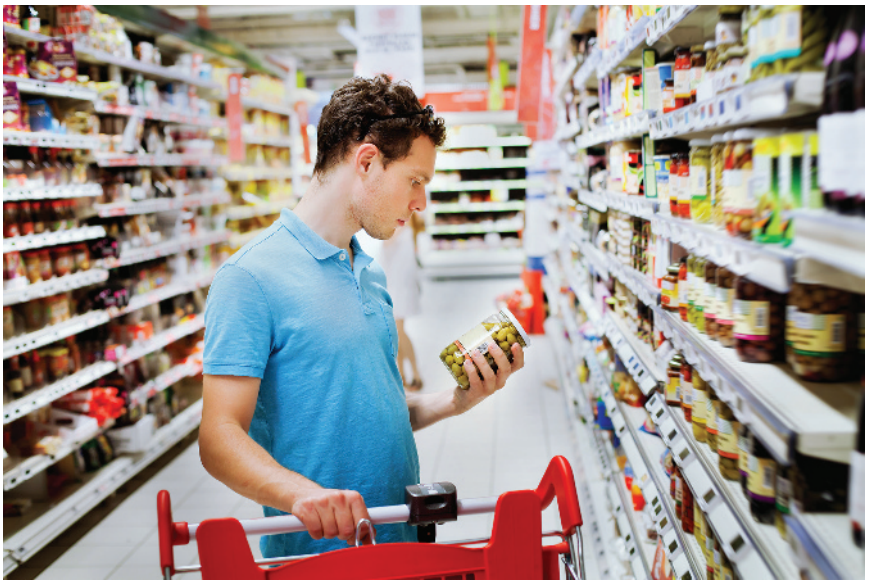
- Milk and cream
- Cheeses and related products
- Frozen desserts
- Bakery products
- Cereal flours and related products
- Macaroni and noodle products
- Canned fruits
- Canned fruit juices
- Fruit butters, jellies, and jams or preserves
- Fruit pies
- Canned vegetables
- Vegetable juices
- Frozen vegetables
- Eggs and egg products
- Fish and shellfish
- Cacao products (cocoa, chocolate)
- Tree nut and peanut products
- Margarine
- Sweeteners and table syrups
- Food dressings and flavorings (mayonnaise, salad dressing, vanilla flavoring)

cannot be too watery. The Standards of Minimum Quality are mandatory and are not to be confused with the voluntary grades of A, B, C (or Fancy, Choice, Standard) set by the USDA for canned fruits and vegetables. Canned foods that do not meet the Standards of Minimum Quality are labeled "Below standard in quality; good food—not high grade."

Standards of Fill

Until a **Standard of Fill** regulation was put into effect, manufacturers did not have to fill a can to the top with its ingredients. Cans were often only partially packed, with the remainder of the volume being filled with fluid. Consumers are now safe from this type of manufacturing fraud. The Standards of Fill require manufacturers to pack solid food of a minimum weight into each can. The food is measured after the liquid is drained from the can. Cans must be filled to their maximum capacity (usually 90%) with solid ingredients.

FIGURE 29-4 Checking food labels for ingredients and nutrition facts.



Ditty_about_summer/Shutterstock.com

Food Labeling

Interest in food labeling began in the 1960s. Consumers began expressing concerns about processed foods and demanding to know exactly what was in the foods they were ingesting (Figure 29-4). As a response to this public concern, the government developed new labeling regulations. It became a legal requirement (through the Fair Packaging and Labeling Act) to include the following information on the food label:

- The ingredients of packaged (canned, bottled, boxed, and wrapped) foods listed in descending order by weight. Food additives, colors, and chemical preservatives are also required to be listed on the label.
- The name and form (crushed, sliced, whole) of the product.
- The net amount of the food or beverage by weight, measure, or count. In addition to net weight, two other types of weight measurement include drained weight and solid content.
- The name and address of the manufacturer, packer, or distributor.
- The nutrient content depicted as Nutrition Facts (Figure 29-5). The other labeling formats allowed for Nutrition Facts are displayed at www.fda.gov/downloads/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/UCM511964.pdf.

The FDA is responsible for ensuring that consumers are informed about a packaged product's ingredients and nutrient content. The exceptions are meat and poultry products, which are regulated by the USDA (25).

Nutrition Facts Label

Food labeling was not always mandatory. It became a requirement for most foods in 1994, when the Nutrition Facts label was adopted as a uniform way to present nutrient information. The FDA made significant changes to the required format and standards for the Nutrition Facts label in May 2016, and all large manufacturers must transition to the new label by June 26, 2018 (42). The Canadian nutrition label is also called Nutrition Facts, but Canada requires two labels—one in English and one in French (1). Food labels provide consumers with pertinent information for making reasonable food choices. The various sections of the Nutrition Facts label (original and updated) are explained now (42).

Serving Size and Serving Number

The first items on the food label are serving size and the number of servings per container. These should be checked

Standards of Fill The amount of raw product that must be put into a container before liquid (brine or syrup) is added.

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FIGURE 29-5 Mandatory nutrient labels assist consumers in making healthy choices.

SIDE-BY-SIDE COMPARISON

Original Label

Nutrition Facts

Serving Size 2/3 cup (55g)
Servings Per Container About 8

Amount per serving

Calories 230	Calories from Fat 72
	% Daily Value*
Total Fat 8g	**12%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**12%**
Dietary Fiber 4g	**16%**
Sugars 1g	
Protein 3g	
Vitamin A	10%
Vitamin C	8%
Calcium	20%
Iron	45%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily value may be higher or lower depending on your calorie needs.

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

New Label

Nutrition Facts

8 servings per container
Serving size 2/3 cup (55g)

Amount per serving

Calories 230

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Source: https://www.fda.gov/downloads/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/UCM501646.pdf

carefully. Because the 1993 serving size requirements no longer reflect typical portion sizes, the FDA's 2016 food label regulations specify more realistic serving sizes: for example, 1 cup for ice cream, 12 ounces for soda, or an entire package (20-ounce soda, 15-ounce can of soup, etc.) if that is the amount consumers would typically consume in one sitting (42). The nutrition information on the label presently refers to a single serving, but when the new regulations are in effect, manufactures must provide information for both a serving and an entire package for certain container sizes, such as pints of ice cream or 24-ounce sodas.

Kilocalories

The total kcalories (referred to as "calories" on the label) and kcalories from fat are listed below the serving information on the original Nutrition Facts label. The updated label omits kilocalories from fat.

Nutrients

The five major nutrients listed on the original Nutrition Facts are (1) fat (grams; total, saturated, and trans), (2) cholesterol (milligrams), (3) sodium (milligrams), (4) total carbohydrate (grams of dietary fiber and sugar), and (5) protein (grams). The "% Daily Value" is provided for these nutrients as well as for vitamins A and C, calcium (Ca), and iron (Fe). The updated Nutrition Facts will also include added sugars (grams) so that consumers can distinguish them from naturally present sugars, and it will replace vitamins A and C with potassium and vitamin D. In addition, quantities (in micrograms for vitamin D and milligrams for the others) as well as % Daily Values for these vitamins and minerals will be included.

Canadian Nutrition Facts use different daily values for certain vitamins and minerals, so it is difficult to design a single label for a product sold in both the United States and Canada (1).

Daily Values

Daily Values are nutrient standards derived from the Daily Reference Values (DRV) and Reference Daily Intakes (RDI). Based on the 2016 regulations, which updated several of these standards, Daily Reference Values refer to fat, saturated fat, cholesterol, protein, carbohydrates, added sugars, fiber, and sodium. Reference Daily Intakes cover other nutrients (vitamins and minerals). Daily Values are based on a daily diet of 2,000 kcalories, and are mandatory for eleven food components but optional for twenty-five others (8, 37).

Other Nutrition Facts Information

The Nutrition Facts label also includes the specific names of flavorings, colorings, and spices. FDA-certified food color additives such as FD&C Yellow No. 5 or 6, Red No. 3 or 40, Blue No. 1 or 2, and Green No. 3 must be declared on all foods except butter, cheese, and ice cream (45). Beverages claiming to contain fruit juice(s) are required to list the percentage of real fruit juice (45).

At the bottom of the Nutrition Facts portion of the label, some manufacturers may also give the American Diabetes Association's exchange calculation based on their "Exchange Lists for Meal Planning" for diabetics.

Food Labeling Exemptions

Although not all foods require labeling, about 90% of all packaged foods carry nutrition information. Some foods do not require a nutrition label; these include raw foods (fresh fruits, vegetables, and fish), game, restaurant food, deli and bakery items, foods containing insignificant amounts of nutrients (coffee, tea, spices), bulk food, infant formula, medical foods, donated foods, and foods in packages with a surface area for labeling of less than 12 square inches, such as gum or breath mints (45).

Food Allergen Labeling

Each year in the United States, up to 200 people die from allergic reactions to food ingredients. The Food Allergen Labeling and Consumer Protection Act (FALCPA), passed in 2004, helps people with allergies avoid these adverse reactions by requiring manufacturers to list food allergens on their labels. Any food containing a major allergen, defined by the FALCPA as a protein from one of the eight foods listed in Table 29-3, must clearly state

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TABLE 29-3 Eight Major Allergens Identified by the Food Allergen Labeling and Consumer Protection Act

Peanuts	Fish
Soybeans	Crustacean shellfish
Cow's milk	Tree nuts
Eggs	Wheat

this on the label. Although more than 160 foods have been identified to cause food allergies, these eight major allergens account for 90% of all food allergies in approximately 2% of adults and 5% of infants and young children (40).

Gluten-Free Products

The gluten-free labeling law was mandated by the FALCPA. According to FDA regulations, the "gluten free" label can only be used on foods with less than 20 ppm gluten (20). However, some consumers feel that labels should follow the stricter standard of 3 to 10 ppm.

Genetically Modified Organisms (GMOs)

The FDA does not require that GMOs be labeled as such unless the foods contain new allergens, have modified nutritional profiles, or represent a new plant (see Chapter 1 for more information).

FDA-Allowed Claims on Labels

Prior to the 1990s, claims that linked a nutrient or food to a disease, in either a positive or a negative way, were not permitted. Now, under the current regulations, the FDA allows three types of claims on food or dietary supplement labels: **health claims**, **nutrient content claims**, and **structure/function claims** (www.fda.gov/Food/IngredientsPackagingLabeling/LabelingNutrition/ucm111447.htm).

Health claims are marketing factors that can impact consumer interest in a product (19). The FDA categorizes health claims as either unqualified or qualified.

Health Claims

A health claim by definition proposes a relationship between its two essential components: (1) a substance (whether a food, food component, or dietary ingredient) and (2) a disease or health-related condition. Approval of a claim by the FDA occurs when a company submits a petition and follows these basic steps: (1) definition of the substance/disease relationship, (2) identification of relevant studies, (3) classification of studies, (4) rating of the studies, (5) rating the strength of the evidence, and (6) reporting a rank (19). When a claim is approved, the FDA posts a letter to its website. Qualified health claims are generally approved within 270 days of filing (19). Unqualified health claims may take twice as long (540 days) to receive approval.

Strict requirements now govern how and when the FDA-approved health claims may be used. The food must contain enough of the nutrient to contribute at least 10% of the Daily Value and must not contain any nutrient or food substance that increases the risk of a disease or health condition. For example, whole milk cannot bear the calcium/osteoporosis claim because of its high saturated fat content. Excess saturated fat has been linked to heart disease. On the other hand, low-fat and nonfat milk do qualify for the calcium/osteoporosis claim (9).

Qualified Health Claims

The original language of the 1993 Nutrition Labeling and Education Act allowed only unqualified food health claims, which required "significant scientific agreement" (SSA); later in the decade, the FDA was forced by a lawsuit filed by attorney Jonathan Emord to provide guidance for the use of qualified health claims (3). Qualified health claims are based on "emerging evidence" of a product's ability to reduce the risk of a given disease (19). The FDA permits the use of one of its qualified health claims on a label if (1) language already approved by the FDA is used, (2) the weight of the evidence supports it, and (3) the company has petitioned the FDA to use the language and received written notification of approval. Examples of qualified health claims that have been approved link foods with reduced risks of cancer, cardiovascular disease, cognitive function, birth defects, diabetes, hypertension, and atopic dermatitis (3). The list of qualified health claims authorized by the FDA continues to grow, but Table 29-4

How & Why?

How are "unqualified" and "qualified" health claims different?

Both types of health claims characterize a relationship between a specific food or one of its components and a disease or health-related condition; the difference is in the degree of scientific evidence supporting this relationship. **Unqualified health claims**, also known as "authorized health claims," must be supported by significant scientific agreement among experts who have examined the available scientific evidence (35). In contrast, **qualified health claims** are supported by at least a little scientific evidence but do not meet the significant scientific agreement standard. As a result, they must be accompanied by a disclaimer or other qualifying language that explains the level of scientific evidence supporting the claim. Both types of claims may be used on conventional foods or dietary supplements (35).

Health claim A statement that describes a relationship between a food, food component, or dietary supplement ingredient and reduced risk of a disease or disease-related condition.

Nutrient content claims Food label descriptions communicating the amount of a nutrient or dietary substance contained in a food or beverage.

Structure/function claims Statements identifying relationships between nutrients or dietary ingredients and a body function.

Unqualified health claim As defined by the FDA, a type of health claim that is supported by significant scientific agreement; also known as an *authorized claim*.

Qualified health claim As defined by the FDA, a type of health claim that must be accompanied by a "qualifying" statement specifying the degree of scientific evidence that supports it. The FDA allows these statements to be made based on the "weight of the evidence" but does not consider them to be backed by significant scientific agreement.

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TABLE 29-4 Selected Qualified Health Claims Allowed by the FDA

- Cancer Risk
  - Tomatoes and/or tomato sauce (prostate, ovarian, gastric, and pancreatic cancers)
  - Calcium (colon/rectal cancer or recurrent colon/rectal polyps)
  - Green tea (breast and prostate cancers)
  - Selenium
  - Antioxidant vitamins
- Cardiovascular disease risk
  - Nuts
  - Walnuts
  - Omega-3 fatty acids
  - Folic acid, vitamin B6, and vitamin B12
  - Monounsaturated fatty acids from olive oil
  - Unsaturated fatty acids from canola oil
  - Corn oil
- Cognitive Function
  - Phosphatidylserine
- Diabetes
  - Psyllium husk
  - Whole grains
  - Chromium picolinate
- Hypertension (and pregnancy-induced hypertension and preeclampsia)
  - Calcium
- Neural tube birth defects
  - 0.8 mg of folic acid
- Atopic dermatitis risk
  - 100% whey-protein partially hydrolyzed infant formula

Source: Adapted from the FDA's website at www.fda.gov/Food/IngredientsPackagingLabeling/LabelingNutrition/LabelClaims/QualifiedHealthClaims/ucm073992.htm.

lists those approved at the time of this textbook's publication. An updated list can be found at www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm073992.htm. In the past, other health claims were reviewed and tentatively found not to have sufficient basis to be authorized by the FDA for use in food labeling (12). Some of these include the link between zinc and the immune systems of elderly people and between green tea and heart disease.

The FDA ranks qualified health claims by the strength of the underlying scientific evidence (3). Claims are rated as A, B, C, or D, with A being the strongest.

Nutrient Content Claims

Nutrient content claims describe the level of a nutrient or dietary substance in a product by using terms such as *free, high, and low.* Common examples include *fat-free, low cholesterol, calorie-free,* and others listed in Table 29-5. Nutrient content claims may also compare the level of a nutrient in a food to that of another food by using terms such as *more, reduced,* and *lite.*

Structure/Function Claims

Structure/function claims describe the role of a nutrient or dietary ingredient intended to affect normal structure or function in humans. For example:

- "Calcium builds strong bones"
- "Fiber maintains bowel regularity"
- "Antioxidants maintain cell integrity"

The manufacturer is responsible for ensuring the accuracy and truthfulness of these claims. Although not preapproved by the FDA, they must be truthful and not misleading. If a dietary supplement (rather than food) label includes such a claim, it must have a "disclaimer" on the label. Disclaimers state that the FDA has not evaluated the claim and that the product is not intended to "diagnose, treat, cure, or prevent any disease" (only a drug can legally make such a claim).

Dietary Supplements

Under the 1994 Dietary Supplement Health and Education Act (DSHEA, pronounced de-shay), dietary supplements are treated as foods (47). Health claims can be made for dietary supplements as long as they are not disease claims, which are only allowed for **drugs**. Manufacturers of dietary supplements that make structure/function claims on labels must submit a

TABLE 29-5 Nutrient Content Claims Allowed for Food Labeling

Description	Amount/Serving
Free*	None or trace amount—<5 kcalories, <½ g fat, <½ g saturated fat, <2 mg cholesterol, <½ g sugar, or <5 mg sodium
Low	<40 kcalories <3 g fat <1 g saturated fat <20 mg cholesterol <140 mg sodium (very low sodium = <35 mg)
Extra lean	<5 g fat <2 g saturated fat <95 mg cholesterol
Lean	<10 g fat ≤4.5 g saturated fat <95 mg cholesterol
Light/Lite	1/3 fewer kcalories Half the fat Can also describe color or texture
Reduced or less	25% less than regular product
More	10% or more of Daily Value
High	20% or more of Daily Value for the nutrient
Good source	10% to 19% of Daily Value for the nutrient
More than	10% or more of the Daily Value than comparison food
Fewer than	25% less than comparison food
Healthy (individual food)	<3 g fat <1 g saturated fat ≤480 mg sodium Cholesterol ≤ disclosure level

*Instead of "free," manufacturers may also use "no," "zero," "without," "trivial source of," "negligible source of," and "dietarily insignificant source of."

For alpha-linolenic acid (omega-3 fatty acid) claims, see www.federalregister.gov/articles/2014/04/28/2014-09492/food-labeling-nutrient-content-claims-alpha-linolenic-acid-eicosapentaenoic-acid-and-docosahexaenoic#h-11.

Drug A product able to treat, prevent, cure, mitigate, or diagnose a disease or disease symptom.

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notification to the FDA no later than 30 days after marketing the dietary supplement. (Further information can be found in the "Structure/Function Claims, Small Entity Compliance Guide" at www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/DietarySupplements/ucm103340.htm.)

Food Additives

Food additives are substances added to food that become part of the food and affect its character. The FDA is responsible for regulating more than 3,000 food additives that are used in the food industry. Some of the more common additives and their functions in foods are listed in Appendix E. The four main purposes of these food additives are discussed in Chapter 3 on food composition, and common examples have been provided throughout the text. The purpose of this section on food additives is to describe the FDA's role in their approval and safety.

Safety of Food Additives

The U.S. government defines *safety* as "reasonable certainty . . . that the substance is not harmful under the intended conditions of use" (34). Two amendments to the Federal Food, Drug, and Cosmetic Act of 1938—the Food Additives Amendment (1958) and the Color Additives Amendment (1960)—state that the FDA must approve the safety of all food additives. Prior to the 1958 Food Additives Amendment, the burden was on the FDA to prove that an additive was harmful before a court order could be issued banning its use. After the amendment was passed, the tables were turned, and it became the manufacturer's responsibility to convince the FDA that the additive was safe through extensive testing on laboratory animals.

Ingredients Not Defined as Additives

The law excludes substances that are on the GRAS list or have prior sanction from being defined as a food additive.

GRAS Substances

Substances on the GRAS list are not officially considered food additives, so they are exempt from the legal requirement for safety testing (41). However, GRAS substances are continually reevaluated, and as new evidence emerges, some substances are removed from the GRAS list—as trans fat was in 2016 (39). This list was originally formed when the FDA appointed a group of scientific researchers to compile a list of substances considered safe. The purpose of the GRAS list was to avoid the time and expense of testing the safety of every substance (23).

Substances with Prior Sanction

These substances were used in foods prior to the passage of the 1958 Food Additives Amendment. As a result, they fall into the category of previous approval or prior sanction.

The Delaney Clause

The **Delaney Clause** (1958) tightened the regulations on food additives but has subsequently been reinterpreted and modified as the techniques for identifying carcinogenic compounds have improved (15). The Department of Health and Human Services has estimated that food additives are linked to only 1% of all cancers. The FDA has banned all food additives that were found to be carcinogenic in laboratory animals, with the exception of saccharin and a few food colorings. Other additives whose safety has been questioned include food colorings, nitrites (see Chapter 7 on meats), pickling additives, BHA/BHT, and pesticides.

How & Why?

How do additives obtain FDA approval?

Additives are never given permanent approval but are subject to review to determine whether the approval should continue, be modified, or be withdrawn. The process of approving a new additive may take years and cost millions of dollars. An additive is first tested on laboratory animals to determine whether it affects life span, cancer rates, incidence of birth defects, allergies, or other health outcomes. A hundredfold margin of safety is applied; that is, if 100 mg of the substance is the minimum level that causes no harmful effect in laboratory animals, then manufacturers may use no more than 1 mg in foods given to humans (30). This safety margin sets the **Acceptable Daily Intake (ADI)** for human consumption. Only food additives on the **Generally Recognized as Safe (GRAS) list**, plus those more recently approved by the FDA, are allowed in the U.S. food supply (16).

How & Why?

How many cancers are related to food additives?

Over the past 50 years, rates of death from cancers, with the exception of lung cancer, have remained relatively the same or have slightly decreased. If food additives influenced cancer death rates, an increase in the general population dying of cancer would most likely have been documented. It has been estimated that if there is a risk, food additives would be responsible for less than 1% of all cancers.

The Bioterrorism Preparedness Act

Through the Bioterrorism Preparedness Act of 2002 and other legislation, the U.S. government made it mandatory for all food facilities to register with the FDA, provide prior notice of food imports, and maintain necessary

Acceptable Daily Intake (ADI) The amount of food additive that can be safely ingested daily over a person's lifetime.

Generally Recognized as Safe (GRAS) list A list of compounds exempt from the food additive definition because they are generally recognized as safe based on "a reasonable certainty of no harm from a product under the intended conditions of use."

Delaney Clause A clause added to the Federal Food, Drug, and Cosmetic Act of 1938 stipulating that "no additive shall be deemed to be safe if it is found to induce cancer when ingested by man or animal."

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records to assist the FDA in determining whether food poses a threat of serious adverse health consequences or death. The regulation covers all food manufacturers, ingredient suppliers, packaging suppliers, and food distributors. Foreign facilities providing food for American consumption are also required to register. Electronic registration is encouraged via the FDA's website at www.fda.gov/Drugs/GuidanceComplianceRegulatoryInformation/DrugRegistrationandListing/ucm084014.htm. Failing to register is a criminal act (21).

U.S. DEPARTMENT OF AGRICULTURE

The U.S. Department of Agriculture (USDA) was originally established for three reasons:

- To increase the income of farmers by developing methods for improving productivity and by generating new markets for farm products
- To reduce hunger and malnutrition
- To inspect and **grade** farm products

Within the USDA is the Agricultural Research Service (ARS), an in-house research agency, which has various locations (www.ars.usda.gov/northeast-area/beltsville-md/beltsville-human-nutrition-research-center) and is charged with the following (www.ars.usda.gov/about-ars) (22):

- Ensuring high-quality, safe food, and other agricultural products
- Assessing the nutritional needs of Americans
- Sustaining a competitive agricultural economy
- Enhancing the natural resource base and the environment
- Providing economic opportunities for rural citizens, communities, and society as a whole
- Providing the infrastructure necessary to create and maintain a diversified workplace

Among some of the foods developed through ARS collaboration were instant mashed potatoes, xanthan gum, sourdough bread starters, lactose-free foods, and reduced-fat mozzarella cheeses (22).

The USDA and its responsibilities have expanded tremendously. This chapter, however, focuses only on the USDA's inspection and grading services. A major difference between inspection and grading is that inspection is mandatory, and grading is voluntary. Another big difference is that the USDA both inspects *and* grades meat, poultry, and eggs, but it only grades dairy products, grains, fruits, and vegetables. These services are conducted through the USDA's Food Safety and Inspection Service (FSIS). Some overlap exists, in that the FDA is responsible for food products containing relatively small amounts of meat (3%) and poultry (2%) (34).

USDA Inspections

The terrible conditions observed in meatpacking plants in 1906 led Congress to pass numerous acts of food-related legislation. This allowed the federal government to inspect plants producing meats, poultry products, and eggs. The goal was to ensure that both the processes and the products were sanitary. As a result, products containing foods that cross state lines must be inspected at the federal level. Products that pass the USDA inspection then receive the blue inspection stamp (Figure 29-6).

State inspection regulations for intrastate commerce (foods that never leave the state, i.e., cross the state line and enter the federal jurisdiction) must equal or exceed USDA standards. Because each state established its own guidelines, state rules (especially with regard to health inspections) sometimes differ from those of other states and even those of the federal government.

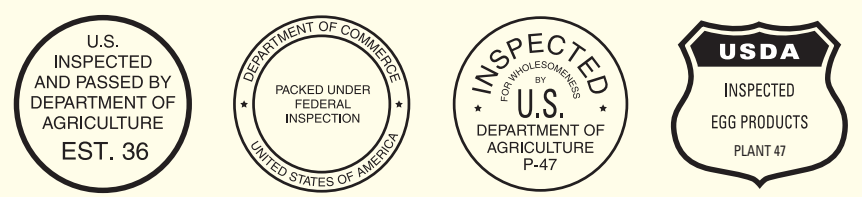
The legislation affecting USDA inspections includes the following:

- Federal Meat Inspection Act (1906). The USDA is responsible for inspecting meat to ensure that it is safe, wholesome, and accurately labeled.
- Agricultural Marketing Act (1946). The USDA's Agricultural Marketing Service administers the inspection and grading of raw and processed foods such as cereal, dairy, fresh fruits and vegetables, poultry, eggs, fish, and shellfish.
- Fish and Wildlife Act (1956). Governs the inspection of fish and shellfish.
- Poultry Products Inspection Act (1957). Requires inspection of all poultry.
- Wholesome Meat Act (1967). Meats that do not travel interstate must meet state inspections equal to federal guidelines. This act also includes provisions for the inspection of foreign processing plants.
- Egg Products Inspection Act (1970). Mandatory inspection of plants producing egg products.
- Pathogen Reduction Hazard Analysis and Critical Control Points (HACCP) Systems Final Rule (1996). Meat and poultry plants must implement mandatory HACCP programs.
- Pathogen Reduction Act (1997). Sets a zero tolerance for *Escherichia coli* in foods.
- Farm Security and Rural Investment Act (2002). The 2002 Farm Bill requires **country of origin labeling**.

Grading The voluntary process in which foods are evaluated for yield (a 1 to 5 grading for meats only) and/or quality (e.g., Prime, Choice, AA, A, Fancy, etc.).

Country of origin labeling The required identification of the country of origin on the label for fresh red meat (beef, pork, lamb, veal), marinated products (marinated meats), seafood, produce, and peanuts.

FIGURE 29-6 USDA inspection stamps.



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FIGURE 29-7 USDA inspectors look for spoiled meat. The Federal Meat Inspection Act of 1906 required that all interstate beef be inspected. However, some believe that the old "sniff and poke" methods need to include more routine and rapid tests detecting pathogenic bacteria.



Vito Palmisano/Stone/Getty Images

The product is exempt if it is an ingredient in another food such as salmon in sushi, nuts in a candy bar, or tenderloin in beef Wellington. Hot dogs and luncheon meats are also exempt.

For 90 years, inspectors relied on sight, touch, and smell to detect spoiled meat (Figure 29-7). Their tests for microorganisms took hours or even days. Recent laws governing meat and poultry safety have radically changed how inspections are conducted (13). To ensure that their plants and equipment are clean, the FSIS (under the HACCP Systems Final Rule) requires that meat and poultry plants incorporate Sanitation Standard Operating Procedures (SSOPs) (18). Food manufacturers are required to develop and implement HACCP programs to identify critical points where microbial contamination could occur, install controls to prevent or reduce those hazards, and document the process (11). Quick microbiological tests that detect *E. coli, Salmonella,* and other bacteria are encouraged. Each meat and poultry manufacturing plant must also adopt HACCP programs to eliminate hazards at every point in the production process. Similar HACCP programs have been recommended for the egg and fruit/vegetable juice industries (10, 11).

USDA Grading

Only food that has passed inspection may be graded for quality, which is further explained at www.ams.usda.gov/services/grading. Unlike inspection, however, USDA grading is voluntary. For those food companies willing to pay for it, USDA grading is available for meat, poultry, eggs, dairy products, fresh fruits and vegetables, and some fish, shellfish, and cereal. There are two types of grading: quantitative and qualitative.

Quantity Grades or Yields

Quantitative grading is reserved for meats. It describes the *yield* or the ratio of the lean muscle tissue to fat, bone, and refuse on the animal's carcass. The yield grade ranges from 1 to 5, with 1 representing the highest yield and lowest waste (Figure 29-8). This type of grade is not commonly seen at the consumer level.

Quality Grades

Consumers are more familiar with quality grades. These are based on a food's appearance, texture, flavor, and other factors, depending on the particular food. Figure 29-9 shows the various quality grades and their characteristics for different types of foods. The differences among individual grades for meat, poultry, fish, dairy, vegetables, and fruits are discussed in their respective chapters. Figure 29-10 shows how different grades of fruit may be used for various food dishes. For example, high-quality U.S. Grade A strawberries would be used to top strawberry shortcake, whereas lower-quality U.S. Grade B strawberries would be reserved for strawberry pie, and even lower U.S. Grade C strawberries would be used for jam.

FIGURE 29-8 USDA Grade Yield stamp.



Product Labeling

Irradiated Foods

Most foods that have been irradiated are labeled with a Radura (see Figure 28-10 in Chapter 28) or proper wording to inform consumers. See Chapter 28 for specific requirements for using the Radura symbol on foods.

Organic Foods

The definition and labeling requirements for organic foods are discussed in Chapter 1 (see Table 1-2) and accessible online at www.ams.usda.gov/grades-standards/organic-standards and www.ams.usda.gov/services/organic-certification.

Country of Origin Labeling (COOL)

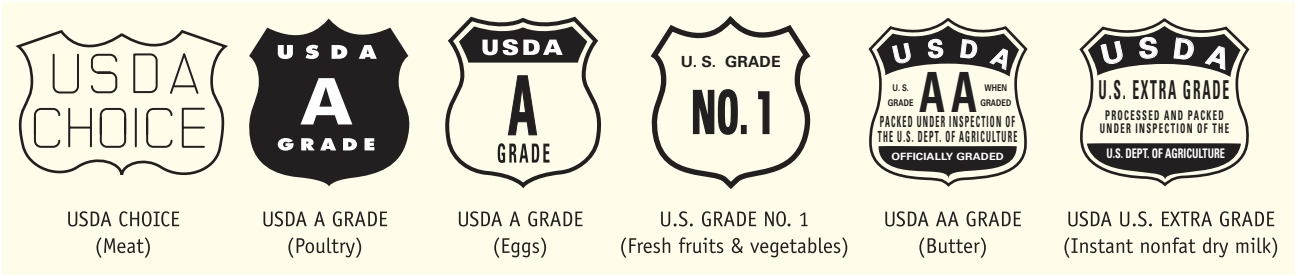
The USDA-enforced country of origin labeling (COOL) law applies to beef, lamb, pork, chicken, fish, shellfish, peanuts, fresh and frozen fruits and vegetables, pecans, macadamia nuts, and ginseng (20). Exempt foods include those served in food-service establishments (such as restaurants) or sold by companies with less than $230,000 in annual sales, exporters, butcher shops, and fish markets (20). COOL labeling regulations were passed in 2002 and became mandatory in 2009. COOL is not intended to provide any information

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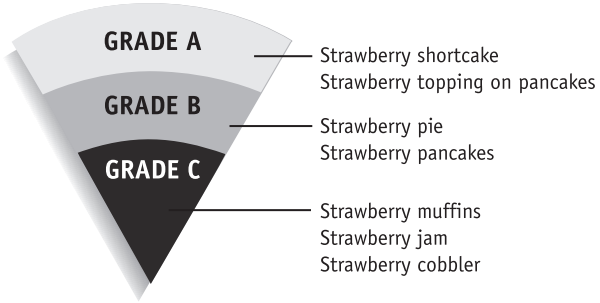
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FIGURE 29-9 USDA quality grade stamps for specific food types.



USDA CHOICE (Meat) | USDA A GRADE (Poultry) | USDA A GRADE (Eggs) | U.S. GRADE NO. 1 (Fresh fruits & vegetables) | USDA AA GRADE (Butter) | USDA U.S. EXTRA GRADE (Instant nonfat dry milk)

FIGURE 29-10 The use of different fruit grades in food preparation.



concerning food safety, but only provides consumers with data on the country from which food originated (28).

COOL labeling categories include the following (20):

- **U.S. only origin.** For animals born, raised, and slaughtered in the United States.
- **Foreign only origin.** For products produced entirely outside the United States.
- **Mixed origin.** This category must be labeled with the country of birth, raising, and slaughter.

Approved COOL labels include statements such as "Product of USA," or may appear as a checkbox (2).

ENVIRONMENTAL PROTECTION AGENCY

The goal of the Environmental Protection Agency (EPA) is to protect human health and the environment. Its food-related function is to determine the safety of new pesticides and set tolerance levels for pesticide residues in foods. The major law empowering the EPA with the authority to regulate the use of certain pesticides is the 1947 Federal Insecticide, Fungicide, and Rodenticide Act (refer to Figure 29-2). This legislation is an exception to the Delaney Clause, allowing certain pesticides that are known carcinogens to be used on raw agricultural commodities as long as the benefits from their use outweigh the risks from their presence (48). It is illegal for foods to bear traces of pesticides in excess of the safe tolerance levels set by the EPA. A small percentage of all fresh fruits, vegetables, and grains, especially those from foreign countries, are continually inspected by the EPA for pesticide residues. The EPA works with the USDA's Pesticide Data Program that tests for pesticide residues on food and publishes the results in their Pesticide Databases and Annual Summaries report available at www.ams.usda.gov/datasets/pdp/pdpdata (26). Among the pesticides tested, 99% of the sampled foods had residues below EPA tolerances. Further consumer information from the EPA on "Food and Pesticides" can be found at www.epa.gov/safepestcontrol/food-and-pesticides and in "From Crop to Table: Pesticide Use in Produce" from *Consumer Reports* that offers guides for making informed purchases (31). The latter publication's advice for cleaning produce is listed in Table 29-6.

The FDA enforces the pesticide tolerances established by the EPA by constantly monitoring pesticide residue levels to ensure that the risk of food contamination remains low (43). Nevertheless, accidental poisonings do occur and are estimated by the EPA to be about 10,000–20,000 a year (31). Farmers and farmworkers with long-term agricultural pesticide exposure are at an increased risk for non-Hodgkin's lymphoma, prostate cancer, lung cancer, Parkinson's disease, bronchitis, and asthma (31).

TABLE 29-6 Produce Cleaning Tips

When organic options are not available or affordable, the following tips can lower exposure to pesticide residues:

- Wash fruits and vegetables under running water for at least 30–60 seconds while gently rubbing produce to dislodge residue.
- Scrub firm edible skin with a produce brush (wash brushes in dishwasher or with hot, soapy water). Consider eating peels that contain nutrients.
- Wash inedible peels before peeling to avoid getting pesticide residues on edible portion from contaminating hands.
- Remove outer leaves of lettuce or cabbage heads.
- Consider buying organic citrus fruits before zesting the peel.
- Wash organic produce as well to reduce exposure from possible pesticide residues drifting from conventional farms, dirt, and potentially harmful microorganisms.

Source: Rangan U, et al. From Crop to Table. Pesticide use in Produce. Consumer Reports. Food Safety and Sustainability Center. March, 2016. http://www.consumerreports.org/content/dam/cro/magazine-articles/2015/May/Consumer%20Reports_From%20Crop%20to%20Table%20Report_March%202015.pdf. Accessed 4/24/2017.

CENTERS FOR DISEASE CONTROL AND PREVENTION

This federal agency dates back to World War II, when the Public Health Service established the Office of Malaria Control to prevent malaria in army camps by killing mosquitoes. Since then, the mission of the Centers for Disease Control

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and Prevention (CDC) has broadened to protection of the health of all Americans. In terms of food, the CDC focuses on preventing and controlling foodborne diseases. The CDC tracks foodborne illness outbreaks across the country, determines their causes, and prevents their recurrence. State health departments report foodborne illness outbreaks (and infectious disease data) to the CDC through the National Outbreak Reporting System (NORS) (4) and the National Healthcare Safety Network (NHSN) (5). The federal agency then uses this information to conduct surveillance and keep online records. The number of outbreaks by year, state, and causative agent can be viewed at wwwn.cdc.gov/foodborneoutbreaks.

OTHER REGULATORY AGENCIES

U.S. Department of Commerce

It may seem odd, but the U.S. Department of Commerce (USDC) is responsible for the inspection of fish and fish products. Specifically, the National Marine Fisheries Service within the USDC oversees these voluntary inspections and gradings. Fish processing plants pay for the service. Fresh fish are not graded because deterioration begins the minute fish are caught. However, grading is available for frozen fish products such as fish sticks, fillets, steaks, and breaded/precooked fish portions. Shellfish require more caution, so oysters, clams, mussels, and whole scallops are sold to consumers only if harvested from certified waters. *The Interstate Certified Shellfish Shippers List*, published monthly by the FDA, describes these certified waters. The updated version of the shellfish list is available online at www.fda.gov/food/guidanceregulation/federalstatefood-programs/ucm2006753.htm.

Federal Trade Commission

The major purpose of the Federal Trade Commission (FTC) is to prevent fraud, deception, and unfair business practices. Thus, the FTC protects consumers from false or deceptive advertising regarding foods and dietary supplements. The FTC enforces the sections of the Federal Food, Drug, and Cosmetic Act that prohibit the sale of products that are misrepresented by advertising or by misleading words, designs, or pictures on the label (16). "Cease and desist" orders are issued by the FTC against a company or individual it believes to be engaging in unlawful trade practices.

Department of the Treasury

Alcoholic beverages fall under the jurisdiction of two agencies within the Department of the Treasury, the Internal Revenue Service (IRS) and the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF). The IRS enforces federal laws regulating alcoholic beverages because alcohol is subject to a federal tax. The ATF is partially responsible for enforcing the laws that regulate the production, distribution, and labeling of alcoholic beverages. A third federal agency involved in alcohol regulation is the FDA, which is responsible for wines with less than 7% alcohol.

State Agencies

Products made and sold exclusively within a state often have to meet state food safety regulations. These are frequently administered at the federal level. However, each state has slightly different laws unique to its specific locality, needs, and problems.

INTERNATIONAL AGENCIES

Global food standards are established by two major international agencies that are part of the United Nations—the Food and Agriculture Organization and the World Health Organization (6). Under joint effort, they created the **CODEX Alimentarius Commission** in 1962 to provide global guidelines concerning food hygiene, food additives, residues of pesticides and veterinary drugs, contaminants (environmental and industrial), and food labeling (6).

The Food and Agriculture Organization

The Food and Agricultural Organization (FAO) was established in 1945 in response to the nutrition awareness created by World War II. Headquartered in Rome, Italy, the FAO's original main objectives were to do the following:

- Eliminate hunger.
- Improve nutrition by enhancing food production and distribution through research, technical assistance, and educational programs.
- Maintain statistics on world food production.

The World Health Organization

The initial objectives of the World Health Organization, headquartered in Geneva, Switzerland, were to develop international cooperation for better health conditions. It aims to achieve this objective by doing the following:

- Conduct research on nutrition, cancer, vaccines, and nuclear hazards.
- Expand government health programs by opening clinics, dispatching experts, and training medical personnel.
- Organize educational campaigns to control diseases.

European Regulation

The European Parliament has established regulations for nutrition and health claims (14). They provide definitions of nutritional claims, which address nutritional properties; health claims, which address the relationship between food and health; and risk-reduction claims, which include claims that a food significantly reduces the risk of a certain disease.

Codex Alimentarius Commission The international organization that develops international food standards, codes of practice, and other guidelines to protect consumers' health.

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PICTORIAL SUMMARY / 29: Government Food Regulations

Ever since it became illegal to dilute wine with water in ancient Greece and Rome, food laws and regulations have been instituted to protect the consumer. Thanks to public demand for legislation against contaminated foods, the U.S. food supply is among the safest in the world.

FEDERAL FOOD LAWS

From the Pure Food and Drug Act of 1906 (the Pure Food Law) to the FDA Food Safety Modernization Act of 2011, the U.S. government has been involved in regulating the country's food supply. One of the most important of these laws is the Federal Food, Drug, and Cosmetic Act, passed in 1938.

FOOD AND DRUG ADMINISTRATION

The Food and Drug Administration (FDA) is a branch of the Department of Health and Human Services.

The FDA:

- Enforces the Federal Food, Drug, and Cosmetic Act of 1938, which ensures that those products are safe, wholesome, and produced under sanitary conditions
- Regulates the production of all food involved in interstate marketing, with the exception of the USDA-regulated meat, poultry, and egg industries. This includes the following:
  - Inspecting facilities and manufacturing processes
  - Setting standards
  - Labeling
  - Regulating food additives
- Conducts research and educates the public about food and nutrition

U.S. DEPARTMENT OF AGRICULTURE

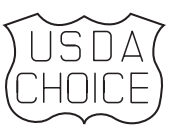
The U.S. Department of Agriculture (USDA) was first established to help farmers improve productivity and find new markets, reduce hunger, and inspect and grade farm products. Since then, its role has expanded tremendously.

The USDA inspects and grades:

- Meat
- Poultry
- Eggs
- Dairy products
- Grains
- Fruits and vegetables



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USDA Choice (Meat)



USDA A Grade (Poultry)



USDA A Grade (Eggs)



U.S. Grade No. 1 (Fresh fruits and vegetables)



USDA AA Grade (Butter)



USDA U.S. Extra Grade (Instant nonfat dry milk)

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) determines the safety of new pesticides and sets tolerance levels for pesticide residues in foods. Fresh fruits, vegetables, and grains, especially those from foreign countries, are continually inspected by the EPA for pesticide residues.

CENTERS FOR DISEASE CONTROL AND PREVENTION

The Centers for Disease Control and Prevention (CDC) has many functions related to preventing and controlling diseases, and one of them is to track outbreaks of foodborne illnesses across the country, determine their causes, and prevent their recurrence. State health departments report their data on such outbreaks to the CDC, which uses this information to conduct surveillance and to maintain records on a national scale.

OTHER REGULATORY AGENCIES

- **U.S. Department of Commerce (USDC):** The National Marine Fisheries Service within the USDC oversees the voluntary inspections and grading of fish and fish products, which are paid for by fish processing plants.
- **Federal Trade Commission (FTC):** The FTC maintains free and fair competition in the economy, and one method of achieving this goal is to protect consumers from false or misleading advertising.
- **Department of the Treasury:** The Bureau of Alcohol, Tobacco, Firearms and Explosives within the Department of the Treasury is responsible for enforcing the laws that regulate the production, distribution, and labeling of alcoholic beverages.
- **State Agencies:** Products made within a state often have to meet safety regulations unique to the state as well as federal regulations.

INTERNATIONAL AGENCIES

- The Food and Agricultural Organization (FAO)
- The World Health Organization (WHO)
- The European Parliament

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Which standards set by the FDA specify the amount of raw product that must be put into a container before liquid is added?
   a. Standards of Identity
   b. Standards of Fill
   c. Standards of Minimum Quality
   d. Standards of Recall

2. In order for the term *fat-free* to appear on a food label, the product must contain less than ___ grams of fat per serving.
   a. ½
   b. 1
   c. 2
   d. 5

3. On the Nutrition Facts label, the % Daily Value is based on a diet providing how many kcalories?
   a. 1,500
   b. 2,000
   c. 2,500
   d. 3,000

4. The amount of a food additive that can be safely ingested daily over a person's lifetime is called the _____.
   a. GRAS list
   b. Delaney Clause
   c. Acceptable Daily Intake
   d. safe quantity

5. One of the main jobs of the Centers for Disease Control and Prevention is to _____.
   a. inspect and grade farm products
   b. reduce hunger and malnutrition
   c. monitor food labeling
   d. track outbreaks of foodborne illnesses

6. The FDA defines a health claim as a statement that
   a. a food may be able to improve a specific health condition.
   b. a food, food component, or dietary supplement ingredient may reduce disease risk.
   c. is not well enough established to meet the significant scientific agreement standard.
   d. is supported by "significant scientific agreement."

7. "No additive shall be deemed safe if it is found to induce cancer when ingested by man or animal" is known as
   a. Good Manufacturing Practice (GMP) regulations.
   b. the Food Code.
   c. COOL.
   d. the Delaney Clause.

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. List the major government agencies responsible for food regulation.
2. What are the major food regulation responsibilities of the FDA?
3. Discuss the product recall process.
4. Define each of the following: *Standards of Identity, Standards of Minimum Quality,* and *Standards of Fill.*
5. The Fair Packaging and Labeling Act requires what information to be placed on food labels? What are the exceptions?
6. Describe the COOL requirements.
7. Define the following: *ADI, GRAS list,* and *Delaney Clause.*
8. Which government agency is responsible for grading? What foods are most commonly graded? Discuss the two types of grading.
9. What government agency is responsible for pesticide regulation?
10. The U.S. Department of Commerce is responsible for the inspection of what type of food?

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30



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Careers in Food and Nutrition

Three Major Food and Nutrition Areas 570
Nutrition Science and Dietetics 571
Food Science 577
Food Service 579
Graduate School 580

"What are you going to do when you graduate?" Many students select a major based on their career goal or their interest in a particular class. The majority change their major at least once before graduating. Deciding on a career is not only challenging but also stressful.

The purpose of this chapter is to assist students in exploring various career opportunities in food and nutrition. It provides an overview of various jobs in the food and nutrition field along with their respective curriculum requirements.

THREE MAJOR FOOD AND NUTRITION AREAS

There are three major branches in the food and nutrition field: (1) nutrition science and dietetics; (2) food science; and (3) food service (Figure 30-1). Each discipline has several different professional associations (Table 30-1). Each association has an annual convention meeting at which members network and learn the latest developments in their field; sponsors affiliates at the state level (each with its own yearly conventions and other meetings throughout the year); hosts a website; and most publish a journal. Dr. Lucia Kaiser, a nutrition professor at the University of California at Davis, advises students to "go to professional society meetings and find out what the professionals are doing." Related to food and nutrition are numerous food and beverage trade associations that can be found at www.careersinfood.com/food-and-beverage-trade-associations-resource-14.htm.

Depending on the size of the academic institution, these three areas of food and nutrition are represented by one major or by separate majors under entirely different departments. Not all universities offer degrees in all three academic areas, so sometimes a student must transfer to pursue a specific career choice. When making a decision on which university or college to attend, students should check the www.EatRight.org website to determine if a school has an "accredited" program (www.eatrightpro.org/resources/acend/accredited-programs/didactic-programs-in-dietetics) and consider location, price, program emphasis, faculty, job placement, and financial aid. The following sections further explain these three possible majors.

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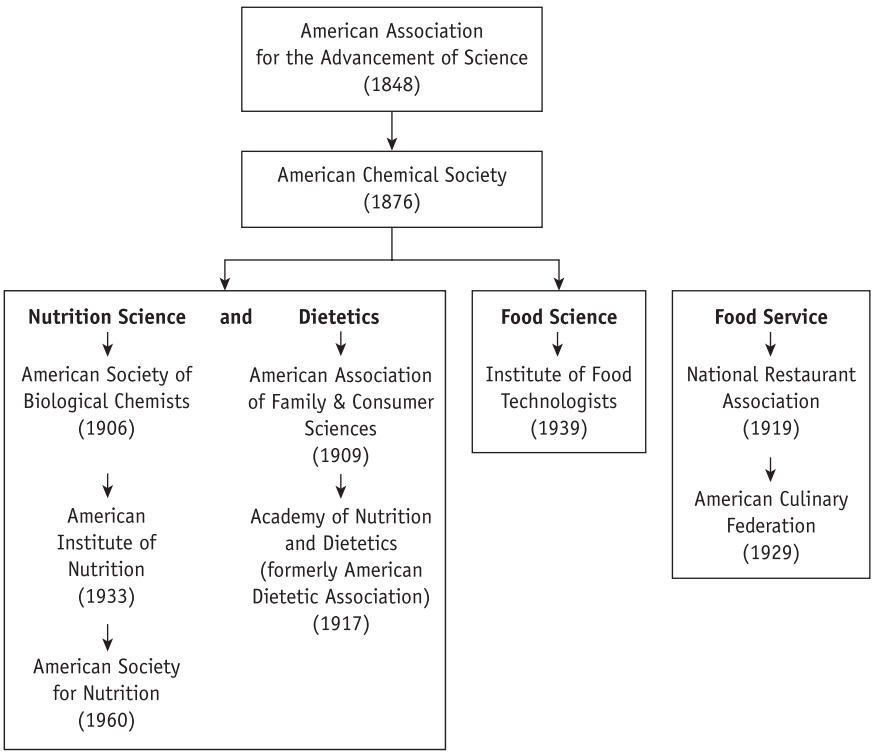
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TABLE 30-1 Selected Professional Associations in the Food and Nutrition Fields

Field	Professional Association*	Journal† or Books	Website†
Nutrition Science and Dietetics	Academy of Nutrition and Dietetics (AND)	*Journal of the Academy of Nutrition and Dietetics*‡	www.EatRight.org
	American Society for Nutrition (ASN)	*Journal of Nutrition* *American Journal of Clinical Nutrition*	www.nutrition.org
	American Clinical Board of Nutrition	(no journal)	www.acbn.org
	American College of Nutrition	*Journal of the American College of Nutrition*	www.americancollegeofnutrition.org
Food Science	Institute of Food Technologists	*Food Technology* *Journal of Food Science*	www.ift.org
	American Chemical Society	(see website—too numerous to list)	www.acs.org
	American Association of Cereal Chemists International	*Cereal Foods World*	www.aaccnet.org
	American Oil Chemists' Society	*Journal of the American Oil Chemists' Society* *Journal of Surfactants and Detergents Lipids*	www.aocs.org
Food Service	American Culinary Federation	(books on website)	www.acfchefs.org
	National Restaurant Association	(books on website)	www.restaurant.org
	Food Service Professionals Network	(books on website)	www.fspn.org
	International Association of Culinary Professionals	(books on website)	www.iacp.com
	Association of Nutrition and Foodservice Professionals	*Nutrition and Foodservice Edge*	www.anfponline.org
	Association for Healthcare Foodservice Research Chef Association	*S. O. Connected* *Culinology Book*	http://healthcarefoodservice.org www.culinology.org

*Student memberships are available.
†Job opportunities are often posted in back of the journal or on the website.
‡The journal has a section called "New in Review" that summarizes the major journal articles of interest to food and nutrition professionals; employment services or agencies that locate jobs; and courses that help you prepare for the registered dietitian nutritionist exam.

FIGURE 30-1 The three main categories in the food and nutrition field.



NUTRITION SCIENCE AND DIETETICS

Nutrition science focuses on what happens to *food in the body*. This science examines how nutrients break down, are absorbed, enter cells, react within a living system (biochemistry), and affect health through deficiencies and excesses and how **medical nutrition therapy** can be used to treat certain diet-related health conditions. Students pursuing

Medical nutrition therapy The provision of nutrition care in clinical settings to manage nutrition-related diseases such as heart disease, diabetes, cancer, renal disease, liver failure, and others. Registered dietitian nutritionists, RDN as part of the health-care team and often referred by a physician, contribute to the patient's care by providing this dietary therapy.

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a major in nutrition often have two options: (1) nutrition science and/or (2) dietetics. A strong scientific foundation is required for both career options.

Nutrition Science

The nutrition science emphasis prepares students for graduate school or professional school in the areas of nutrition, food science, medicine, dentistry, veterinary, physical therapy, pharmacy, physician's assistant, chiropractor, naturopathy, and other health-related professions (Table 30-2). Additional health careers include nursing, physician assistant, clinical psychologist (PhD, PsyD), licensed professional counselor (LPC), licensed clinical social worker, and many others found at https://explorehealthcareers.org/field/allied-health-professions. Related careers include medical writer (www.amwa.org) and medical illustrator (www.ami.org). See the section in this chapter on "Graduate School" for advanced degree information.

Nutritionist

The word *nutritionist* is a generic term that has no professional definition. Even a nutrition undergraduate degree by itself does not qualify a person to counsel patients about their diets. As a result, individuals with nutrition degrees from colleges or universities usually continue their education through a dietetic internship to become qualified as registered **registered dietitian nutritionist** or through graduate school to become nutrition or food professors, researchers, or extension agents.

Currently in the United States, only registered dietitian nutritionists are reimbursed by insurance companies through the referring physician's insurance code (8). Reimbursement practices are slowly changing for registered dietitian nutritionists, who can now be reimbursed directly for some medical conditions covered by Medicare (the federal health insurance program for patients who are 65 and older). However, some people pursue the nutritionist title and seek direct payment instead of third-party reimbursement (getting paid through an insurance company). Food and nutrition professionals can also obtain professional liability insurance.

The website www.quackwatch.org/04ConsumerEducation/nutritionist.html provides a more detailed explanation of the various routes of becoming certified as a nutritionist. Professionals generally accept the nutrition certification routes shown in Figure 30-2. According to the Quackwatch website, certain other nutrition "certifications" should be viewed skeptically as "Questionable Credentials."

Registered Dietitian Nutritionist (RDN; old term was registered dietitian, RD) A health professional who counsels people about their medical nutrition therapy (carbohydrate-controlled, low-fat, low-sodium, etc.). Registration requirements consist of completing an approved 4-year college degree, exam, internship, and ongoing continuing education. Categories include generalists, specialists, and advanced practitioners.

Nutrition care process A standardized process for providing high-quality nutrition care implemented by registered dietitian nutritionists (RDN) and nutrition dietetic technicians, registered (NDTR).

Dietetics

Three major career options are available in dietetics: registered dietitian nutritionist (RDN) (previously registered dietitian, RD) (title initials vary in Canada); nutrition dietetic technician, registered (NDTR) (previously dietetic technician, registered [DTR]); and dietary clerk (or dietary aide). Not every nutrition department has a dietetics program, and not every community college has a nutrition dietetic technician program accredited by the Accreditation Council for Education in Nutrition and Dietetics (ACEND) of the Academy of Nutrition and Dietetics (AND). Accredited programs can be found at www.EatRight.org/ACEND (click on "Accredited Programs" in the left column to see Coordinated and Didactic Programs in Dietetics to become a registered dietitian nutritionist and Nutrition Dietetic Technician, Registered Programs to become a dietetic technician). AND is over 100 years old with more than 100,000 credentialed practitioner members. Request their "Member's Benefits Guide" for a full listing of their extensive services (312-899-0040 or enter "Member Benefits" in the search box at www.EatRight.org). Valuable information for students about the dietetics field is available through this organization at www.eatrightpro.org/resources/career/become-an-rdn-or-dtr. The Career Center at this site offers assistance in finding scholarships, financial aid, mentors, and jobs.

Registered Dietitian Nutritionist (RDN)

Dietitians (dieticians) counsel people about diet (Figure 30-3). They help prevent and treat diet-related illnesses by promoting healthy eating habits, recommending dietary modifications through medical nutrition therapy, and supervising the preparation and serving of meals at hospitals and other institutions. They are encouraged to base client care decisions on the *Nutrition Care Manual* (www.nutritioncaremanual.org), *Pediatric Nutrition Care Manual, Sports Nutrition Care Manual,* and *Evidence-Based Nutrition Practice Guidelines,* which are clinical practice recommendations based on the latest research summaries (www.andeal.org). These resources are available to AND members, and the *Nutrition Care Manual* is sometimes available through libraries that purchase a subscription. It is also important for registered dietitian nutritionists to approach client care using the **nutrition care process** (NCP), which is a systematic problem-solving method (21), and to document the process within the medical record because "If it's not documented, it didn't happen" (5).

Academic Requirements

The Commission on Dietetic Registration (CDR) defines a registered dietitian nutritionist (RDN) as an individual who meets the following requirements:

1. Completed a degree from an Accreditation Council for Education in Nutrition and Dietetics (ACEND)–approved 4-year undergraduate program or its equivalent. A baccalaureate degree is recommended, but students may hold a different

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TABLE 30-2 American Medical Association's List of Allied Health Careers*

Accrediting Agency	Occupations	Website
Accreditation Council for Occupational Therapy Education (ACOTE)	Occupational therapist Occupational therapy assistant	www.aota.org/Education-Careers/Accreditation.aspx
Accreditation Review Commission on Education for the Physician Assistant (ARC-PA)	Physician assistant	www.arc-pa.org
American Association of Colleges of Pharmacy	Pharmacist Pharmacist technician	www.aacp.org
American Art Therapy Association (AATA)	Art therapist	https://arttherapy.org
American Board of Genetic Counseling (ABGC)	Genetic counselor	www.abgc.net
American Orthoptic Council (AOC)	Orthoptist	http://orthoptics.org/aoc
American Physical Therapy Association (APTA)	Physical therapist Physical therapist assistant	www.apta.org
Commission on Accreditation of Allied Health Education Programs (CAAHEP)	Anesthesiologist assistant Athletic trainer Cardiovascular technologist Cytotechnologist Diagnostic medical sonographer Electroneurodiagnostic technologist Emergency medical technician–paramedic Health information administrator Health information technician Kinesiotherapist Medical assistant Medical illustrator Ophthalmic medical technician/technologist Orthotist/prosthetist Perfusionist Respiratory therapist (advanced) Respiratory therapist (entry-level) Specialist in blood bank technology Surgical technologist	www.caahep.org
Accreditation Council for Education in Nutrition and Dietetics (ACEND)	Nutrition Dietetic Technician, Registered Registered Dietitian Nutritionist	www.EatRight.org/ACEND
Commission on Dental Accreditation (CODA) of the American Dental Association	Dental assistant Dental hygienist Dental laboratory technician	www.ada.org/en/coda
Commission of Opticianry Accreditation	Ophthalmic dispensing optician Ophthalmic laboratory technician	www.coaccreditation.com
Council for Accreditation of Counseling and Related Educational Programs (CACREP)	Community counselor Marriage and family counselor/therapist Mental health counselor Student affairs practitioner School counselor	www.cacrep.org
American Speech-Language-Hearing Association, and Audiology Foundation of America	Audiologist Speech–language pathologist	http://stats.bls.gov/ooh/Healthcare/Audiologists.htm www.asha.org www.audfound.org
Council on Rehabilitation Education	Rehabilitation counselor	www.core-rehab.org
Joint Review Committee on Education in Radiologic Technology (JRCERT)	Radiation therapist Radiographer	www.jrcert.org
Joint Review Committee on Educational Programs in Nuclear Medicine Technology (JRCNMT)	Nuclear medicine technologist	www.jrcnmt.org
National Accrediting Agency for Clinical Laboratory Sciences (NAACLS)	Clinical laboratory technician/med lab Tech-associate degree Clinical laboratory technician/med lab Tech-certificate Clinical laboratory scientist/medical Technologist Histologic technician/technologist Pathologists' assistant	www.naacls.org
National Association of Schools of Music (NASM)	Music therapist	https://nasm.arts-accredit.org

Contact individual schools to determine prerequisites that **differ among health careers.**

For a partial list of allied health profession careers, see https://en.wikipedia.org/wiki/Allied_health_professions.

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undergraduate degree or be enrolled in a graduate program. As long as they fulfill all the AND course requirements, they can receive a **verification form** by the dietetic program director (each program's approved courses vary slightly).
2. Been accepted to and completed a supervised practice program (internship; or this practical experience can be part of step 1 if the undergraduate degree is in the form of a Coordinated Program [CP] that includes the internship as part of the educational experience). A helpful e-book is *Getting Matched: A Guide for Dietetics Students*.
3. Passed the Registration Examination for Registered Dietitian Nutritionists. The four major exam areas as of 2017–2021 include I. Principles of Dietetics (25%), II. Nutrition Care for Individuals and Groups (40%), III. Management of Food and Nutrition Programs (21%), and IV. Foodservice Systems (14%). Specific topics under each of the these domains are listed at www.cdrnet.org/vault/2459/web/files/RDTestSpecs2017.pdf.
4. Pays the annual registration maintenance fee.
5. Stays updated through a Professional Developmental Portfolio (PDP) by accruing 75 hours of approved continuing professional education during every 5-year reporting period.

FIGURE 30-2 Nutrition certification routes.

American Society for Nutrition (ASN) (www.nutrition.org)

Previously called the American Institute of Nutrition. Open to individuals who have published meritorious nutrition research.

American Clinical Board of Nutrition (www.acbn.org)

People with graduate degrees (PhD, MD) can obtain certification in clinical nutrition (MDs only) or human nutritional sciences (MDs and PhDs). This board certification requires passing a comprehensive examination.

American College of Nutrition (www.americancollegeofnutrition.org)

Certified Nutrition Specialist (CNS) credential to those with an accredited master's or doctoral degree who also have clinical experience.

Without completing the preceding dietetics track, few individuals will find work in the area of dietary counseling. A professor stated, "I even know PhDs who could not find community work in nutrition because they lacked a dietetics background." She added that it is "better to get the right course work in graduate school, even if you do not plan to do an internship right away." A dietetics verification form opens more career doors.

Supervised Practice Programs

Internships provide supervised experience in a clinical setting that averages a year in length but can range from 6 months to 2 years. The longer or part-time programs often combine the experience with a master's degree. About 48% of all registered dietitian nutritionists hold a master's degree, and 4% go on to complete their doctorates (17, 18). Internships are competitive, so students need a strong grade point average (GPA) and three letters of recommendation. It also helps to have nutrition- or food-related work experience and extracurricular activities (student nutrition club, health fairs, nonprofit organizations, etc.). One way to gain experience is through www.allaccessinternships.com. The currently approved list of internships can be found at found at www.EatRight.org/ACEND (click on "Accredited Programs"). Students should be aware that the military also

Verification form Documentation provided by the dietetic program director to an individual who has completed the undergraduate AND course requirements approved by the AND for that particular academic institution. This form is required for (1) acceptance into an AND internship and (2) taking the AND examination.

Internships Corporate internships are temporary job positions (usually for 3 months during the summer or for 6 months, which includes a summer and a semester) in industry, government, or academia. Dietetic internships are supervised practice experiences that average 12 months (6 to 24 months).

FIGURE 30-3 Registered dietitian nutritionist assisting patient with dietary choices.



create jobs 51/Shutterstock.com

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offers internships through the U.S. Army and U.S. Air Force (see Military Careers under the "Useful Websites" listing). The U.S. Navy hires registered dietitian nutritionists, who enter the service as officers. All three branches require a minimum of 3 years of service, and if service is continued, the military offers excellent retirement packages (15).

Professional Developmental Portfolio (PDP)

After a person becomes a registered dietitian nutritionist, professional skills and registration are maintained through the accrual of Continuing Professional Education Units (CPEU). These are obtained by attending seminars, workshops, national AND meetings, academic course work, or other preapproved avenues (see www.EatRight.org) that are required to maintain registration. The Academy's largest annual conference in the fall, Food & Nutrition Conference Expo (FNCE), is a good way to load up on hours. Otherwise, registration requires that the profesional exam be retaken. To maintain registration, a registered dietitian nutritionist pays an annual registration fee to the AND (this is separate from the membership fee) and maintains a Professional Development Portfolio to accumulate 75 hours of continuing education units every 5 years (1). The Commission on Dietetic Registration website (http://cdrnet.org/pdp/professional-development-portfolio-guide) lists the five steps of the Professional Development Portfolio process used to record CPEUs.

A less formal way of staying up to date without CPEU credit is through the AND's "Daily News," a daily e-mail newsletter that lists the top food and nutrition news stories (12).

Types of Registered Dietitian Nutritionists

The three types of registered dietitian nutritionists are competent, proficient, and expert practitioners (3, 8).

A competent practitioner is a registered dietitian nutritionist who is starting practice (or practice within a new focus area) and may assume responsibilities across several areas of practice, such as clinical, administrative, community health, research, education, food and nutrition management, or consultation and business (private practice) (Table 30-3). Figure 30-4 shows the percentage of each type of registered dietitian nutritionist working in the field according to a survey by the AND (17).

A registered dietitian nutritionist may specialize in one or more particular areas of practice, become a proficient or expert practitioner, and obtain supplemental certifications. Examples of these specialties include the following:

- ***Board-Certified Specialist.*** Board-certified specialties can be obtained through the AND (www.cdrnet.org/certifications) in the following areas: Gerontological Nutrition (CSG), Obesity and Weight Management (CSOWM), Oncology Nutrition (CSO), Pediatric Nutrition (CSP), Renal Nutrition (CSR), and Sports Dietetics (CSSD).
- ***Certified Diabetes Educator (CDE).*** Registered dietitian nutritionists can become certified as specialists in counseling clients with diabetes by contacting the National Certification Board for Diabetes Educators (NCBDE) at www.ncbde.org (www.cdecb.ca for those in Canada).
- ***Certified Nutrition Support Clinician (CNSC).*** This specialization offered by the American Society of Parenteral and Enteral Nutrition (ASPEN; www.nutritioncare.org) is for parenteral (nutrition through a tube that enters the vein) and enteral feedings (nutrition through a tube that enters the gut).
- ***Certificate of Training.*** A certificate of training (which may or may not contribute to a specialty) can be obtained by participating in workshops on adult (www.cdrnet.org/weight-management-adult-program) and child/adolescent (www.cdrnet.org/weight-management-childhood-adolescent-program) weight management that are occasionally offered by the AND (not CDR).
- ***Dietetic Practice Groups (DPG).*** Registered dietitian nutritionists who specialize in an area can meet and network with other interested registered dietitian nutritionists by joining a DPG. AND lists them at www.EatRightpro.org.

Regardless of whether they have any of the preceding special certifications or DPGs, clinical registered dietitian nutritionists are considered "specialists" in one of the following areas if they devote more than 50% of their time to allergy management, bariatrics, cardiology, developmental disorders, diabetes, geriatrics, eating disorders, HIV/AIDS, oncology (cancer), psychiatric care, kidney (renal) disease, substance abuse, surgery, transplants, or weight management. Pediatric/neonatal nutrition and nutrition support are additional specialties. Advanced practitioners are registered dietitian nutritionists who have acquired an expert knowledge base in a more complex practice that often includes a master's or doctoral degree. Although the CDR does not offer any advanced-level certifications, an available option is to become Board Certified in Advanced Diabetes Management (BC-ADM). The American Association of Diabetes Educators (AADE; www.diabeteseducator.org) provides tools

How & Why?

How does a registered dietitian nutritionist work for the U.S. Public Health Service?

The U.S. Public Health Service (PHS) Commissioned Corps led by the U.S. Surgeon General is one of seven uniformed services of the United States (i.e., Army, Navy, Air Force, Marines, Coast Guard, and National Oceanic and Atmospheric Administration). Its mission is public health, not defense. RDs work in clinical or research settings; testing; inspection of food production facilities for the FDA and USDA; conducting research at the National Institutes of Health (NIH) and the Centers for Disease Control (CDC); coordinating nutrition programs for the Indian Health Services, Health Resources and Services Administration, Bureau of Prisons, and Centers for Medicare and Medicaid Services; developing national health and nutrition programs and dietary guidelines; and responding to public health emergencies (10). More information can be found at www.usphs.gov.

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TABLE 30-3 Types of Registered Dietitian Nutritionist Positions and Their Major Duties

Types of Registered Dietitian Nutrition	Employer Examples	General Duties
Clinical registered dietitian nutritionist	Approximately 77% of registered dietitian nutritionists work as clinical dietitians in hospitals, clinics, nursing homes, and rehabilitation. Federal registered dietitian nutritionist jobs can be found at www.usajobs.gov. The U.S. Army, Air Force, and Navy employ registered dietitian nutritionists (see Military Careers under the "Useful Websites" listing).	Responsible for meeting the nutritional needs of patients by providing regular diets or medical nutrition therapy (MNT) prescribed to patients by their physicians. Assess patients' conditions and nutritional needs, plan a nutrition therapy program, implement the plan, and evaluate the results (23).
Administrative or chief registered dietitian nutritionist	Same as above.	Responsible for the management of the nutrition department and/or food-service department of hospitals, schools, nursing homes, and prisons. Duties include supervising clinical and food-service registered dietitian nutritionist; formulating department policies; training; supervising kitchen personnel; coordinating menus; purchasing food, equipment, and supplies; and ensuring food safety and sanitation of the department.
Community (public health or international health) registered dietitian nutritionist	Primary employers are government organizations such as state or county health departments, cooperative extension agencies, the federal government, or international organizations such as WHO (www.who.int/careers/en) and FAO (www.fao.org/employment/en). Federal registered dietitian nutritionist jobs are listed at www.usajobs.gov. The American Overseas Dietetic Association is at www.eatrightoverseas.org.	Work in disease prevention and health promotion for the community. Projects include WIC (Women, Infants, and Children), cholesterol screening programs, hypertension awareness campaigns, Meals on Wheels, and elderly feeding programs. National nutrition programs can be found at http://fnic.nal.usda.gov (click on "Nutrition Assistance Programs").
Corporate registered dietitian nutritionist	Jobs exist in health care and food corporations, grocery chains, or specialized commodity boards (American Beef Council, Dairy and Nutrition Council, American Egg Board, etc.). Corporations can also hire registered dietitian nutritionists as sales representatives for their food products, pharmaceuticals, and dietary supplements.	Public relations, marketing and sales of food products, and nutrition consulting.
Private practice or consulting registered dietitian nutritionist	Self-employed registered dietitian nutritionists work independently and may contract with hospitals, clinics, nursing homes, physicians' offices, HMOs, day-care centers, schools, restaurants, sport teams,* and employee fitness programs.	Clinical nutrition or food-service management consulting. It helps to have hospital experience. An increasingly popular role for the registered dietitian nutritionist is as a "health coach" (14).
Research or teaching registered dietitian nutritionist	Registered dietitian nutritionists who have an advanced degree (doctorate) work for universities or medical schools (usually in the capacity of a professor), corporations (food or pharmaceutical), or the government (U.S Department of Agriculture, Food and Drug Administration, National Institutes of Health, etc.).	Research and/or teaching.

*Many students are interested in being a sports nutritionist, but few full-time positions exist. Consultant registered dietitian nutritionists are usually hired to provide nutrition guidance to teams and athletes, and not all teams hire registered dietitian nutritionists.

for "diabetes educators to help patients change their behavior and accomplish their diabetes self-management goals." The AADE is an accrediting body for diabetes education that provides "physician offices, clinics, pharmacies and community centers with a way to ensure that they are offering their patients comprehensive, effective diabetes self-management education." The International Association of Eating Disorders Professionals provides certifications (www.iaedp.com).

Licensure

The AND website warns that "The majority of states have enacted laws which regulate the practice of dietetics. Should you plan to practice dietetics in these states, it is important that you contact a state regulatory agency prior to practicing dietetics. In many states, it is a VIOLATION of state law to practice dietetics without a license." The agency contact information for each individual state is available at www.cdrnet.org.

Dietetic Technician, Registered (DTR)

Dietetic technicians, registered (DTRs), assist registered dietitian nutritionists (22). The official route to becoming a DTR involves completing an AND-approved program (www.EatRight.org). Three pathways are listed on the AND website for becoming a nutrition dietetic technician (2):

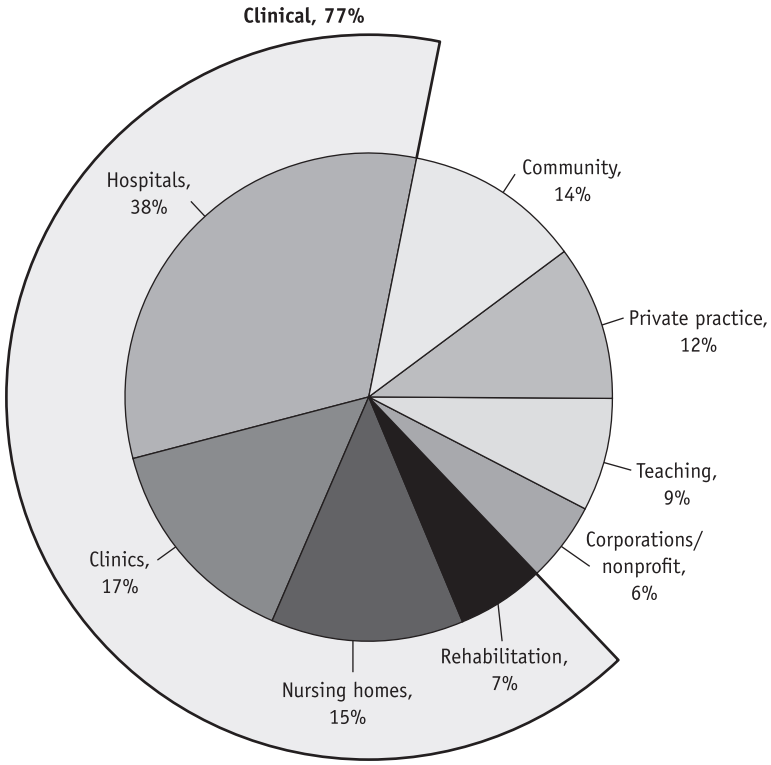
- Pathway I: A 2-year associate degree from an ACEND-accredited dietetic technician program. Many programs

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FIGURE 30-4 The percentage of registered dietitian nutritionists employed in various areas of dietetic practice.



(Totals exceed 100% because more than one choice was possible to respondents)

are offered through community colleges that offer a 2-year associate degree.
- Pathway II: A 4-year bachelor's degree (ACEND-accredited didactic program in dietetics) and completion of a supervised practice (accredited for dietetic technicians).
- Pathway III: A 4-year bachelor's degree (ACEND-accredited didactic program in dietetics) without the supervised practice.

However, despite the degree recommendation, some dietary technicians advance from entry-level dietary clerk positions without obtaining an official degree. Next, the individual passes the CDR Registration Examination for Dietetic Technicians and pays the annual registration maintenance fee. Fifty hours of CPEUs are required every 5 years to maintain registration.

Dietary Clerk or Dietary Aide

Dietary clerk or dietary aide jobs are entry-level positions, usually in a hospital dietary department. Students can often fill these entry-level positions to increase their experience and improve their chances of obtaining a dietetic internship. To locate these types of jobs, students can search the local newspaper or hospital human resources boards on the Internet or contact the hospital administrative registered dietitian nutritionist directly. Briefly explain that you are a student majoring in nutrition and that you are seeking experience in the form of either shadowing one or more registered dietitian nutritionists for a day, volunteering, working part time, or working full time during the summer. Sometimes these starter jobs lead to full-time positions. Ashorkor Tetteh, a person contemplating a career change, said, "Work experience has taught me that what a job entails on a day-to-day basis can turn out to be very different from what is initially imagined." To find a registered dietitian nutritionist to shadow, contact the nutritionist directly at local hospitals; go to www.diabeteseducator.org for certified dietetic educators or www.nutritioncare.org for a certified nutrition support registered dietitian nutrition; attend local or state AND meetings, and click the "Find an Expert" link at AND and its state dietetic associations at www.EatRight.org.

FOOD SCIENCE

Food science (food technology) focuses on *food outside of the body*. Students study food using the scientific disciplines of chemistry, biology, microbiology, mathematics, physics, and engineering. Specifically, food science determines the physical and chemical constituents of food and how these substances change during product development, production, processing, preservation, packaging, distribution, preparation, and storage.

Food Scientist

The majority of food scientists (food technologists) work in the food industry for corporations in their processing, ingredient, and/or manufacturing plants (Figure 30-5). Others work for the government (USDA, FDA), universities or colleges (professors or extension agents), or international agencies such as the Food and Agricultural Organization (FAO) and World Health Organization (WHO). Related occupations include but are not limited to food chemists, dairy scientists, and microbiologists.

If food science is your major, consider that major food companies are regionally located, so food scientists often relocate to the food corporation's headquarters, laboratory, or plant. Before graduating, Dave Gaidos, product manager for General Mills, selected his job by searching in the library to determine where the food companies were located.

Academic Requirements

To become food scientists, students graduate with a bachelor's degree in food science, food technology, or food engineering from a program listed with the Institute of Food Technologists (IFT) (for a list of IFT-approved food science programs, go to www.ift.org). Students with undergraduate degrees in nutrition or related areas may apply; even those with degrees in

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FIGURE 30-5 Food scientist working at a food corporation.



science photo/Shutterstock.com

TABLE 30-4 Selected Corporations Offering Summer Food Science Internships*

Campbell Soup Company
ConAgra
Dairy One
Frito-Lay
General Mills
Gorton's
Häagen-Dazs Company
H.J. Heinz Company
The International Food Network
Kellogg Company
Kraft Foods/Kraft Kitchens
M&M/Mars Incorporated
Nabisco
National Starch & Chemical Company
Nestlé
Pepperidge Farm
PepsiCo Incorporated
Pepsi-Cola Company
Pfizer Incorporated
Pillsbury Technology Center
Taco Bell
Unilever United States Incorporated
Warner-Lambert
International Internships are available at:
The International Association for the Exchange of Students for Technical Experience (IAESTA; www.iaeste.org)

*Seek out other internships by contacting the corporation.

Co-op Work-study program with a corporation that is often customized for the student.

unrelated areas may apply if they have completed the necessary prerequisite courses. When selecting either an undergraduate or a graduate school to attend, be aware that not all food science or nutrition programs offer the IFT-recommended courses; it is important to visit the IFT website for a list of qualified schools. Students often pursue graduate degrees in order to qualify for research, teaching, or management positions. The IFT also lists available jobs in the food industry that sometimes have higher salaries than those in other food and nutrition areas (12).

Graduates may apply to take the Certified Food Scientist (CFS) exam offered by IFT. This multiple-choice test has 100 items covering the areas of product development, quality assurance and control, food chemistry and food analysis, regulations, food microbiology, food safety, food engineering, and sensory evaluation and consumer testing.

Internship or Co-Op Experience

Food science students can improve their employment opportunities after graduation by completing an internship or **co-op** (Table 30-4). Students often find these opportunities through their food science department, recruiters visiting the campus (larger food science departments), or food corporations. A survey by the National Association of Colleges and Employers discovered that corporations offer jobs to about half of the students who complete an internship or co-op. Fellowships and scholarships are also offered by corporations and some food associations (see www.allfoodbusiness.com/national_assoc.php for a partial list of food associations). Lisa Pannell, food scientist in Product Development for General Mills, recommends an international internship. As a student, she received an internship in a Holland cheese factory by applying through the International Association for the Exchange of Students for Technical Experience (www.IAESTE.org).

Contacting Companies

Contact information for various corporations is available at www.hoovers.com, www.thomasnet.com, or, more specifically, www.thomasnet.com/products/food-products-30772305-1.html. *Food and Beverage Market Place* (www.greyhouse.com/food.htm) is a publication that lists food/beverage-related companies. Another related site is the Food and Consumer Products of Canada (www.fcpc.ca).

Types of Food Scientists

Once hired, food scientists often specialize in one or more of the positions listed in Table 30-5. A few tips from food scientists follow. Barbara Garter, the senior product development scientist at Kellogg Company, advises students not to "try and prove themselves to be all knowing, but rather develop skills in networking, collaborating, and teamwork to be really successful in the real world." For instance, she says, the important knowledge about food ingredients and how they function in foods was "learned on the job" and not in school. Food ingredient suppliers, she says, "were critical in helping me gain knowledge. Knowing who to call with technical questions is a very useful skill."

Carrie Yonts, corporate analytical chemist at the J.M. Smucker Company, stated that it is important for food chemists to have experience running equipment at food companies because "wet [liquid or bench] chemistry is used in college laboratories." She added, "Students should force themselves to become familiar with running the equipment and troubleshooting problems. Instrumentation knowledge is both practical and looks great on a résumé." Further information on food

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TABLE 30-5 Selected Food Scientist Positions in Food Companies

Food Scientist Position	General Duties
Research and development (R&D)	Formulate new food and beverage products, technologies, or manufacturing methods.
Food engineers	Focus on the process of producing new or existing food and beverages (process design, energy efficiency, product manufacturability, heat profiles, equations, mass balances, and process optimization).
Quality control (QC)/assurance	Ensure that food and beverages meet quality standards at each processing step. Sampling schemes, analytical methods, and statistical process/quality control.
Food microbiology/food safety	Test brand-new product lines for food safety at every step of production—new ingredients, sanitation on the line, and bacterial testing; plants must be compliant to GMPs, and meat and poultry Safety is addressed through HACCP.
Sensory evaluation specialist	Use consumer testing to determine whether consumers like the product. See Chapter 2 on food evaluation.
Flavor chemist	Ensure that food or beverage flavors are appealing to consumers and maintain their flavors through processing and storage.
Lab technician	Work in the lab with duties such as batching syrups, doing finished product checks (Brix, sulfuric acid content, etc.), micro testing of the water, etc.
Plant manager	Manage all aspects of plant operations and supervise employees.
Ingredient manager	Select ingredient vendors, make sure all vendors are following GMPs, and ensure the quality and food safety of ingredients.
Marketing and sales	Ensure that the food or beverage product is sold to pay for the corporate structure.
President/chief executive officer/general manger	Lead the food or beverage corporation; executive management.
University professor	Focus on teaching, research (grant writing and publishing), and service (committees, community presentations, etc.).
University extension specialist (land grant universities)	Communicate with and assist the public with research reported by university researchers.

science jobs can be found in *Careers in Food Science,* authored by Hartel and Klawitter (10).

Food Science Technician

Food science technicians assist food scientists in food development, quality control, laboratory research, food safety, and other aspects of food production. To become a food science technician, students obtain a 2-year degree from a community college or technical school listed on the IFT website.

FOOD SERVICE

A wide selection of careers is available in the food-service field, which deals with two basic areas: (1) management and (2) food preparation. As a result, the curriculum is either business based for the management side (restaurant management, lodging management, travel and tourism) or culinary based for the food preparation aspect of food service. This section focuses primarily on culinary education and professions.

Academic Preparation for Culinary Arts

Culinary institutes, cooking schools, and apprenticeships are three ways to obtain professional culinary training (Figure 30-6). Programs range from 2 months to 4 years in length, depending on whether a 4-year bachelor's degree, 2-year associate degree, or less-than-1-year diploma or certificate is awarded. Important factors to consider when choosing an educational option are accreditation, cost, student-to-faculty ratio, and placement rates. Location is also important as 4- and 2-year degrees are often offered by private institutions, community colleges, or hotel/restaurant management schools within a university. Many private schools teach food preparation. The American Culinary Federation (ACF) is considered the primary certification institution for culinary arts professionals. It offers fourteen levels of culinary certifications, including those for becoming a master chef (7). Its website at www.acfchefs.org lists accredited schools. Other listings of culinary/cooking schools can be found at www.allculinaryschools.com. Students should weigh the sometimes high tuition costs against the probability of obtaining an executive chef position. Lower-level food-service positions do not always pay as well as those higher positions.

- ***Culinary Institutes.*** These are the prestigious, very expensive educational routes toward becoming a certified culinary professional. Students may obtain a specialized degree in baking and pastry.
- ***Cooking Schools.*** Smaller versions of culinary institutes provide specialized training via a certificate or diploma. Many mainstream cooking schools and programs focus on French cuisine, but specializations for international cuisines can include Italian, Chinese, Japanese, Thai, and others.
- ***Apprenticeships.*** On-the-job training is available through numerous internships or apprenticeships for students who want to specialize in food service. The largest employers are food-service management companies. They offer internships throughout the year in finance and accounting, culinary arts, front office, and banquets/catering. The ACF lists more than forty apprenticeship programs by state at www.acfchefs.org.

Types of Food-Service Positions

Major culinary positions include those of chef, food-service manager, sales and marketing representative, and dietary manager. These and other positions are

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FIGURE 30-6 Culinary jobs provide careers for those interested in food preparation.



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covered in more detail in books such as *Food Jobs* by Ireana Chalmers (6) and *Culinary Careers* by Rick Smilow and Anne McBride (20).

Chef

Chapter 6 on meal management describes the different types of administrative (executive, production manager, or sous chef) and cook (sauce, fish, vegetable, soup, roast, broiler, pantry, pastry, and relief) positions in a food-service organization.

Food-Service Manager

A business-based degree from a business or hotel and travel school assists graduates in preparing for jobs as food-service managers in several venues—restaurants, hotels, catering, schools, universities, and the travel industry (air, train, ship).

Sales and Marketing

One of the jobs available to graduates is as a sales representative for food equipment and food products. Ray Kroc, founder of McDonald's, started as a sales representative selling cups and then milk-shake mixers to restaurants.

Dietary Manager

Dietary managers work for institutions that serve food, specifically hospitals, nursing homes, other health-care facilities, correctional institutions, and schools. Students can become dietary managers by enrolling in certain community college programs that vary in length from 12 to 18 months. The Association of Nutrition and Food-service Professionals (ANFP) (www.anfponline.org) offers certificates to students meeting the requirements to become Certified Dietary Managers (CDM). Lists of ANFP-approved programs (schools) are available at www.anfponline.org/become-a-cdm/anfp-approved-programs.

After finishing the program, students must pass an examination and apply for a certification through the Certifying Board of Dietary Managers. To maintain certification, graduates obtain 45 hours of CPEUs every 3 years.

Food-Service Certifications

Several certifications are available in the culinary field, including the following (19):

- Certified Culinary Professional (CCP) (www.iacp.com)
- Foodservice Management Professional (FMP) (https://managefirst.restaurant.org)
- School Nutrition Specialist (SNS) (https://schoolnutrition.org)
- Certified Culinarian (CC) (www.acfchefs.org)
- The Research Chefs Association (RCA) (www.culinology.com) includes chefs, food scientists, salespeople, and other food professionals interested in the development of new products and services (9). RCA has sixteen culinology programs within various universities and colleges and offers two certifications: Certified Research Chef (CRC) and Certified Culinary Scientist (CCS).

GRADUATE SCHOOL

A professor from one of the top nutrition graduate schools said, "Many students have little vision of why they are in graduate school, but they score well on their **GREs** and have good undergraduate GPAs." It's important to hone your career goal and plan accordingly. In addition, if you are planning to do research in graduate school, it's a good idea to research the different graduate schools. *Peterson's Guide to Graduate Schools* and similar publications (and related websites) list graduate schools by discipline, location, cost, number of students accepted, number of graduates, and other pertinent information helpful to applying students (4). Both the AND and the IFT also list graduate schools on their websites. You can also e-mail a specific department's chairperson to locate the chair of the department's graduate program and the student president of the graduate club. International students can find contacts by getting in touch with the international club on campus.

Prerequisites

You do not always need an undergraduate degree in dietetics, nutrition science, or food science to be accepted into a graduate school program. However, certain courses are usually required for admittance to individual graduate

GRE The Graduate Record Examination®; a general test that measures verbal reasoning, quantitative reasoning, critical thinking, and analytical writing skills.

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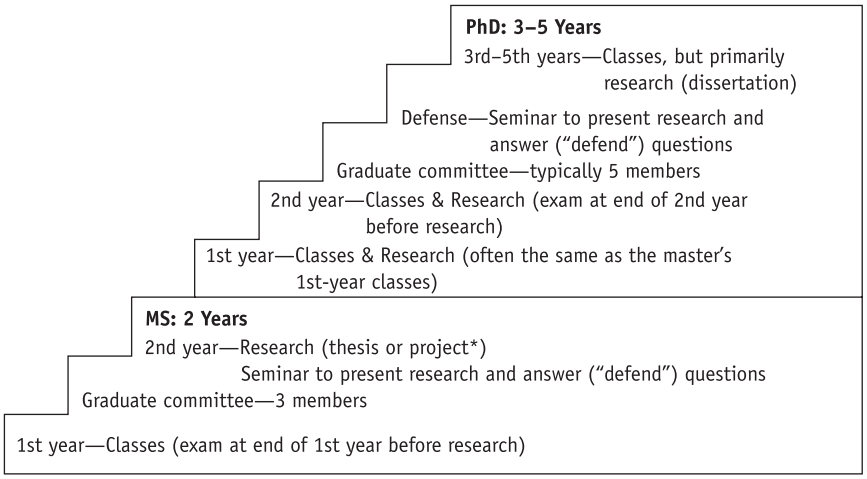
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programs, and it is up to you to determine whether those prerequisites have been met. Once in graduate school, many nutrition majors take undergraduate dietetic classes to qualify for the verification form so that they may apply for an internship and become a registered dietitian nutritionist. Sometimes 400-level (senior-level) courses apply to a graduate degree that usually consists of 600- to 700-level courses. It is also possible for students to pursue a master's degree while they take dietetics courses.

Academic Requirements

In general, a master's degree in nutrition takes an average of 2 years to complete, and a doctorate takes 3 to 5 years (Figure 30-7). Research conducted by students is called a "thesis" for master's candidates and a "dissertation" for doctoral candidates. The length of the doctoral degree program depends on the university, the individual's undergraduate degree (it does not have to be food or nutrition), and whether or not the student stayed in the same school for his or her degrees (BA, BS, MA, MS, PhD). Students apply to both the graduate school of a university and their desired department through the chair of the graduate program. Many schools, but not all, require that the student seek out and be accepted by a major professor (with or without funding) prior to being accepted into the department. If accepted into a department, graduate students may apply for teaching or research assistantships (TA or RA, respectively). If available, these jobs are 20-hour-a-week positions assisting faculty in either teaching or research. They are recommended for students interested in becoming professors and/or those needing financial assistance. If the school enrollment deadline is missed, or the student is not sure what major to select, he or she can enroll as an "unclassified" graduate student at some, but not all, universities.

FIGURE 30-7 General steps toward obtaining a master's or doctoral degree in food or nutrition sciences.



*Projects are expanded term papers allowing students to enroll in more courses. They are not recommended for graduate students wishing to pursue careers in research or teaching.

Examination Requirements

Graduate and professional schools often require that individuals interested in applying take the GRE® (www.ets.org). The biggest mistake that undergraduate students make is not planning far enough ahead so they can take the exam in time for the results to be submitted before the application deadline for their chosen post-baccalaureate program. However, the GRE® is also available year

CAREER CORNER

Dr. Liz Applegate was both a biochemistry major at the University of California at Davis (UC Davis) and a professional triathlete with sponsors when people started asking her questions about sports nutrition. *Runner's World* contacted her to write a monthly column. She had her first child the same year that she received her doctorate (PhD). "If you want to be a sports nutritionist," she says, "get a master's degree with the registered dietitian nutritionist qualification or a doctoral degree because then you will have a university affiliation."

The university formalized what she was doing into a joint position—teaching in the Department of Nutrition and holding the position of Director of Sports Nutrition in the Department of Intercollegiate Athletics. She was also the sports nutritionist for the Sacramento Kings and the Oakland Raiders sports teams.



Dr. Liz Applegate

Dr. Liz Applegate, Senior Lecturer/Sports Nutritionist/ Entrepreneur

Liz feels that she was contacted to hold the nutritionist positions because of her public appearances and writings, and the well-respected reputation of UC Davis. If she had it to do over again, she "would go back and take more English and journalism courses, any courses dealing with communication—oral or written." She is the keynote speaker at scientific, industry, and athletic meetings; is the author of six nutrition-related books (including a textbook) and over 300 articles for national magazines; and has been a guest on more than 200 international, national, and local radio and television shows, including Good Morning America and CNN and ESPN programs.

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round at certain computer-based test centers. Professional schools all have their own individual exam requirements, such as the Medical College Admission Test (MCAT®). Foreign students will need to submit their **Test of English as a Foreign Language (TOEFL®)** scores (www.ets.org).

Professional Schools

An undergraduate degree that includes the proper prerequisites can be used to apply for professional schools—medical, dental, veterinary, physical therapy, pharmacy, psychotherapy, and others. Students must complete the recommended prerequisites for these schools, which are often listed on their websites or may be obtained from an adviser specializing in this field. Premedical and other professional student clubs are recommended for students.

Naturopathic schools are another option, but students should verify that the school is accredited (https://aanmc.org/naturopathic-schools), as there are many "schools" that are not. Note that only certain states license naturopathic practitioners. The American Naturopathic Medical Association (www.anma.org) provides more information.

Graduate-Degree Jobs

Researcher

Many graduate students think they will be researchers upon graduation because that is their main focus in graduate school. The larger food companies and certain government agencies do hire food and nutrition researchers (usually PhDs); however, university research is conducted primarily by professors. Research positions at universities that are not affiliated with a teaching position are often supported by "soft" money. This means that the employee must obtain grants to keep the position open. Grant funding success rates often range from 15 to 30%. If asked, funding agencies often disclose the percentage of grant applications they receive that are funded.

Summer internship programs in biomedical research (clinical research) for students are offered at the National Institutes of Health, the number-one federal government agency funding health-related research (see www.training.nih.gov/programs). Students interested in becoming researchers may want to determine which principal investigator they would like to work under before applying to graduate schools. This advice also holds true for students who want to become professors; however, many other factors are important when choosing a graduate school.

FIGURE 30-8 Professors usually obtain doctoral degrees to teach at colleges and universities.



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Professor

To become a professor, many (but not all) individuals complete postdoctorate programs to gain more experience before applying for teaching and/or research positions at colleges and universities. Most 4-year universities and colleges hire individuals with doctoral degrees for **tenure track** positions. Those with master's degrees are sometimes hired as instructors or for part-time positions at universities or as professors at community colleges, although the trend is toward hiring candidates with doctoral degrees. Professors focus on teaching, research, and service for their advancement (Figure 30-8). In terms of research, they must be skilled at grant writing, procuring funding, and conducting and publishing research. The number of papers published in peer-reviewed journals (top-tiered journals are preferred), student-evaluation scores, and community service (speeches, committee work, etc.) are also important when a person is reviewed for promotion.

It is highly recommended that the new faculty member focus on a particular research subject (preferably, but not necessarily, their graduate research topic) to create a series of publications that builds their expertise and support for future funding and tenure. New faculty members are encouraged to apply for tenure-track positions and to find a mentor. Established researchers may allow them to join in on research projects in order to add their names to grants and research articles as a coinvestigator and coauthor. The mentor could also teach the new faculty member university politics, a learned skill whose importance should never be underestimated.

Test of English as a Foreign Language™ (TOEFL) A test that measures the ability of nonnative speakers to understand English as it is spoken, written, and heard in colleges and universities.

Tenure track The process in which new faculty members are hired as assistant professors and are on probation for approximately 5 years. If their yearly contract is renewed for 5 years in a row based on satisfactory performance, they may apply for tenure (permanent hire) and promotion to associate professor. The next and final step is promotion to full professor.

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TABLE 30-6 Estimated Salaries for Various Jobs in Dietetics, Food Science, and Food Service

Position	Median Salary	Salary Range
Dietetics		
Administrative registered dietitian nutritionist (department supervisor)	$70,157	$58,931–$81,382
Registered dietitian nutritionist (RDN)	$64,000	$53,361–$76,548
Nutrition and dietetic technician, registered (NDTR)	$41,089	$29,509–$453,078
Dietary clerk	$27,831	$22,625–$35,821
Food Science		
Food scientist	$68,249	$42,289–$96,613
Food chemist (with PhD)	$80,391	$58,450–$105,077
Research and product development	$77,812	$63,500–$86,000
Quality control/assurance	$84,500	$52,260–$94,950
Marketing and sales	$105,000	$85,000–$115,000
Food Service		
Executive chef	$68,227	$45,484–$101,813
Pastry chef	$48,292	$37,552–$88,157
Sous chef	$42,645	$25,591–$63,066
Line cook	$21,952	$15,908–$31,317

Source: Adapted from Salary.com, accessed on 9/25/12; Ward B. Compensation and benefits survey 2011: moderate growth in registered dietitian and dietetic technician, registered, compensation in the past 2 years. Journal of the Academy of Nutrition and Dietetics 112(1):29–40, 2012; 2011 IFT Membership Employment & Salary Report; and www.cbsalary.com.

How & Why?

How do I find research articles for my papers?

Research articles can be found online through two major indexing websites in the field of food and nutrition: (1) PubMed (www.pubmed.gov) provides free access to MEDLINE, a listing of medical health abstracts provided by the U.S. National Library of Medicine; and (2) Food Science and Technology Abstracts® (FSTA), which is the world's largest database of information on food science. It is available through subscription, usually paid for by certain university libraries. Full access to PubMed articles is also paid for by libraries. Both undergraduate and graduate students should be familiar with both resources for writing their research papers.

Salary is another important factor to consider when choosing a career. Table 30-6 lists estimated median salaries along with their high and low ranges. As with any profession, salaries vary by reporting year, region, academic degree, length of employment (entry level, midcareer, late career), scope of responsibility and supervision, company size, and number of people in the field. Medical and pension plans may or may not be available from an organization, and this should be considered as part of the overall salary package.

Pharmaceutical and Nutraceutical Industries

Individuals with food and nutrition degrees can also work for pharmaceutical or nutraceutical companies that produce and sell drugs, food products, or dietary supplements (vitamins, minerals, herbs, etc.). Students can potentially create connections with people in these industries through the following:

- Internships
- Networking at industry conferences
- Natural Products Association via www.npainfo.org
  - Expo East & West (www.naturalproductsexpo.com); three national conferences occur each year—the largest is in the West (spring)—along with one in the East (fall) and one held internationally
- Reading top trade journals
  - *Nutraceuticals World* (www.nutraceuticalsworld.com)
  - *Nutrition Industry Executive* (www.niemagazine.com)
  - *Nutrition Today* (http://journals.lww.com/nutritiontodayonline/pages/default.aspx)
  - *Prepared Foods* (www.preparedfoods.com)
  - *Functional Ingredients Magazine* (http://newhope.com/functional-ingredients)
- Being active on industry trade websites
  - www.NewHope.com
  - www.FoodNavigator.com
  - www.NaturalProductsInsider.com
  - www.NutritionalOutlook.com
  - www.Nutraingredients-USA.com

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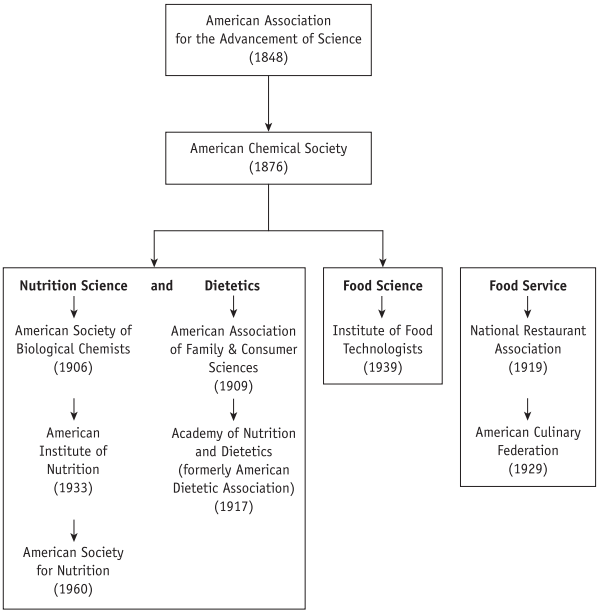
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PICTORIAL SUMMARY / 30: Careers in Food and Nutrition

THREE MAJOR FOOD AND NUTRITION AREAS

There are three major categories for food/nutrition careers: nutrition science and dietetics, food science, and food service.

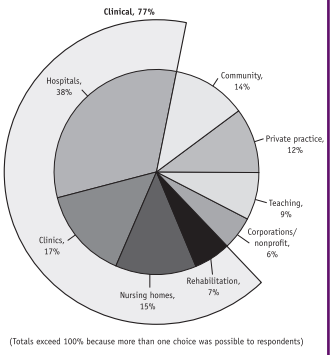


NUTRITION SCIENCE AND DIETETICS

Nutrition science focuses on what happens to food in the body. This science looks at how nutrients break down, are absorbed, enter cells, react within a living system (biochemistry), and affect health through deficiencies and excesses, as well as how medical nutrition therapy can be used to treat certain diet-related health conditions.

Jobs in Nutrition Science and Dietetics

- **Graduate or professional school.** The nutrition science emphasis prepares students for graduate school or professional school in the areas of nutrition, food science, medicine, dentistry, veterinary science, physical therapy, pharmacy, physician's assistant practice, chiropractic, naturopathy, and other health-related professions.
- **Nutritionist.** The word "nutritionist" is a generic term that has no professional definition.
- **Registered dietitian nutritionist (RDN) (dietitians or dieticians).** Health professionals that counsel people about diet; reduce dietary risk factors for various diseases, and treat illnesses by recommending dietary modifications through medical nutrition therapy. Types of registered dietitian nutritionists include clinical, administrative, community health, research, education, and private practice.



(Totals exceed 100% because more than one choice was possible to respondents)

- **Nutrition dietetic technicians, registered (NDTR).** These professionals assist registered dietitian nutritionists (RDN).
- **Dietary clerk or aide.** These jobs are entry-level positions usually located in a hospital dietary department.

FOOD SCIENCE

Food science (food technology) deals with food outside of the body. Specifically, food science determines the physical and chemical constituents of food and how these substances change during product development, production, processing, preservation, packaging, distribution, preparation, and storage.

Jobs in Food Science

Jobs in food science include but are not limited to flavor chemist, lab technician, plant manager, ingredient manager, marketing and sales representative, upper-level manager (president, CEO, general manager), and university professor or extension specialist.

- **Food scientist.** The majority of food scientists (food technologists) work in the food industry for corporations in their processing, ingredient, and/or manufacturing plants. Others work for the government (USDA, FDA), universities or colleges, or international agencies (FAO, WHO).
- **Food science technicians.** They assist food scientists in food development, quality control, laboratory research, food safety, and other aspects of food production.

FOOD SERVICE

A wide selection of careers is available in the food-service field, which deals with two basic areas: (1) management (restaurant management, lodging management, travel and tourism), and (2) culinary arts (the food preparation aspect of food service). Culinary institutes, cooking schools, and apprenticeships are three ways to obtain professional culinary training.

Jobs in Food Service

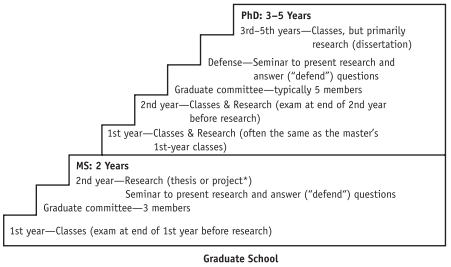
- **Chef** (administrative and various food-service stations)
- **Food-service manager**
- **Dietary manager**
- **Sales and marketing representative**

GRADUATE SCHOOL

In general, a master's degree in nutrition takes an average of 2 years to complete, whereas a doctorate usually takes 3 to 5 years. Students may also pursue professional degrees—medical, dental, veterinary, physical therapy, and etc.

Jobs after Graduate School

- **Researcher.** Larger food companies and certain government agencies hire food and nutrition researchers (usually PhDs); however, university research is conducted primarily by professors.
- **Professor.** Professors focus on teaching, research, and service for their advancement.
- **Pharmaceutical and nutraceutical industry jobs.** The diverse positions in these two major fields can sometimes be filled by graduates with food and nutrition degrees.



*Projects are expanded term papers allowing students to enroll in more courses. They are not recommended for graduate students wishing to pursue careers in research or teaching.

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CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The majority of registered dietitian nutritionists are employed within a _____ setting.
   a. school
   b. private practice
   c. community
   d. clinical

2. One of the major professional associations established for food scientists is the _____.
   a. Academy of Nutrition and Dietetics (AND)
   b. Institute of Food Technologists (IFT)
   c. American Culinary Federation (ACF)
   d. Foodservice Professionals Network (FPN)

3. The job of ensuring that foods and beverages meet quality standards at each processing step is the responsibility of the _____.
   a. plant manager
   b. quality control department
   c. sensory evaluation specialist
   d. lab technician

4. A person who specializes in counseling people about diabetes is called a _____.
   a. registered dietitian nutritionist RDN
   b. certified diabetes educator CDE
   c. food counselor
   d. community nutrition specialist

5. The research paper completed by a doctoral candidate is called a _____.
   a. dissertation
   b. thesis
   c. research project
   d. defense

6. One of the major professional associations established for food-service positions is the _____.
   a. Academy of Nutrition and Dietetics (AND)
   b. Institute of Food Technologists (IFT)
   c. American Culinary Federation (ACF)
   d. Foodservice Professionals Network (FPN)

7. Culinary training is available through
   a. the Academy of Nutrition and Dietetics.
   b. certifications.
   c. culinary institutes, cooking schools, and apprenticeships.
   d. the Institute of Food Technologists.

*See Appendix F for answers to multiple-choice questions.

Short Answer/Essay

1. Define the three major career areas in food and nutrition.
2. How would a student pursue a career in dietetics?
3. How would a student pursue a career path in food science?
4. What are the general steps for pursuing a graduate degree?
5. List some of the jobs available to food science graduates.
6. List and briefly define the different types of registered dietitian nutritionists.
7. List and briefly define the different types of culinary certification.
8. Explain some of the specializations available to registered dietitian nutritionists.
9. What is a nutritionist?
10. How does the academic preparation of a nutrition and dietetic technician, registered, differ from that of a registered dietitian nutritionist?

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Appendixes

A: Food Preparation Equipment **A-1**
B: Food Yields **B-1**
C: Substitution of Ingredients **C-1**
D: Flavorings and Seasonings **D-1**
E: Common Food Additives **E-1**
F: Answers to Multiple-Choice Questions **F-1**

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Appendix A: Food Preparation Equipment

Appendix A provides a brief overview of food preparation equipment—primary equipment, auxiliary equipment, and utensils.

PRIMARY EQUIPMENT

Primary equipment consists of ranges, ovens (conventional, convection, and microwave), refrigerators, and usually dishwashers.

Ranges (Stove Tops)

Ranges can have open or flat-top surfaces with electrical or gas burners (Figure A-1). Gaining in popularity are induction cooktops.

Ovens

The conventional oven is an enclosed space located below the range, but it can also be a separate unit (Figure A-2).

FIGURE A-1 Ranges.



iStock.com/Fedor Kondratenko

Open top



Jupiterimages/Getty Images

Flat top

Primarily used for baking and roasting, they are also used for braising, poaching, and simmering.

Ovens rely on hot air for heating food, primarily by convection, but conduction and radiation can also occur.

Baked foods rely on freely moving currents for the transfer of heat, so it is important to ensure that baking pans are placed on the racks in such a way as to allow the efficient flow of air currents. Figure A-2 shows some of the types of ovens that are available to food-service establishments as described here:

FIGURE A-2 Three types of ovens.



John Cooper/Alamy Stock Photo

Conventional oven



iStock.com/Adrian beesley/Onfilm

Double-deck convection oven



Courtesy of Vulcan-Hart

Convection oven

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- **Stack or deck oven.** Each component of the stack has a separate thermostat.
- **Convection oven.** Hot air is circulated by a fan, baking contents more quickly.
- **Revolving or carousel oven.** Trays rotate like a Ferris wheel, ensuring even temperature distribution.
- **Impingement oven.** Hot-air jets heat food more quickly (5).
- **Infrared oven.** Heat is generated by a very hot infrared bulb.
- **Brick-lined, hearth, or wood-bearing ovens.** Can heat to extra-hot temperatures creating better tasting and crusted baked breads and pizzas.
- **Pizza oven.** Reaches very hot temperatures to bake pizza.
- **Microwave oven.** Heats or warms foods within minutes.

Refrigerators/Freezers

The proper refrigeration and freezing of foods is one of the most important factors in preventing foodborne illness. Refrigerator temperatures should be maintained at or below 40°F (4°C), and freezers or freezer compartments at 0°F (−18°C). Household refrigerators are classified by the location of the freezer—above, below, or beside the refrigerator section (Figure A-3). Food-service establishments usually have a walk-in refrigerator and freezer, which may range in size from a small closet to a large room. Other types of freezers/refrigerators include reach-ins, roll-ins, and pass-throughs (Figure A-4).

FIGURE A-3 Refrigerator-freezers..



One-door, freezer compartment inside



Freezer below food compartment



Freezer above food compartment



Side-by-side refrigerator/freezer

FIGURE A-4 Food-service refrigerators and freezers.



Victory Refrigeraton

Reach-in



Courtesy of Victory Refrigeration, part of AFE

Walk-in



Courtesy of Victory Refrigeration, part of AFE

Roll-in

Dishwashers

The two categories of dishwashers are household dishwashers and commercial dishwashers.

The three basic types of household dishwashers are as follows:

- **Built-in dishwasher.** Integrated under the counter to match the cabinets.
- **Portable dishwasher.** Used by attaching the hoses to the kitchen faucet; one hose drains into the sink.
- **Convertible dishwasher.** Used as a portable or installed permanently as a built-in.

Commercial or food-service dishwashers are so large that they often require a separate room.

Equipment Standards and Safety

NSF. The National Sanitation Foundation (NSF) seal of approval assures buyers of food-service equipment that certain standards of sanitation and safety have been met in its design and production. This nonprofit organization is interested in the promotion of public health and has established minimum standards of construction for food-service equipment (3). Information about equipment or approved manufacturers can be obtained by searching at www.nsf.org/Certified/Food (or by e-mailing info@nsf.org).

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UL. Another private organization overseeing the safety of electrical equipment is the Underwriters Laboratory (UL), which ensures that an electrical appliance, cord, or plug has passed certain tests for electrical shock, fire, and other related injuries (6).

AUXILIARY EQUIPMENT

In addition to the primary equipment in a kitchen, auxiliary equipment includes griddles, tilting skillets, broilers, grills, steamers, deep fryers, woks, crockery, cutting equipment, mixers, and coffee/tea makers.

Griddles

Griddles supplement range units. Their larger, flat, smooth surfaces are ideal for preparing eggs, hamburgers, pancakes, French toast, and hash browns (Figure A-5). Food-service griddles contain a drip cup to collect draining fat. Preparation is easier when grill surfaces are primed by smearing them with oil followed by a brief heating. To maintain the primed surface, griddles are never washed with soap and water, but scraped clean, wiped with a grease mop, and then polished with a soft cloth.

Tilting Skillets

Found only in large food-service operations, the tilting skillet, brazier, or fry pan can be used to make anything from chili to poached eggs. The wide range of temperature settings stretches from low braising to high frying heats. As a result, it can be used as a fry pan, brazier, griddle, stockpot, steamer, or steam table. The entire skillet can be tilted to pour out liquid-based contents (Figure A-6).

FIGURE A-5 Griddle.

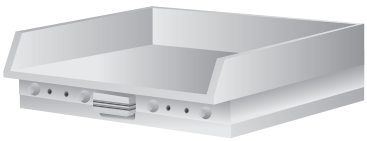


FIGURE A-6 Tilting skillet.



The Groen Co/Unified Brands

Broilers and Grills

The difference between broiling and grilling is the heat source: the broiler's heat is above the food, whereas the grill's is below the food. Temperature control is achieved by moving the grid up or down. Heat may be provided by wood, charcoal, electricity, or gas.

Steamers

The two basic types of steamers used in food-service organizations are cabinet or compartment steamers and steam-jacketed kettles (Figure A-7).

- **Cabinet steamers.** Stacked one above the other with the door of each sealed tight with clamps.
- **Steam-jacketed kettles.** Used more for fluid-type foods such as stocks, soups, stews, and custards. They range in size from 1 quart to 200 gallons. The steam is not generated inside the kettle but is circulated between the double-layered metal plates of the kettle's outer shell. A handle is used to tilt the entire steam-jacketed kettle to pour out the food.

Steam heats foods by moist heat. Most steamers in a food-service establishment steam under pressure, which is measured by a gauge in pounds per square inch (psi). Pressure steamers allow food to heat to temperatures higher than boiling, which decreases cooking time. Vegetables can be cooked at pressures of 10 to 15 psi, reaching a temperature of 250°F (120°C). Lower pressures and temperatures (5 to 10 psi, 225°F [105°C]) are used to cook meats, which would fall apart at the higher pressures required for vegetables. Cooked vegetables and even some fish maintain their texture, color, taste,

FIGURE A-7 Food-service steamers.



Cabinet steamer Steam-jacketed kettle

The Groen Co./Unified Brands

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and nutrients best when they are properly steamed or microwaved. Rice, pasta, poultry, eggs, fish, and shellfish may also be steamed, but the flavor of meats and poultry will usually be diminished by the process.

Safety is particularly important with steamers. They should never be run without water, and they should be periodically checked to ensure that safety valves are working. They should never be opened until the pressure has gone down, and then they should always be opened away from the face.

Deep Fryers

Breaded fish and vegetables, fried chicken, and French fries are some of the foods commonly prepared in deep fryers. Frying is similar to boiling, except that in frying the liquid is fat, which can reach higher temperatures than water. Food is loosely placed in a wire basket, which is then submerged in heated oil. When the food floats to the top of the oil, it can be considered cooked. The basket is then removed and set aside so that the oil can drain from the food. The fryers themselves may be small enough to be portable or so large that they are floor mounted (Figure A-8). Most deep fryers have automatic heat controls.

Woks

This large bowl-shaped pan is central to Chinese cooking. It comes either (1) equipped with a metal ring to fit over a range burner (Figure A-9), or (2) self-contained with an electrical cord. The most time-consuming step in using a wok is cutting the foods into many small, uniform pieces. The actual cooking of the foods is a quick process, lasting approximately 5 to 10 minutes. It starts with high heat under the wok, which has been lightly coated with oil (usually sesame or peanut oil). The foods that take the longest to cook are added first. The food is stirred rapidly for a few minutes, for even cooking, and then the heat is lowered and the pan covered so the steam thus generated can complete the process.

FIGURE A-8 Deep fryer.



© Frymaster, LLC, 8700 Line Ave., Shreveport, LA 71106.

FIGURE A-9 Wok.



Crockery

Crockery, or electric slow cookers, have been popular for some 40 years and are particularly good for moist-heat cooking of meat and legumes. Crockery cooking is long and slow, with controlled heat that needs little or no supervision. A meal started in the morning will be ready to eat by dinnertime. Because there is some evidence that crockery may not keep food sufficiently hot for the entire duration of cooking, its use has lately been discouraged by some food experts due to the risk of foodborne illness.

Cutting Equipment

Meat slicers, food choppers, and grinders are common pieces of equipment in food-service establishments (Figure A-10).

Meat Slicer

Carelessness in the use of a meat slicer causes more food-service accidents than any other kind of equipment. The following safety tips apply: The machine should always be unplugged when not in use. After the slicer is plugged in, the blade control is adjusted for the desired slicing thickness, and the blade guard positioned. The food, usually boneless meats, but possibly cheese, vegetables, fruits, and even bread, is then placed on the carriage and held there firmly with the guard before the switch is turned on. The carriage is moved back and forth by its handle in a smooth motion.

The equipment should be thoroughly sanitized after use and between the cutting of different types of foods. This is especially important with raw meats. The cord must be removed from the socket and the blade control set at zero before cleaning. Metal utensils should never be used to scrape food from the blade because they may nick the slicer. Manufacturer's instructions should be followed in removing the various parts and subjecting them to the sanitizing solution and to rinsing and drying. The blade guard should be replaced immediately

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FIGURE A-10 Cutting equipment.



Slicer



Food chopper



Grinder

2007 Hobart Corporation

to prevent any risk of cuts. The use of protective gloves through the whole cleaning process is highly recommended.

Food Chopper or Cutter

Another potentially dangerous piece of food-service equipment is the food chopper or cutter. The key to preventing injuries here is to turn the machine off, allow the knife blades to come to a rest, and flip the safety catch on before removing the food with a bowl scraper. The hands should never go into the bowl. The guard can be raised to remove any remaining food. Meats with bones or gristle should not be processed with food choppers because they will damage the gears and knives.

Mixers

Mixers are convenient for controlling the rate at which ingredients are combined. They are used to prepare whipped cream, beaten egg whites, and mashed potatoes. In the food-service industry, models range in size from tabletop to floor size.

FIGURE A-11 Tabletop mixer and three typical attachments: (a) wire whip—incorporates air, (b) flat beater—general mixing, and (c) dough hook—mixing heavy doughs.



a b c

Photo courtesy of KitchenAid® Home Appliances

Attachments vary from a paddle for general mixing, to whips for cream or eggs, to dough arms for kneading yeast dough (Figure A-11). Additional attachments may be added, including a shredding, grating, or slicing attachment and a grinder for meats and other foods. Some home mixers have similar attachments.

For safety's sake, attachments must be securely in place before the machine is turned on, and it is best to disconnect the power entirely before removing them. Spoons or hands in the bowl during mixing are not recommended, but rubber scrapers can be used occasionally to scrape down the sides of the mixing bowl.

Blenders and Food Processors

Blenders and food processors allow further refinements to mixing food (Figure A-12). In blenders, the blades or mixing component is on the bottom. They are used for everything from making milk shakes to blending the vegetables used in making gazpacho, a Spanish cold soup. Food processors are more versatile and allow cutting, chopping, grinding, slicing, and shredding foods, and even kneading dough. They come with specialized blades for accomplishing all these tasks, and many even come with a juicing attachment.

Coffee/Tea Makers

Many homes and food-service venues use automatic coffee makers daily (Figure A-13). Food-service operations serve coffee from an electric urn or automatic coffee brewer. Electric urns are connected to a hot water source and automatically shut off after the coffee is finished brewing. The hot water

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FIGURE A-12 Blenders and food processors.



nito/Shutterstock.com

Blender



Sean van Tonder/Shutterstock.com

Food processor

FIGURE A-13 Coffee makers and tea dispensers.



Electric urn



Iced tea dispenser



Coffee brewer and dispenser



Courtesy of CecilWare Corporation

Drip coffee maker

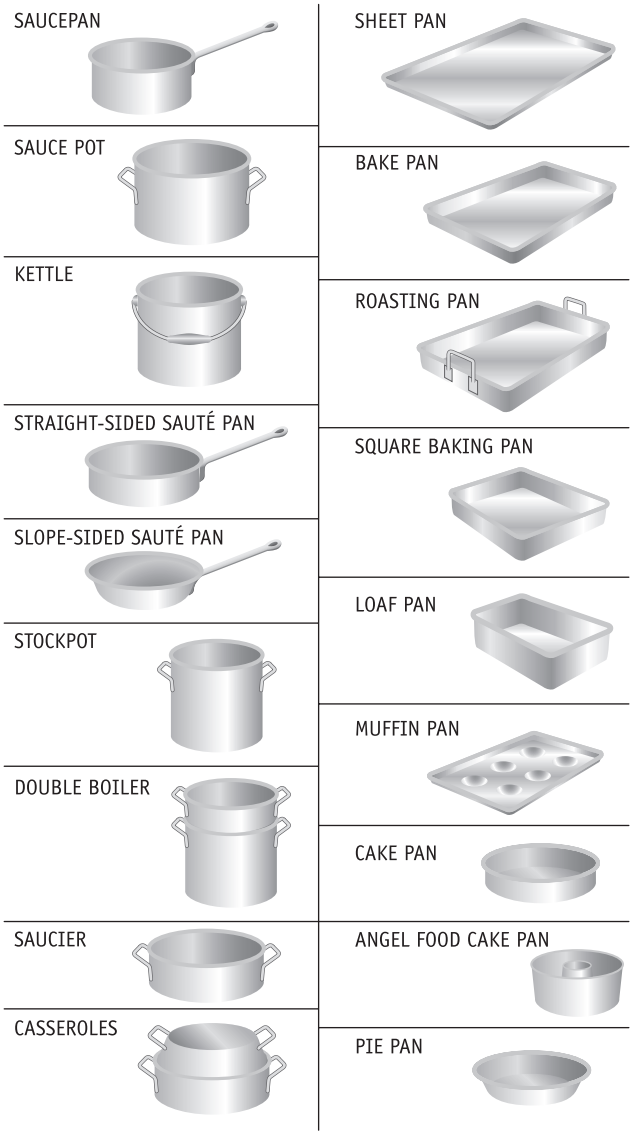
running through a coffee brewer stops after the decanter or pot is full.

COOKWARE

Pots and Pans

Pots and pans are distinguished from one another by their size, shape, and handle (Figure A-14). Another defining feature of a pot, pan, or kettle is the capacity defined by (1) the number of quarts, or (2) inches (baking pans and skillets are described in inches, for example, 8- or 9-inch cake pan) (6).

FIGURE A-14 Common pots and pans.



Pots. Pots have two handles and are used when preparing large quantities.

Pans. Saucepans and frying pans have a single long handle and less capacity. Saucepans are usually straight-sided, whereas frying pans can be either straight- or slope-sided. The flattest pans are those used for baking and roasting. The sturdiest and thickest pans are used for roasting. A double boiler consists of a bottom pan in which water is heated, and a top pan containing a food item that must be kept below the boiling point. These are used for preparing certain sauces and to keep food hot without burning.

Pan Shapes and Colors

Cakes come in a variety of shapes because the pans can be round, square, or oblong. There are special pans for making sponge and angel food cakes; the angel food cake pan

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usually has a tubular segment in the middle that separates from the sides for easy removal of the cake. Spring-form pans allow one to "spring" open the sides for easy removal of the cake. Cookie sheets, sometimes referred to as baking sheets, have no sides (except one or two that are raised for handling), allowing the hot air to flow evenly over the cookies. Heavy-duty sheet pans with four sides can also be used for preparing cookies and myriad other foods such as biscuits, bread, pizza, bread crumbs, roasted nuts, and even some meats. Full-sheet pans are used in restaurants for bulk baking, whereas half-sheets (half the size of full sheets) are reserved for home use (4). Some of the half-sheets purchased at supermarkets may warp at temperatures over 300°F (149°C) but not pans made of heavy-duty aluminum or steel. The aluminum pans tend to be more popular because their lighter color reflects heat, which helps to prevent overbrowning and baking (4). In addition, they do not rust. The darker the pan, as seen in steel pans or those coated with a nonstick surface, the darker the cookies.

One advantage of the darker sheet pans is that they absorb heat, resulting in a crisper crust for pizza and fruit pies. Regardless of the color, professional bakers use kitchen parchment on baking sheets to prevent sticking, to move items around with ease, and to protect against burning (4).

Pot and Pan Materials

Pots and pans are made from a variety of materials (Figure A-15):

- Aluminum, copper, and stainless steel
- Nonstick coatings
- Cast iron
- Glass and glass/ceramic combinations

FIGURE A-15 Materials that make the pot.



Stainless steel: Poor heat conductor, which is why they are often bottom-coated with copper.

Nonstick coatings: Tolerate high heats and eliminate sticking that can occur with stainless steel.

Aluminum: Excellent heat conductor and lightweight, but it reacts with foods that are acidic, alkaline, or sulfurous.

Anodized aluminum: Surface is electrochemically sealed to make it nonreactive.

Cast iron: Superb at retaining heat, but slow to heat or cool; needs to be completely dried and primed.

Digital Works

Best Heat Conductors

Aluminum, copper, and combinations of copper and stainless steel are the best conductors of heat (6). Aluminum accounts for more than half the cookware sold in the United States, but it is very lightweight and prone to denting. Aluminum may also react chemically with many foods, particularly those high in acid, and it is not recommended for storing foods. Copper is an excellent heat conductor, but it is costly and requires special care. A further disadvantage is that excessive copper may dissolve into the food being prepared, causing nausea and vomiting. Therefore, copper pans are usually lined with stainless steel or tin. Stainless steel is known for its durability and easy cleaning; however, it is a poor conductor of heat and tends to generate hot spots, which may scorch the food. To keep this from happening, the bottoms of many stainless steel pans are coated with copper or aluminum.

Nonstick Pans

Nonstick pans reduce the amount of fat needed to prevent sticking, but their surfaces are easily scratched, so plastic, rubber, or wooden utensils are recommended.

Cast Iron Pans

Cast iron pots and pans are heavy, heat slowly, rust easily, and are difficult to clean. They do, however, retain high temperatures for longer periods of time, heat evenly, and add extra iron to the diet. Acidic foods such as tomato sauces tend to absorb more iron: 5 mg of iron are absorbed for every 3 ounces of spaghetti sauce cooked in a cast iron pan.

Cast iron pots and pans may be cleaned in one of two ways. The first involves a preliminary priming or conditioning of the pan with a very thin coat of vegetable oil, after which it is heated and cooled. A primed pan is cleaned by scraping and wiping away food particles after each use. Reconditioning may be done whenever necessary. The second method is to wash the pan with soap and water, heat it to dry, and then coat it with a minute amount of oil. This second method is more likely to remove any traces of rancid fat, which can impart an off-flavor to any food subsequently prepared in the pan.

Glass Pans

Heat-proof glass, such as Pyrex, and glass/ceramic combinations, such as Corningware, break more easily than metal-based pots and pans but have the advantage of not reacting

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with foods. Most casserole pans, which are usually oval or oblong with low sides, are made of such materials. Baking temperatures should be reduced by 25°F (4°C) when using tempered glass. The newer versions of glass/ceramic materials can be moved from the range or oven to the refrigerator or freezer, and later be taken from the cold and placed directly into the oven or microwave. Glass pots and pans are not allowed in food-service operations, however, because of possible breakage and liability problems.

Utensils

Utensils are vital items needed for cutting, stirring, turning, measuring, and serving food. The utensils covered in this section include knives and utensils used in preparation, measuring, and serving.

Knife Utensils

Knives are to the chef as brushes are to the artist. Some people consider them to be the most important tools in food preparation. Knowing the different kinds of knives, their particular tasks, and how to care for them is crucial to the preparation of foods. The food to be cut determines what type of knife should be used. The basic knife starter set consists of chef's, paring, slicing, boning, and utility knives. The first three types of knives often complete the set of many home kitchens. Common knives used in food preparation are shown in Figure A-16.

Purchasing Knives

Knives can range in price from a few to several hundred dollars. When selecting a knife, qualities to consider include size, weight, balance, the length of the tang, and the materials from which the blade and handle are made. Although the size selected will be determined by the use for which the knife is intended, the other factors depend on more qualitative assessments.

Weight and Balance Sometimes the "balance" or the feel of the knife in the hand is a factor in selection. Some knives are blade-heavy, others handle-heavy, and some feel evenly divided between the two. A person should select the knife that feels "right" in his or her hand (2).

Tang Another quality that varies among knives is the length of the tang, the part of the metal blade that extends into the handle. Better-quality knives have a tang that extends the full length of the handle.

Blade Probably the most important factor in selecting a knife is the type of steel used for the blade: carbon, stainless steel, or high-carbon stainless steel. Carbon blades are almost obsolete because they are highly susceptible to rust and lose their edge quickly. Stainless steel, on the other hand, is rust-resistant but is difficult to sharpen and to keep sharp. This steel is, in fact, a combination of metals, including chromium, which is added for its resistance to stains, corrosion, and heat. Despite its name, stainless steel is not stain-proof, but it does stain less than knives not made from stainless steel when it comes into contact with food and beverages, especially salad dressing, vinegar, salt, mustard, tea, and coffee.

High-carbon stainless-steel knives are usually preferred because, in addition to not staining, they keep a sharp edge and do not rust (2). High-carbon knives are further distinguished by whether they have a stamped or a forged blade. Stamped blades are cut from a sheet of steel, ground, and then polished. Because they are mass-produced, they are less expensive than forged knives. Forged blades are made from a single piece of steel that has been exposed to extremely high heat, submerged in a chemical bath, and set in a die before being hammered into shape by hand. The resultant blades are more costly, but they are also heavier and tougher, hold their edge longer, and require less pressure when cutting.

Handle The knife's handle may be made of wood, carved bone, plastic, or metal. Wood is easier to hold, but water damage from frequent washing reduces the length of its life. Plastic or metal handles are more durable, but they are slippery. Bone-handled knives are both water- and wear-resistant and, when combined with a high-carbon stainless-steel knife, can last a lifetime or more.

Care of Knives

Cutting knives should never go in a dishwasher. Strong detergents not only dull the blade but, when combined with hot water and air, can ruin wooden handles. Nicks can occur if the blade bumps against other metal utensils. Instead, knives should be washed immediately after use with soap or detergent, dried thoroughly, and then stored in such a way that their blades do not contact each other to prevent nicks. The blades may be kept separated by slipping them into a wooden knife block (blade turned upward) or a shallow knife block that fits inside a drawer, or by placing them along a magnetic strip.

Knives can be sharpened using one of the many electric and mechanical knife sharpeners on the market, but a better result can be achieved by hand. The two basic ways to hand-sharpen a knife are with a stone or a steel implement. The sharpening stone, also known as a whetstone, is used by rubbing a bit of moisture on the stone and sliding each side of the blade along it until the proper sharpness is acquired. Sharpening often requires two whetstones of different grits—300 to 1,000 to start, and 1,000 to 3,000 for a fine finish. A sharpening steel looks like a round sword and is held firmly in one hand while the knife, held in the other hand, is brandished against the steel (Figure A-17). Most chefs employ both implements, for different purposes: one for getting an edge and the other for refining it.

Cutting Boards

Cutting boards are used primarily for cutting meat, poultry, vegetables, and fruits, but they may also be used for kneading and rolling out dough. They may be made of wood, hard plastic,

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FIGURE A-16 Common knives used in food preparation.



French or chef's knife

Chef's Knife The chef's, or French, knife is one of the largest and serves as an all-purpose knife for cutting meats and for mincing, dicing, and chopping a variety of foods. Chef's knives are commonly available in blade lengths of 6, 8, and 12 inches, and the side of their blades can be used to crush garlic cloves, ginger slices, and peppercorns (2).



Utility knife

Utility Knife The 6–8 inch utility knife is geared toward lighter duties such as cutting tomatoes or carving meat.



Paring knife

Paring Knife The smaller, shorter, 2- to 4-inch paring knife is used for more delicate jobs that require close control, such as the trimming of vegetables, fruits, and small pieces of meat like chicken breasts.



Boning knife

Boning Knife The slightly curved boning knife is handy for separating meat from bone (e.g., deboning the breast of a chicken), disjointing poultry, cutting between the joints of larger pieces of meat, and dicing raw meats.



Slicer

Slicing Knife Slicing knives are long and flexible enough to portion off thin slices of meat or poultry.



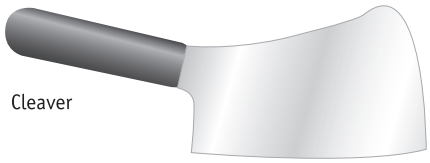
Serrated slicer

Serrated Slicer Serrated slicers are useful for cutting tomatoes, bread, or angel food cake.



Butcher knife

Butcher Knife A variety of butcher knives are available for cutting raw meats.



Cleaver

Heavy Cleavers Additional knives that are found in food-service areas include heavy cleavers for cutting through bone.

Steak or Scimitar Knife These knives (not pictured) are used for cutting steaks from the appropriate parts of a carcass.

Oyster and Clam Knives Oyster and clam knives (not pictured) are used for opening these shellfish.

glass, or ceramic tiles; the latter three, however, are hard on knife blades (1). Cutting boards should be carefully scraped and thoroughly washed and dried every time they are used.

Preparation Utensils

Figure A-18 shows some of the supporting utensils most commonly used in food preparation. Spoons, available in solid, slotted, or perforated versions, are used for mixing and serving. The holes in the slotted and perforated spoons allow liquids to drain. Wire whisks are used for mixing and are categorized by their shapes. Straight (French) whisks are ideal for general purposes or smooth sauces. The very thin wires of balloon whisks are designed for beating the maximum amount of air into thin liquids such as egg whites and cream. Flat whisks are fashioned for creating sauces and gravies when it is important to lift up materials from the corners of a pan (7).

Spatulas come in a variety of shapes for their many purposes. Rubber spatulas or scrapers are used to scrape bowls or to fold beaten egg whites or other ingredients into each other. The straight spatula or palette knife is used for measuring ingredients, and it is ideal for spreading icings onto cakes. The sandwich spreader, with a broader blade, is used, as the name implies, on sandwich fillings, butter, and jams. A pie server is an angled spatula used to lift pie, cake, or pizza wedges. Similar in design, but wider and with a larger bend, is the offset spatula, which is used to turn items such as hamburgers, eggs, and pancakes.

Other preparation utensils include the bench scraper, for scraping and for cutting dough; the pastry wheel, which is designed to cut pastry dough, but which can also be used to cut

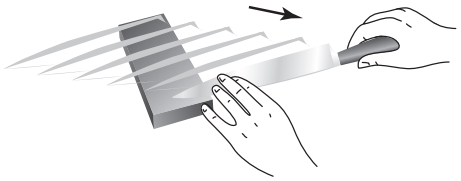
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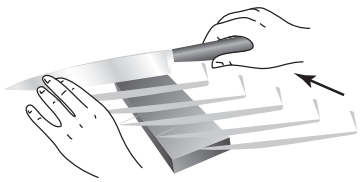
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FIGURE A-17 Sharpening knives using either a stone (whetstone or water stone) or steel.

STONE
Produces a sharp cutting edge*



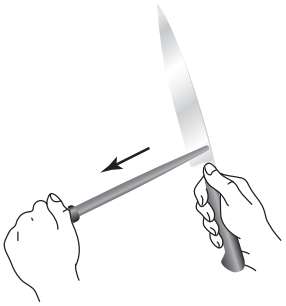
Hold the blade at a 45 degree angle to the stone (rough side up). Pull it gently toward you across the entire surface of the stone, making sure the entire blade is sharpened from the tip to its heel in one stroke.



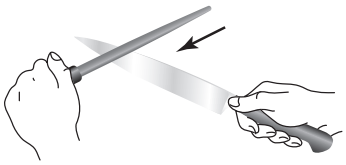
Turn the knife over and perform the procedure in the opposite direction. Four times across the stone on each side (rough and smooth) is usually sufficient to sharpen a knife.

* Stones are pretreated prior to sharpening knives—either by first saturating them lightly with vegetable oil (which has to be cleaned off) or soaking them in water (which does not require cleaning). Never sharpen knives on an electric knife sharpener that may tear the steel and shorten the blade's life span.

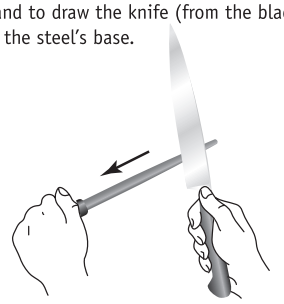
STEEL
Maintains a sharp cutting edge



Place the heel of the knife at an angle *under* the steel's tip.



Firmly holding the steel in the left hand, and use one smooth stroke with the right hand to draw the knife (from the blade's heel to the tip) down to the steel's base.



Place the heel of the knife at an angle on top of the steel's tip. Retain this angle while moving the knife down the steel (from the blade's heel to the tip) in one smooth stroke.

pizza; and the pastry brush, which is used to coat pastry with egg white or sugar glaze.

Types of Measuring Utensils

About five different types of measuring utensils are frequently used in food preparation: liquid and dry measuring cups, measuring spoons, ladles, and scoops (Figure A-19).

Liquid Measuring Cups These are available in 1-cup, 2-cup (1 pint), and 4-cup (1 quart) capacities. Their volumes are divided into increments of ¼, ⅓, ½, ⅔, and ¾ cup. They are usually glass, have a pouring lip, and are all-purpose.

Dry Measuring Cups Fractional, flat-topped (no pouring lip), single-volume cups (¼, ⅓, ½, and 1) are best because they can be leveled with a spatula for a more accurate result. Accuracy is also improved by using the 1-cup measure rather than four ¼ cups.

Measuring Spoons Used to measure both liquid and dry ingredients requiring less than ¼ cup, they consist of 1 tablespoon, and 1, ½, ¼, and occasionally ⅛ teaspoon. A tablespoon equals 3 teaspoons, and 2 tablespoons equal 1 fluid ounce.

Ladles Liquids can be measured by long-handled ladles that are individually stamped on their handles (oz or ml) with their capacity in ounces (Table A-1).

TABLE A-1 Ladles—Approximate Measures and Their Uses

Ladle Size	Measure	Use
1 oz	2 Tbsp	Sauces, salad dressings, cream
2 oz	¼ C	Gravies, sauces
3 oz	⅓ C	Cereals, casseroles, meat sauces
4 oz	½ C	Puddings, creamed vegetables
6 oz	¾ C	Stews, creamed entrées, soup
8 oz	1 C	Soup
12 oz	1½ C	
16 oz	2 C (pt)	
24 oz	3 C	
32 oz	4 C (qt)	

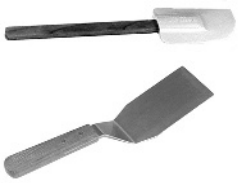
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FIGURE A-18 Food preparation utensils.

Spatulas



Larger offset spatulas or turners—To turn meat, pancakes, potatoes, and other foods while browning. The offset or bend keeps the hand away from the hot surface.

Turner's blade—Solid or perforated and used as a scraper to remove grease and other materials.

Tongs



To turn meat while broiling, lift vegetables like corn-on-the-cob from a steamer, serve food, and serve ice cubes.

Fork



To turn meat while cooking or to hold meat and other foods while being sliced.

Whisks



Straight whisk—For general purposes and smooth sauces.



Balloon whisk—For incorporating air into egg whites and whipped cream.



Flat whisk—For sauces and gravies.

Molds



Molds—A variety of shapes are used for gelatins and desserts.

Brushes



Pastry brushes—To spread melted butter or thin mixtures such as icings or eggs and water.



Grease brushes—To remove grease from soups, stocks, and sauces.



Vegetable brushes—To clean vegetables and fruits.

Spoons, skimmers, and strainers



Wooden spoons—For stirring, mixing, creaming, tossing, folding, and serving.



Solid spoons—To lift foods, including the liquid, out of the pot. They are also used to spoon liquids over foods.



Slotted or perforated spoons—To lift foods out of the liquid in which they were cooked.



Skimmers—To remove scum and grease from the top of stocks, gravies, and other liquids; also used to lift food out of hot liquid.



Strainers—A variety of sizes and shapes are used for separating solids and liquid. The mesh varies from fine to coarse. A sieve has similar uses but is a stainless steel perforated cup with a handle.



Colander—To drain cooked foods such as pasta and to rinse salad greens and berries.



China cap—To strain liquids from solids when making soups and gravies; also used to puree foods. A pointed wooden mallet is used to force food through the strainer.

Flour and dough utensils



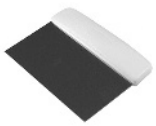
Sifter—To sift flour or powdered sugar, and to blend dry ingredients.



Pastry blender—To cut shortening into flour.



Rolling pin—To roll out pastry, rolls, and cookies.



Dough scraper—To scrape the dough from the board.



Pastry bags—To make shaped pastries and decorations. The bag is used with a variety of tips or tubes designed to create different shapes when a soft food such as icing is squeezed through.

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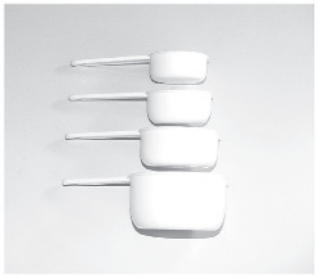
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FIGURE A-19 Measuring utensils.



Liquid measuring cup



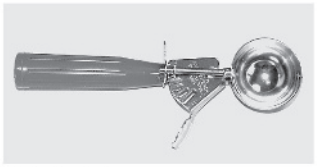
Dry measuring cups



Measuring spoons



Ladles



Scoop/Disher/Dipper

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Scoops or Dippers or Dishers The various sizes of these scoops are identified by a scoop number stamped on the handle or release mechanism and a corresponding color (e.g., a number 16 scoop holds 2 fluid ounces and is blue). Table A-2 indicates the number of portions from a quart (e.g., a number 8 scoop yields eight ½-cup portions from 1 quart). The larger the scoop or dipper number, the smaller the serving. Portion scoops are used primarily by food-service establishments for serving ice cream, mashed potatoes, and other soft foods.

Serving Utensils

At last, the meal is ready to be eaten, and serving utensils enter the picture. Basic tableware includes salad forks, dinner forks, regular knives, steak knives (optional), soup spoons, and teaspoons. A more extensive "wardrobe" of tableware might include butter knives, small two-tined forks known as seafood forks, dessert spoons, luncheon knives and forks (which are slightly smaller than standard knives and forks), iced-tea spoons, and grapefruit spoons. Eating utensils, for sanitary reasons, should always be touched by the handles.

TABLE A-2 Scoops—Approximate Measures and Their Uses

Scoop or Dipper Number*	Weight	Volume	Use
6	5 oz	⅔ C	Soups
8	4 oz	½ C	Luncheon entrées, potatoes
10	3 oz	⅜ C	Desserts, meat patties, ice cream
12	2½–3 oz	⅓ C	Vegetables, desserts, puddings
16	2 oz	¼ C	Muffins, cottage cheese, croquettes, dessert
20	1¾ oz	3 Tbsp ¾ tsp	Muffins, cupcakes, meat salads
24	1⅓ oz	2 Tbsp 2 tsp	Cream puffs, ice cream
30	1–1¾ oz	2 Tbsp ¾ tsp	Drop cookies
40	0.8 oz	1 Tbsp 1½ tsp	Whipped cream, toppings, gravy
60	½ oz	1 Tbsp	Salad dressings, toppings
70	⅓ oz	2¾ tsp	Cream cheese, salad dressing, jelly
100	¼ oz	2 tsp	Whipped butter

*Dipper/scoop = servings/quart

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Appendix B: Food Yields

The quantity to purchase for an approximate yield.

Food	Quantity to Purchase	Approximate Yield
DAIRY		
Cheese	1 lb	2 C/4 C (grated)
Cheddar	1 lb	2 C
Cottage	1 lb	2 C
Cream	1 C (½ pt)	2 C
EGGS		
Whole	1 lb	1¾ C
Whites (fresh)	8–11	1 C
Yolks (fresh)	12–14	1 C
FATS AND OILS		
Butter/Margarine	1 lb	2 C
Vegetable oil	1 lb	2⅙ C
Vegetable shortening	1 lb	2⅓ C
FLOUR		
All-Purpose	1 lb	4 C (sifted)
Cake	1 lb	4½ C (sifted)
Cornmeal	1 lb	3½ C (sifted)
Rye	1 lb	3½–5 C
Whole wheat	1 lb	3⅓ C (sifted)
FRUIT		
Apples	1 lb/3 med	3 C (sliced)
Bananas	1 lb/3 med	2½ C (sliced)
Berries	1 quart	3½–4 C (sliced)
Coconut	1 lb shredded	5 C
Dates	1 lb whole	2¼ C or 2 C (pitted)
Lemon	1 med	⅓–½ C juice 1½–3 tsp (grated)
Orange	1 med	⅓–½ C juice 1–2 Tbsp (grated)
Peaches	1 lb	4 C (sliced)
Prunes	1 lb	2⅓ C
Raisins	1 lb	3 C
NUTS		
Almonds	1 lb shelled	3 C
Pecans	1 lb shelled	4 C
Peanuts	1 lb shelled	3 C
Walnuts	1 lb shelled	4 C
SUGAR/SALT		
Brown	1 lb	2¼–2½ C (firmly packed)
Confectioners'	1 lb	4–4½ C (sifted)
Granulated	1 lb	2–2¼ C
Honey	1 lb	1–1¼ C
Salt	1 lb	1½ C

(Continued)

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Appendix B *(continued)*

The quantity to purchase for an approximate yield.

Food	Quantity to Purchase	Approximate Yield
VEGETABLES		
Beets	1 lb/4 med	2 C
Cabbage	1 lb	4 C (shredded)
Carrots	1 lb/4 med	3 C (diced)
Celery	1 lb/½ bunch	4 C (diced)
Corn	3 ears	1 C (kernels)
Dried beans	1 lb/2 C	5–6 C (cooked)
Green beans	1 lb	3 C (chopped)
Lettuce	1 lb/med	6 C
Onion	1 med	½ C (diced)
Parsley	1 med bunch	½–1 C (finely chopped)
Potatoes	1 lb/3 med	2½ C (diced)
		3 C (peeled and sliced)
		2 C (mashed)
		2 C (French fries)
Tomatoes	1 med	1 C (chopped)
MISCELLANEOUS		
Bread crumbs (fresh)	2 slices	1 C
	1 lb loaf	10 C
Chocolate		
Baking	8-ounce pkg	2 C (grated)
Cocoa	1 lb	4 C
Unsweetened	8-ounce pkg	8 1-ounce squares
Coffee	1 lb (beans; about 6 C)	~50 C (depends on strength)
	1 C	7½ C
	½ C	3¾ C
	2 Tbsp	6 fluid ounces
Crackers		
Graham	12	1 C (fine crumbs)
Saltines	18	1 C (coarse crumbs)
	24	1 C (fine crumbs)
Gelatin	1 envelope	1 T gelatin powder
Rice	1 C uncooked	3–4 C cooked

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Appendix C: Substitution of Ingredients

If Missing	Measurement	Substitute
DAIRY		
Whole milk	1 C	= ½ C evaporated milk + ½ C water
		= ⅓ C nonfat dry milk + water to make one C + 2 Tbsp fat
	1 quart	= 4 oz nonfat dry milk + water to make 1 qt + 1¼ oz fat
		= ½ C heavy cream + ½ C cold water
Sweetened condensed	1 C	= ¾ C sugar + ⅓ evaporated milk + 2 Tbsp butter
Buttermilk/sour milk	1 C	= 1 C fresh milk + 1 Tbsp fat vinegar or lemon juice (let stand for 5 minutes)
	1 C	= 1 C unflavored plain yogurt
Cream		
Half & half	1 C	= ¾ cup milk + 2 Tbsp fat
		= ½ C milk + ½ C light cream
Heavy (whipping)	1 C	= ¾ C milk + ⅓ C butter or margarine
Sour cream	1 C	= 1 C yogurt
EGGS		
Whole	one	= 2 egg yolks + 1 Tbsp water
		= 2 Tbsp dried whole eggs + 2½ Tbsp water
Whites, fresh	1 white	= 2 Tbsp thawed frozen egg white or 2 tsp dry egg white + 2 Tbsp water
Yolks, fresh	1 yolk	= 3½ Tbsp thawed frozen egg yolk or 2 Tbsp dry egg yolk + 2 tsp water
FATS AND OILS		
Butter/margarine	1 C	= 1 C margarine/butter
		= ⅞ to 1 C hydrogenated fat + ½ tsp salt
		= ⅞ C lard + ½ tsp salt
		= ⅞ C vegetable oil
FLOUR		
All-purpose	1 C sifted	= 1 C unsifted all-purpose flour minus 2 Tbsp
		= 1½ C bread flour
		= 1 C rye
		= 1 C + 2 Tbsp cake flour
		= 1 C minus 2 Tbsp cornmeal
		= 1 C graham flour
		= 1 C minus 2 Tbsp rice flour
		= 1 C rolled oats
		= 1 C + 2 Tbsp coarsely ground whole wheat or graham flour or 13 Tbsp gluten flour
		= 1¼ C rye flour
		= ½ C barley flour
	1 Tbsp (as thickener)	= ½ Tbsp cornstarch, potato starch, rice starch, arrowroot starch
		= 1 Tbsp quick-cooking tapioca, waxy rice flour, waxy corn flour
Self-rising flour	1 lb	= 4 C of all-purpose flour + 2 Tbsp baking powder, 2 tsp salt
		= 1 C = (1 C of all-purpose flour minus 2 tsp) + 1½ tsp baking powder + ½ tsp salt
Cake flour	1 C sifted	= ⅞ C sifted all-purpose flour or 1 C minus 2 Tbsp sifted all-purpose flour

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Appendix C *(continued)*

If Missing	Measurement	Substitute
MISCELLANEOUS		
Allspice	1 Tbsp	= ½ tsp cinnamon + ½ tsp ground cloves
Baking powder	1 tsp	= ¼ tsp baking soda + ½ tsp cream of tartar
		= ¼ tsp baking soda + ½ C buttermilk or sour milk (replaces ½ C of liquid used in recipe)
Broth	1 C	= 1 bouillon C (or 1 envelope powdered broth or 1 tsp powdered broth) + 1 C boiling water
Catsup	1 C	= 1 C tomato sauce + ½ C sugar + 2 Tbsp vinegar
Chili sauce	1 C	= 1 C tomato sauce + ¼ C brown sugar + 2 Tbsp vinegar + ¼ tsp cinnamon + dash allspice/ ground cloves
Chives		= Scallion greens
Chocolate		
Unsweetened	1 ounce	= 3 Tbsp cocoa + 1 Tbsp fat
Baking	1 square	= 3 Tbsp carob powder + 2 Tbsp water
Semisweet	2 ounces	= 1 ounce unsweetened chocolate + 2 tsp sugar
Cocoa	3 Tbsp	= 1 oz chocolate if recipe reduced by 1 Tbsp of fat
		= 3 Tbsp carob powder
Cornstarch	1 Tbsp	= 2 Tbsp all-purpose flour
	1 ounce	= 2 oz all-purpose flour
Garlic	1 medium clove	= ½ tsp garlic salt
		= ⅛ tsp garlic powder
Herbs	1 Tbsp (fresh)	= ¼ tsp dried ground
		= 1 tsp dried leaf
Lemon juice	1 Tbsp	= ½ Tbsp vinegar
Mayonnaise	1 C	= ½ C yogurt + ½ C mayonnaise
		= 1 C sour cream
		= 1 C cottage cheese (pureed)
Pumpkin pie spice	1 tsp	= ½ tsp cinnamon + ¼ tsp nutmeg + ⅛ tsp allspice + ⅛ tsp cardamom
Tomatoes (canned)	1 C	= ½ C tomato puree + ½ C water
Tomato juice	1 C	= ½ C tomato puree or sauce + ½ C water
Tomato puree	2 C	= 1¼ C water + ¾ C tomato paste
Tomato sauce	2 C	= 1¼ C water + ¾ C tomato paste
SUGAR/SWEETENERS		
Granulated	1 C	= 1⅓ C brown sugar
		= 1½ C Confectioners' sugar
		= 1 C honey minus ¼ to ⅓ liquid in recipe
		= 1¼ to 1½ C corn syrup minus ¼ to ½ liquid in recipe
		= 1⅓ C molasses minus ⅓ C liquid in recipe
Brown	1 C	= ½ C granulated sugar + ½ C liquid brown sugar
		= 1 C granulated sugar + 2 Tbsp molasses or dark corn syrup
Confectioners'	1 C	= made by grinding 2 C granulated sugar in a processor
Honey	1 C	= 1¼ C sugar + ¼ C liquid
Corn syrup	1 C	= 1 C sugar + ¼ C liquid
Molasses	1 C	= ½ C honey 1¼ C melted brown sugar

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Appendix D: Flavorings and Seasonings

Name	Uses
Allspice	Allspice combines the flavors of cloves, cinnamon, and nutmeg. Whole allspice is used for pickling, gravies, broiled fish, and meats. Ground allspice is used for baked goods, fruit preserves, puddings, and relishes.
Almond	Almonds can be used in every dish from soup to dessert. Almond extract is used in cookies, confections, and Chinese cuisine.
Anise	Anise is a popular favorite for a few gourmet dishes such as Oysters Rockefeller. In addition, it is used in bakery products, candies (especially licorice candy), certain kinds of cheese, pickles, and many liqueurs and cordials, including anisette and absinthe.
Anise-pepper	This is one of the ingredients in Chinese Five Spices and is commonly used for fish and strongly flavored foods.
Balm	Balm has a pleasant lemon scent and can be chopped and combined with other herbs for use in omelets and salads and in the production of several liqueurs. In addition, balm leaves are used to flavor soups and dressings.
Basil	Basil is a key ingredient in Mediterranean and Thai cooking. Sweet basil is preferred for Italian dishes, but other varieties include anise, cinnamon, lemon, opal, and Thai basil.
Bay leaves	Bay leaves can be used either fresh or dried. They are one of the ingredients in bouquet garni, and they are used in bouillon, marinades, olives, and pickles. They combine well with fish, potatoes, or tomatoes.
Bouquet garni	This is a French term meaning "bundle of sweet herbs." The bouquet garni is used in soups, stews, or any dish in which there is sufficient liquid to absorb the flavors.
Caper	Capers are much used in European cuisine. They are commonly used in making caper sauce, which is usually eaten with boiled lamb. They also go well with fish dishes and with casseroles of chicken and rabbit.
Caraway	The seeds (actually the dried whole fruits) are used in cakes, cheeses, confections, fresh cabbage, meat dishes, rye bread, salads, and sauerkraut. The chopped green leaves can be used in soups and salads. The roots can be cooked and eaten as a vegetable.
Cardamom seed	Freshly ground cardamom has many uses, including breads, cakes, cookies, cheese, curries, custard, liver sausage, meat dishes, pilaus, pork sausage, and punches.
Cassia	The cinnamon stick can be used in dishes to impart flavor and is then removed before serving; for example, some punches are flavored in this manner. Powdered cassia is used in combination with allspice, nutmeg, and cloves for spicing mincemeat, curries, pilaus, meat dishes, desserts, and cakes. It is one of the ingredients of the famous Chinese Five Spices.
Cayenne pepper	A little goes a long way, but it is a spice that adds considerable interest to egg dishes, fish, and meat recipes.
Celery salt	This spice is slightly bitter, but it combines well with bouillon, eggs, fish, potato salad, and salad dressing.
Celery seed	Celery seeds have a slightly bitter taste, but they contribute a useful flavoring. They add special interest to many salads and salad dressings.
Chervil, garden	Chervil, which has a mild anise-caraway flavor, is one of the ingredients of fines herbes, a mixture of chopped fresh herbs extensively used in French recipes. Chervil is used in omelets, soups, salads, sauces, and white wine vinegar. It should not be cooked but must be added at the last minute; otherwise, it loses its flavor.
Chinese five spices	Chinese Five Spices (a blend of anise-pepper, star anise, cassia, cloves, and fennel seed) is an integral part of some of the recipes from the Far East. It can also be used to good advantage in flavoring pork dishes.
Chives	Chives are ideal as a garnish because of their delicate onion flavor and bright green color. Chives add interest and flavor to buttered beets, eggs, cottage or cream cheese, potato and other salads, sliced tomatoes, and soups.
Cinnamon	Cinnamon has a more delicate flavor than cassia and is more suitable for sweet dishes, cakes, and cookies.
Citron	Citron peel has a peculiar taste, quite different from other citrus. Is used in the United States as candied peel to be added to cakes, cookies, candies, and desserts.
Cloves	Whole cloves are used in many meat dishes, but a little goes a long way. Cloves are stuck into lemon slices for tea, into onions, and into hams for baking; they are also popular for apple cookery and pickle making. In the East, they go into many of the curry dishes. Whole cloves are also included in recipes for spiced wine and some liqueurs. Ground cloves are used in baked goods, borscht (beet soup), chocolate puddings, potato soup, and stews.
Cola	Cola is used in many soft drinks, and for coloring and flavoring some wines.
Coriander (cilantro)	Coriander leaves are popular in Near, Middle, or Far East recipes, as well as in Mexico and South America. The seeds are a principal ingredient of curry. Whole coriander seeds can be used in cakes, cookies, biscuits, gingerbread, green salads, pickles, and poultry stuffing. Ground seeds are added to many meat and sweet dishes.
Cress Watercress Garden cress	The cresses are primarily used in salads and sandwiches, but they can be used to flavor soup, cooked greens, or sauces for fish dishes and to garnish meals.
Cumin	Cumin's principal use is in curry powder. It is also used to flavor bread, stuffed eggs, meats, rice dishes, and soups. Commercially, it may be found in cheese, chutney, pickles, meats, and sausage.

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Appendix D *(continued)*

Name	Uses
Curry (powder)	Curry powder may be added to eggs, chicken, fish, meats, rice, soups, or a salad made of sweet potatoes and pineapple.
Dill	Dill loses its flavor when cooked, so it should be added at the last minute. Fresh dill leaves can be used for dishes containing chicken, mushrooms, or spinach. The seeds are used in dill pickles and dill vinegar, but they can be added to meat dishes, meat and fish sauces, sauerkraut, salads, and borscht (beet soup).
Fennel	Fennel has an anise-like flavor and is good with many foods: apple pie, candies, fish, liqueurs, pastries, pork, soups, and sweet pickles.
Fenugreek seed	Fenugreek seeds are usually used in Indian curries and chutneys.
Fines herbes	A combination of several herbs such as basil, chervil, chives, marjoram, oregano, parsley, rosemary, sage, tarragon, and thyme. Fines herbes can be used in many dishes such as fish sauces, meat stuffings, omelets, salads, salad dressings, and soups.
Garlic	Garlic blends with a wide range of dishes such as fish, game, meats, and vegetables.
Ginger	Ginger is used in numerous foods, including beverages, biscuits, cakes, cookies, fish, gingerbread, ginger beer, ginger wine and cordials, puddings, sauces, and spice mixtures. It is used mostly in sweet preparation in European and North American cooking, but in the Orient, it is used extensively for chutney, fish, meat, and pickles.
Horseradish	Many cooks limit the use of horseradish to a sauce used on meats, but it can be added to chicken salads, egg dishes, and mayonnaise for use on fish dishes or in tomato combinations.
Leek	The leek is rather like a very mild onion that is used mostly in soups and chowders. However, the leek may also be used as a bouquet for pork or lamb.
Lemon	Lemon juice can be used on salads instead of vinegar, and it is the predominant favorite for serving with most fishes. Grated lemon rind is added to cakes, cookies, desserts, and sauces to give an added taste dimension.
Licorice	Licorice is used to flavor candy, chewing gum, and soft drinks. CAUTION: Licorice raises the blood pressure of some people dangerously high because it contributes to the retention of sodium.
Lime	Limes impart a unique taste to dishes, which cannot be replaced by lemons. Fish is often marinated in lime juice before cooking.
Mace	Mace can be added to apple dishes, beets, cakes, hot chocolate, coffee cakes, cookies, custards, eggnog, gingerbread, and muffins.
Marjoram	Marjoram is related to thyme; hence, they are often used together or to replace each other. It can be added to almost every dish to advantage. It should be added immediately before serving as the flavor is easily lost in cooking. Marjoram is used with egg dishes, lamb, poultry, sausage, soups, stews, and vegetables.
Mint Peppermint Spearmint	Peppermint flavoring is used mostly for candies, cordials, desserts, icings, and liqueurs. Spearmint is the preferred mint for lamb as well as for iced tea and mint juleps. It can also be used in soups, stews, fish, and meat sauces.
Monosodium Glutamate (MSG)	MSG does not have any flavor of its own, but it intensifies and enhances the flavor in other foods, especially meat and fish.
Mustard Black Brown White Yellow	Whole mustard seeds add pungency to many foods, including pickles, meats, and salads. Powdered dry mustard is a common kitchen spice. Its sharp, hot flavor develops when the powder is moistened. It is used for roast beef, mustard pickles, sauces, and gravies. Prepared mustard is a mixture of powdered mustard with salt, spices, and lemon juice, with wine or vinegar to preserve the mustard's pungency. It may be used with ham, hamburgers, hot dogs, and sandwich spreads.
Nutmeg	Nutmeg is traditionally used in sweet foods such as cakes, custards, doughnuts, eggnog, pies, and puddings, but it goes very well with meat, sausage, spinach, sweet potatoes, and vegetables.
Onion	Onions are used either as a separate vegetable or as a flavoring for other foods. The leaves of the onion, along with the bulb, are used in salad.
Oregano	Oregano is used extensively in Italian cooking and can be added to cheese dishes, chili beans, fish, gravies, meats, sauces, sausage, salads, and soups.
Paprika	Paprika is used in many dishes both for its flavor and as a garnish. It can be added to chicken, sweet corn, fish, meats, sausages, tomato catsup, and tomato juice.
Parsley	Parsley can be added to fish and fish sauces, meats, sauces, soups, and vegetables. It is commonly used as a decoration for buffet dishes.
Pepper	Pepper loses much in aroma when ground or cooked, so freshly ground pepper should be used whenever possible. Pepper can be purchased as whole peppercorns, cracked, coarsely ground, or finely ground. Except for sweet dishes, pepper can be added to most dishes.
Poppy seed	Poppy seeds have a pleasant nut-like flavor and aroma and are used primarily in baked goods, on the tops of rolls and bread, and in cakes and pastries. However, they are also used in confections, fruit salad dressings, and curries.
Rosemary	Rosemary is good with soups, on broiled steaks, or with other meat dishes, sauces, and vegetables. The taste is aromatic, pungent, and slightly bitter.

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Appendix D *(continued)*

Name	Uses
Saffron	Saffron is used as a flavoring and coloring (yellow) spice in biscuits, confections, boiled fish, fish soup, fancy rolls, and rice, as well as in some European dishes.
Sage	Sage is available whole, rubbed, or ground. It is used for baked fish, meats, meat stuffings, sausages, cheeses, and sauces.
Savory	Savory is available whole or ground and is often combined with other herbs to flavor meats. In addition, it can be used in beans, scrambled eggs, peas, salads, sauces, and sausages.
Sesame seed	Sesame seeds develop a beautiful nutty taste when sprinkled on buns, rolls, or cakes, and then baked. They are also used in confections.
Shallot	Shallots can be used in the same way as the onion, although the flavor is much more subtle. Shallots should never be browned, as browning turns them bitter.
Soy sauce	Soy sauce can be used in a wide array of dishes, especially beef, chicken, fish, soups, turkey, and vegetable dishes.
Star anise	Star anise has a strong flavor similar to anise, but slightly more bitter and pungent. In Chinese cooking, it is used for duck and pork recipes.
Sweet basil	Basil can be used for green beans, fish, soups, squashes, stews, tomatoes, and vinegar.
Sweet cicely	The plant smells and tastes somewhere between anise and licorice. The taproot can be boiled and used for salads, and the green fruit can be served with salad dressing. Europeans use the leaves in soups and salads. The plant is also used for flavoring desserts and liqueurs.
Tarragon	Tarragon is best known for flavoring vinegar, but it is also used for beef, chicken, eggs, fish, pickles, cookies, salads, and tartar sauce. It has a slight anise flavor.
Thyme	Thyme is used with fish dishes, meats, poultry, sauces, tomato dishes, and vegetables.
Turmeric	Turmeric and mustard are inseparable partners (it is used to color mustard); and turmeric is superb for almost every meat and egg dish, for pickles, and for curries. It adds yellow color.
Vanilla	Vanilla is almost always used in sweet dishes such as bakery products and desserts.
Wintergreen	Wintergreen is used mainly for candies and lozenges.

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Appendix E: Common Food Additives

Name	Function	Food Use and Comments
Acetic acid	pH control; preservative	Acid in vinegar is acetic acid; many food uses.
Adipic acid	pH control	Buffer and neutralizing agent; used in confections.
Ammonium alginate	Stabilizer and thickener; texturizer	Extracted from seaweed. Widespread food use.
Annatto	Color	Extracted from seeds of *Bixa orellana*. Butter, cheese, margarine, shortening, and sausage casings; coloring foods in general.
Arabinogalactan	Stabilizer and thickener; texturizer	Extracted from Western larch. Widespread food use; bodying agent in essential oils, nonnutritive sweeteners, flavor bases, nonstandardized dressings, and pudding mixes.
Ascorbic acid (vitamin C)	Nutrient; antioxidant; preservative	Widespread use in foods to prevent rancidity and browning; used in meat curing; generally recognized as safe (GRAS) additive.
Aspartame	Sweetener, low calorie	Soft drinks, chewing gum, powdered beverages, whipped toppings, puddings, gelatin, tabletop sweetener.
Azodicarbonamide	Flour-treating agent	Aging and bleaching ingredient in cereal flour.
Benzoic acid	Preservative	Widespread food use.
Benzoyl peroxide	Flour-treating agent	Bleaching agent in flour; may be used in some cheeses.
Beta-apo-8 carotenol	Color	Natural food color. General use not to exceed 30 mg per lb or pt of food.
BHA (butylated hydroxyanisole)	Antioxidant; preservative	Fats, oils, dry yeast, beverages, breakfast cereals, dry mixes, shortening, potato flakes, chewing gum, sausage; often used in combination with BHT.
BHT (butylated hydroxytoluene)	Antioxidant; preservative	Rice, fats, oils, potato granules, breakfast cereals, potato flakes, shortening, chewing gum, sausage; often used in combination with BHA.
Biotin	Nutrient	Rich natural sources are liver, kidney, pancreas, yeast, milk; vitamin supplement.
Calcium alginate	Stabilizer and thickener; texturizer	Extracted from seaweeds. Widespread food use.
Calcium carbonate	Nutrient	Mineral supplement.
Calcium lactate	Preservative	General-purpose and/or miscellaneous use.
Calcium phosphate	Leavening agent; sequestrant, nutrient	General-purpose and/or miscellaneous use; mineral supplement.
Calcium propionate	Preservative	Bakery products, alone or with sodium propionate; inhibits mold and other microorganisms.
Calcium silicate	Anticaking agent	Used in baking powder, salt, and food; GRAS for use in baking powder and salt.
Canthaxanthin	Color	Widely distributed in nature. Color for foods; more red than carotene.
Caramel	Color	Miscellaneous and color for foods.
Carob bean gum	Stabilizer and thickener	Extracted from bean of carob tree (*Locust bena*). Numerous foods such as confections, syrups, cheese spreads, frozen desserts, and salad dressings.
Carrageenan	Emulsifier; stabilizer and thickener	Extracted from seaweed. A variety of foods, primarily those with a water or milk base, especially ice cream.
Cellulose	Emulsifier; stabilizer and thickener	Component of all plants. Inert bulking agent in foods; may be used to reduce caloric content of food.
Citric acid	Preservative; antioxidant: pH control agent; sequestrant	Widely distributed in nature in both plants and animals. Miscellaneous use; used in lard, shortening, sausage, margarine, chili con carne, cured meats, and freeze-dried meats.
Citrus Red No. 2	Color	Coloring skins of oranges.
Cochineal	Color	Derived from the dried female insect, *Coccus cacti*. Provides red color for such foods as meat products and beverages.

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Appendix E *(continued)*

Name	Function	Food Use and Comments
Corn endosperm oil	Color	Source of xanthophyll for yellow color. Used in chicken feed to color yolks of eggs and chicken skin.
Cornstarch	Anticaking agent; drying agent; formulation aid; processing aid; surface-finishing agent	Digestible polysaccharide used in many foods often in a modified form; example foods include baking powder, baby foods, soups, sauces, pie fillings, imitation jellies, custards, and candies.
Corn syrup	Flavoring agent; humectant; nutritive sweetener; preservative	Derived from hydrolysis of cornstarch. Employed in numerous foods, such as baby foods, bakery products, toppings, meat products, beverages, condiments, and confections.
Dextrose (glucose)	Flavoring agent; humectant; nutritive sweetener; synergist	Derived from cornstarch. Major users of dextrose are confection, wine, and canning industries; used to flavor meat products; used in production of caramel.
Diglycerides	Emulsifiers	Uses include frozen desserts, lard, shortening, and margarine.
Dioctyl sodium sulfosuccinate	Emulsifier; processing aid; surface active agent	Employed in gelatin dessert, dry beverages, fruit juice drinks, and noncarbonated beverages with cocoa fat; used in production of cane sugar and in canning.
Disodium guanylate	Flavor enhancer	Derived from dried fish or seaweed. Variety of uses.
Disodium inosinate	Flavor adjuvant	Derived from dried fish or seaweed; sodium guanylate is a by-product. Variety of uses.
EDTA (ethylenediaminetetraacetic acid)	Antioxidant; sequestrant	Calcium disodium and disodium salt of EDTA employed in a variety of foods, including soft drinks, alcoholic beverages, dressings, canned vegetables margarine, pickles, sandwich spreads, and sausage.
FD&C colors: Blue No. 1, Red No. 40, Yellow No. 5	Color	Coloring foods in general.
Gelatin	Stabilizer and thickener; texturizer	Derived from collagen. Employed in many foods, including confectionery, jellies, and ice cream.
Glycerine (glycerol)	Humectant	Miscellaneous and general-purpose additive.
Grape skin extract	Color	Colorings for carbonated drinks, beverage bases, ades, and alcoholic beverages.
Guar gum	Stabilizer and thickener; texturizer	Extracted from seeds of the guar plant. Employed in such foods as cheese, salad dressings, ice cream, and soups.
Gum arabic	Stabilizer and thickener; texturizer	Gummy exudate of Acacia plants. Used in a variety of foods.
Gum ghatti	Stabilizer and thickener; texturizer	Gummy exudate of plant growing in India and Ceylon. A variety of food uses.
Hydrogen peroxide	Bleaching agent	Modification of starch and bleaching tripe; bleaching agent.
Hydrolyzed vegetable (plant) protein	Flavor enhancer	To flavor various meat products.
Invert sugar	Humectant; nutritive sweetener	Primarily used in confectionery and brewing industry.
Iron	Nutrient	Dietary supplements and foods.
Iron-ammonium citrate	Anticaking agent	Used in salt.
Karaya gum	Stabilizer and thickener	Derived from dried extract of *Sterculia urens*. Variety of food uses; a substitute for tragacanth gum.
Lactic acid	Preservative, pH control	Normal product of human metabolism. Numerous uses in foods and beverages; a miscellaneous general-purpose additive.
Lecithin (phospha-tidylcholine)	Emulsifier; surface active agent	Normal tissue component of the body; naturally occurring in eggs; commercially derived from soybeans. Margarine, chocolate, and wide variety of other uses.
Mannitol	Anticaking; nutritive sweetener; stabilizer and thickener; texturizer	Special dietary foods. A sugar alcohol.
Methylparaben	Preservative	Food and beverages.

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Appendix E *(continued)*

Name	Function	Food Use and Comments
Modified food starch	Drying agent; formulation aid; processing aid; surface finishing agent	Digestible polysaccharide used in many foods and stages of food processing; examples include baking powder, puddings, pie fillings, baby foods, soups, sauces, candies, and so on.
Monoglycerides	Emulsifiers	Widely used in foods such as frozen desserts, lard, shortening, and margarine.
MSG (monosodium glutamate)	Flavor enhancer	To enhance the flavor of a variety of foods, including various meat products.
Papain	Texturizer	Used as a meat tenderizer. Achieves results through enzymatic action.
Paprika	Color; flavoring agent	To provide coloring and/or flavor to foods.
Pectin	Stabilizer and thickener; texturizer	Richest source of pectin is lemon and orange rind; present in cell walls of all plant tissues. Used to prepare jellies and similar foods.
Phosphoric acid	pH control	Used to increase effectiveness of antioxidants in lard and shortening.
Polyphosphates	Nutrient; flavor improver; sequestrant; pH control	Numerous food uses.
Polysorbates	Emulsifiers; surface active agent	Polysorbates designated by numbers such as 60, 65, and 80; variety of food uses, including baking mixes, frozen custards, pickles, sherbets, ice creams, and shortening.
Potassium alginate	Stabilizer and thickener; texturizer	Extracted from seaweed. Wide usage.
Potassium bromate	Flour treating agent	Employed in flour, whole wheat flour, and fermented malt beverages, as well as to treat malt.
Potassium iodide	Nutrient	Added to table salt or used in mineral preparations as a source of dietary iodine.
Potassium nitrite	Curing and pickling agent	To fix color in cured products such as meats.
Potassium sorbate	Preservative	Inhibits mold and yeast growth in foods such as wines, sausage casings, and margarine.
Propionic acid	Preservative	Mold inhibitor in breads and general fungicide; used in manufacture of fruit flavors.
Propyl gallate	Antioxidant; preservative	Used in products containing oil or fat; employed in chewing gum; used to retard rancidity in frozen fresh pork sausage.
Propylene glycol	Emulsifier; humectant; stabilizer and thickener; texturizer	Miscellaneous and/or general-purpose additive; uses include salad dressings, ice cream, ice milk, custards, and a variety of other foods.
Propylparaben	Preservative	Fungicide; controls mold in sausage casings; GRAS additive.
Saccharin	Nonnutritive sweetener	Special dietary foods and a variety of beverages; baked products; tabletop sweeteners.
Saffron	Color; flavoring agent	Derived from plant of western Asia and southern Europe. Used to color sausage casings, margarine, or product branding inks.
Silicon dioxide	Anticaking agent	Used in feed or feed components, beer production, production of special dietary foods; ink diluent for marking fruits and vegetables.
Sodium acetate	pH control; preservative	Miscellaneous and/or general-purpose use; meat preservation.
Sodium alginate	Stabilizer and thickener; texturizer	Extracted from seaweed; widespread food use.
Sodium aluminum sulfate	Leavening agent	Baking powders, confectionery; sugar refining.
Sodium benzoate	Preservative	To retard flavor reversion (e.g., in margarine).
Sodium bicarbonate	Leavening agent; pH control	Separation of fatty acids and glycerol on rendered fats; neutralize excess and clean vegetables in rendered fats, soups, and curing pickles.
Sodium chloride (salt)	Flavor enhancer; formulation acid; preservation	Widespread use of salt in many foods.
Sodium citrate	pH control; curing and pickling agent; sequestrant	Evaporated milk; miscellaneous and/or general-purpose food use; accelerate color fixing in baking products.

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Appendix E *(continued)*

Name	Function	Food Use and Comments
Sodium diacetate	Preservative; sequestrant	An inhibitor of molds and rope-forming bacteria in baking products.
Sodium nitrate (Chile Saltpeter)	Curing and pickling agent; preservative	Used with or without sodium nitrite in smoked, cured fish; cured meat products.
Sodium nitrite	Curing and pickling agent; preservative	May be used with sodium nitrate in smoked, cured fish, cured meat products, and pet foods.
Sodium propionate	Preservative	A fungicide and mold preventative in bakery products, alone or with calcium propionate.
Sorbic acid	Preservative	Fungistatic agent for foods, especially cheeses; other uses include baked goods, beverages, dried fruits, fish, jams, jellies, meats, pickled products, and wines.
Sorbitan monostearate	Emulsifier; stabilizer and thickener	Widespread food usage such as whipped toppings, cakes, cake mixes, confectionery, icings, and shortenings; also many nonfood uses.
Sorbitol	Humectant; nutritive sweetener; stabilizer and thickener, sequestrant	Occurs naturally in berries, cherries, plums, pears, and apples; a sugar alcohol. Examples of use include chewing gum, meat products, icings, dairy products, beverages, and pet foods.
Sucrose (table sugar)	Nutritive sweetener; preservative	Sugar occurs naturally in some fruits and vegetables. The most widely used additive; used in beverages, baked goods, candies, jams and jellies—an endless list, including meat products.
Tagetes (Aztec marigold)	Color	Source is flower petals of Aztec marigold. To enhance yellow color of chicken skin and eggs, incorporated in chicken feed.
Tartaric acid	pH control	Occurs in many fruits, free or combined with calcium, magnesium, or potassium. Used in the soft drink industry, confectionery products, bakery products, and gelatin desserts.
Titanium dioxide	Color	For coloring foods generally, except standardized foods; used for coloring ingested and applied drugs.
Tocopherols (vitamin E)	Antioxidant; nutrient	To retard rancidity in foods containing fat; used as a supplement.
Tragacanth gum	Stabilizer and thickener; texturizer	Derived from the plant *Astragalus gummifier.*
Turmeric	Color	Derived from rhizome of *Curcuma longa.* Food use in general, except standardized foods; to color sausage casings, margarine or shortening; ink for branding or marking products.
Vanilla	Flavoring agent	Used in various bakery products, confectionery and beverages; natural flavoring extracted from cured, full-grown unripe fruit of *Vanilla panifolia.*
Vanillin	Flavoring agent and adjuvant	Widespread confectionery, beverage, and food use; synthetic form of vanilla.
Yellow prussiate of soda	Anticaking agent	Employed in salt.

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Appendix F: Answers to Multiple-Choice Questions

Chapter 1	Chapter 7	Chapter 13	Chapter 19	Chapter 25
1. b	1. c	1. c	1. c	1. b
2. d	2. d	2. d	2. b	2. a
3. d	3. a	3. b	3. d	3. b
4. b	4. a	4. d	4. d	4. c
5. d	5. d	5. b	5. b	5. d
6. d	6. c	6. d	6. b	6. c
7. d	7. b	7. a	7. a	7. b

Chapter 2	Chapter 8	Chapter 14	Chapter 20	Chapter 26
1. a	1. b	1. d	1. c	1. a
2. c	2. c	2. a	2. d	2. d
3. d	3. d	3. b	3. b	3. c
4. c	4. d	4. a	4. a	4. a
5. c	5. c	5. b	5. c	5. d
6. c	6. b	6. a	6. c	6. a
7. a	7. c	7. d	7. b	7. d

Chapter 3	Chapter 9	Chapter 15	Chapter 21	Chapter 27
1. a	1. d	1. d	1. b	1. b
2. b	2. c	2. b	2. a	2. c
3. d	3. b	3. d	3. a	3. b
4. b	4. a	4. d	4. d	4. a
5. d	5. d	5. a	5. b	5. d
6. a	6. b	6. a	6. c	6. a
7. d	7. c	7. c	7. b	7. c

Chapter 4	Chapter 10	Chapter 16	Chapter 22	Chapter 28
1. c	1. c	1. b	1. b	1. d
2. d	2. c	2. a	2. a	2. a
3. c	3. a	3. c	3. d	3. a
4. d	4. d	4. c	4. b	4. b
5. c	5. d	5. c	5. b	5. c
6. c	6. b	6. d	6. d	6. b
7. b	7. c	7. a	7. d	7. c

Chapter 5	Chapter 11	Chapter 17	Chapter 23	Chapter 29
1. a	1. d	1. b	1. b	1. b
2. d	2. b	2. c	2. d	2. a
3. a	3. c	3. a	3. b	3. b
4. b	4. d	4. b	4. b	4. c
5. c	5. c	5. d	5. a	5. d
6. a	6. b	6. a	6. c	6. b
7. d	7. d	7. c	7. b	7. d

Chapter 6	Chapter 12	Chapter 18	Chapter 24	Chapter 30
1. c	1. a	1. b	1. d	1. d
2. a	2. c	2. b	2. d	2. b
3. c	3. d	3. d	3. d	3. b
4. a	4. a	4. a	4. b	4. b
5. d	5. d	5. c	5. a	5. a
6. d	6. d	6. a	6. c	6. c
7. b	7. b	7. c	7. a	7. c

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Glossary

À la meunière Fish seasoned, lightly floured, and sautéed in clarified butter or oil and served with a sauce made with butter and parsley.

Acceptable Daily Intake (ADI) The amount of food additive that can be safely ingested daily over a person's lifetime.

Adenosine triphosphate (ATP) A universal energy compound in cells obtained from the metabolism of carbohydrate, fat, or protein. The energy of ATP, which is located in high-energy phosphate bonds, fuels chemical work at the cellular level.

Agglomerate To gather into a mass or ball. In the case of milk, the smaller protein particles regroup into larger, more porous particles.

Aging Holding meat after slaughter to improve texture and tenderness. A ripening that occurs when carcasses are hung in refrigeration units for a longer period than that required for the reversal of rigor mortis.

Al dente "To the tooth" in Italian; refers to pasta that is tender, yet firm enough to offer some resistance to the teeth.

Albedo The white, inner rind of citrus fruits, which is rich in pectin and aromatic oils.

Amphoteric Capable of acting chemically as either an acid or a base.

Antioxidant A compound that inhibits oxidation, which can cause deterioration and rancidity.

Aromatic compound A compound that has a chemical configuration of a hexagon.

As purchased (AP) Refers to the total amount of food purchased prior to any preparation.

Aspic A clear gel prepared from stock or fruit or vegetable juices.

Astringency A sensory phenomenon characterized by a dry, puckery feeling in the mouth.

Atoms The basic building blocks of matter; individual elements found on the periodic table.

Au gratin Food prepared with a browned or crusted top. A common technique is to cover the food with a bread crumb/sauce mixture and pass it under a broiler.

Au jus Served with its own natural juices; a term usually used in reference to roasts.

Bacteria One-celled microorganisms abundant in the air, soil, water, and/or organic matter (i.e., the bodies of plants and animals).

Baking powder A chemical leavener consisting of a mixture of baking soda, acid(s), and an inert filler such as cornstarch.

Baking soda A white chemical leavening powder consisting of sodium bicarbonate.

Barding Tying thin sheets of fat or bacon over lean meat to keep the meat moist during roasting. The sheets of fat are often removed before serving.

Baste To add a liquid, such as drippings, melted fat, sauce, fruit juice, or water, to the surface of food (usually roasting meat) to help prevent drying.

Batter A flour mixture that contains more water than a dough and whose consistency ranges from pourable to sticky.

Beading The formation of tiny syrup droplets on the surface of a baked meringue.

Beurre manié (burr mahn-YAY) A thickener made by blending equal parts of soft butter and flour together into a soft paste.

Bile A digestive juice made by the liver from cholesterol and stored in the gallbladder.

Biological value The percentage of protein in food that can be used by an animal for growth and maintenance. High-quality, complete proteins are considered to have a high biological value.

Biotechnology The alteration of a gene in a bacterium, plant, or animal for the purpose of changing one or more of its characteristics; previously called genetic engineering.

Bisque Traditionally, a cream soup made from shellfish. Marketers sometimes label creamed vegetable soups as bisques.

Blanch To dip a food briefly into boiling water and then into ice water to stop the cooking.

Blind bake To bake an unfilled piecrust.

Bloom (1) An undesirable, fuzzy, grayish appearance on chocolate's surface due to the recrystallization of fat or sugar. It results from improper cooling, fat incompatibility, high humidity, or temperature fluctuations during storage. (2) Cottony, fuzzy growth of molds. Also see cuticle.

Body The consistency of frozen desserts as measured by their firmness, richness, viscosity, and resistance to melting.

Boiling point The temperature at which a heated liquid begins to boil and changes to a gas.

Bouillon A broth made from meat and vegetables and then strained to remove any solid ingredients.

Bouquet garni A bundle of parsley, thyme, bay leaf, and whole black pepper rolled in a leek and tied together with twine.

Bran The hard outer covering just under the husk that protects the grain's soft endosperm.

Broth Stock made from meat or meat/bone combinations and some water with little or no flavoring. Broths are seldom reduced (simmered until much of the water evaporates) and therefore are not as strong-flavored as stocks.

Brown stock The stock resulting from browning bones and/or meat prior to simmering them.

Calorie The amount of energy required to raise 1 gram of water 1°C (measured between 14.5°C and 15.5°C at normal atmospheric pressure). A kilocalorie (kcalorie, kcal), the unit commonly used

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to measure food energy, is equal to 1,000 calories.

Candling A method of determining egg quality by examining eggs placed against a light.

Caramelization A process in which a dry sugar, or a sugar solution with most of its water evaporated, first melts into a clear, viscous liquid and then turns into a smooth, brown mixture as it is heated.

Carryover cooking The phenomenon in which food continues to cook after it has been removed from the heat source as the heat is distributed more evenly from the outer to the inner portion of the food.

Casein The primary protein (80%) found in milk; it can be precipitated (solidified out of solution) with acid or certain enzymes.

Catechins Flavonoid pigments that are a subgroup of the flavonol pigments.

Chalaza (pl. chalazae) The ropy, twisted strands of albumen that anchor the yolk to the center of the thick egg white.

Chemesthesis The ability to feel a food's chemical properties (e.g., cool mints or hot chili peppers).

Chiffon cake A cake made with fat and an egg white foam that combines the characteristics found in both shortened and unshortened cakes.

Chymosin (rennin) An enzyme sold commercially as rennet that causes milk to clot, forming a curd.

Clarified butter Butter that will not burn because its milk solids and water have been removed.

Clarify To make or become clear or pure.

Co-op Work-study program with a corporation that is often customized for the student.

Coagulate To clot or become semi-solid. In milk, denatured proteins often separate from the liquid by coagulation.

Coagulation The clotting or precipitation of protein in a liquid into a semi-solid compound.

Coarse dispersion (suspension) A type of dispersion in which the particles are larger than 1 micrometer in diameter and remain "suspended" in the continuous phase.

Codex Alimentarius Commission The international organization that develops international food standards, codes of practice, and other guidelines to protect consumers' health.

Collagen A pearly white, tough, and fibrous protein that provides support to muscle and prevents it from overstretching. It is the primary protein in connective tissue.

Colloidal dispersion A type of dispersion in which the particles are between 2 nanometers and 1 micrometer in diameter and thus too large to go into solution, but not large enough to precipitate out of the continuous phase.

Complete protein A protein, usually from animal sources, that contains all the essential amino acids in sufficient amounts for the body's maintenance and growth.

Compound A substance whose molecules consist of unlike atoms.

Conduction The direct transfer of heat from one substance to another that it is contacting.

Congener An alcohol by-product such as methanol or wood alcohol.

Connective tissue A protein structure that surrounds living cells, giving them structure and adhesiveness within themselves and to adjacent tissues.

Consistency A food's firmness or thickness.

Consommé A richly flavored soup stock that has been clarified and made transparent by the use of egg whites.

Convection The transfer of heat by moving air or liquid (water or fat) currents through and/or around food.

Country of origin labeling The required identification of the country of origin on the label for fresh red meat (beef, pork, lamb, veal), marinated products (marinated meats), seafood, produce, and peanuts.

Court bouillon Seasoned stock containing white wine and/or vinegar.

Cover The table setting, including the place mat, flatware, dishes, and glasses.

Critical control point (CCP) A point in the HACCP process that must be controlled to ensure the safety of the food.

Cross-contamination The transfer of bacteria, other microorganisms, or food allergens from one food or surface to another.

Cruciferous A group of indole-containing vegetables named for their cross-shaped blossoms; they are reported to have a protective effect against cancer in laboratory animals. Examples include broccoli, brussels sprouts, cabbage, cauliflower, kale, mustard greens, rutabaga, kohlrabi, and turnips.

Crumb The cell structure within the interior of a baked product that is revealed when it is sliced and that affects texture. Evaluation is based on cell size (called open, if medium to large, or closed, if small), cell shape, and cell thickness (thin walls occur in fine crumb, whereas thick walls predominate in a coarse crumb).

Crumbing A ceremonious procedure of Russian service in which a waiter, using a napkin or silver crumber, brushes crumbs off the tablecloth into a small container resembling a tiny dust pan.

Crustacean An invertebrate animal with a segmented body covered by an exoskeleton consisting of a hard upper shell and a soft under shell.

Crystalline candy A type of candy formed from a sugar solution handled so that the sugar crystallized; most crystalline candies are characterized by many fine, small crystals.

Crystallization The precipitation of crystals from a solution into a solid, geometric network.

Culture The ideas, customs, skills, and art of a group of people in a given period of civilization.

Curd The coagulated or thickened part of milk.

Cure To preserve food through the use of salt and drying. Sugar, spices, or nitrates may also be added.

Curing The aging of cheese in controlled conditions of temperature and humidity.

Current Good Manufacturing Practices (cGMPs) A set of regulations, codes, and guidelines for the manufacture of food products, drugs, medical devices, diagnostic products, and active pharmaceutical ingredients (APIs).

Cuticle (bloom) A waxy coating on an eggshell that seals the pores from bacterial contamination and moisture loss.

Cycle menu A menu that cycles through a certain order of meals over a period of 1 or more weeks (usually 3 or 4). Cycle menus offer a combination of variety and controlled costs.

Deglaze To add liquid to pan drippings and simmer/stir to dissolve and loosen

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cooked-on particles sticking to the bottom of the pan.

Degorge To peel and slice vegetables, sprinkle them with salt, and allow them to stand at room temperature until droplets containing bitter substances form on the surface; the moisture is then removed.

Dehydrate To remove at least 95% of the water from food through exposure to high temperatures.

Delaney Clause A clause added to the Food, Drug, and Cosmetic Act of 1938 stipulating that "no additive shall be deemed to be safe if it is found to induce cancer when ingested by man or animal."

Denaturation The irreversible process in which the structure of a protein is disrupted, resulting in partial or complete loss of function.

Density The concentration of matter measured by the amount of mass per unit volume. Objects with a higher density weigh more for their size.

Dextrinization The breakdown of starch molecules to smaller, sweeter-tasting dextrin molecules in the presence of dry heat.

Dextrose equivalent (DE) A measurement of dextrose concentration. A DE of 50 means the syrup contains 50% dextrose.

Dietary fiber The undigested portion of carbohydrates remaining in a food sample after exposure to human digestive enzymes.

Dispersion A system (mixture) containing particles (solid, liquid, or gas) dispersed in a continuous phase (solid, liquid, or gas).

Distillation A procedure in which pure liquid is obtained from a solution by boiling, condensation of the vapor, and collection of the condensed liquid in a separate container.

Diverticulosis An intestinal disorder characterized by formation of pockets that bulge out from the digestive tract, especially the colon.

Dough A flour mixture that is dry enough to be handled and kneaded.

Drug A product able to treat, prevent, cure, mitigate, or diagnose a disease or disease symptom.

Drupes Fruits with seeds encased in a pit. Examples are apricots, cherries, peaches, and plums.

Dry-heat preparation A method of cooking in which heat is transferred by air, radiation, fat, or metal.

Edible coating A thin layer of edible material, such as natural wax, oil, or petroleum-based wax, that serves as a barrier to gas and moisture.

Edible portion (EP) Food in its raw state, minus that which is discarded—bones, fat, skins, and/or seeds.

Electrolyte An electrically charged ion in a solution.

Emulsifier A compound that possesses both water-loving (hydrophilic) and water-fearing (hydrophobic) properties so that it disperses in either water or oil.

Emulsion A liquid dispersed in another liquid with which it is usually immiscible (incapable of being mixed).

Endosperm The largest portion of the grain, containing all of the grain's starch.

Enriched Modified by the addition of certain nutrients at levels established by federal standards to replace those lost during processing (refers to refined grain products).

Enrobe To coat food with melted chocolate that hardens to form a solid casing.

Enzymatic browning A reaction in which an enzyme acts on a phenolic compound in the presence of oxygen to produce brown-colored products.

Enzyme A protein that catalyzes (causes) a chemical reaction without itself being altered in the process.

Essential nutrients Nutrients that the body cannot synthesize at all or in amounts sufficient to meet the body's needs.

Essential oil An oily substance that is volatile (easily vaporized), with 100 times the flavoring power of the material from which it originated.

Eviscerate To remove the entrails from the body cavity of an animal.

Extractives Flavor compounds consisting of nonprotein, nitrogen-containing substances that are end products of protein metabolism.

Fermentation The conversion of carbohydrates to carbon dioxide and alcohol by yeast or bacteria.

Finfish Fish that have fins and internal skeletons.

Fire point The temperature at which a heated substance (such as oil) bursts into flames and burns for at least 5 seconds.

Flash point The temperature at which tiny wisps of fire streak to the surface of a heated substance (such as oil).

Flatware Eating and serving utensils (e.g., knives, forks, and spoons).

Flavor The combined sense of taste, odor, and mouthfeel.

Flavor reversion The breakdown (oxidation) of α-linolenic acid, an essential fatty acid found in certain vegetable oils, leading to an undesirable flavor change prior to the start of actual rancidity.

Flavoring Any substance that adds a new flavor to food.

Flocculation A process in which colloid particles come out of suspension and solidify in the form of flocs, or flakes.

Foam A colloidal dispersion of a gas in a liquid.

Food additive A substance added intentionally or unintentionally to food that becomes part of the food and affects its character.

Food Code An FDA publication updated every 2 years that explains how food-service organizations can prevent foodborne illness while preparing food. Available at www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/ucm2006808.htm.

Food cost The cost of foods purchased, often expressed as a percentage obtained by dividing the raw food cost by the menu price.

Food fraud Deliberate substitution, addition, tampering, or misrepresentation of food, ingredients, packaging, or statements made about a product for economic gain. Also known as Economically Motivated Adulteration (EMA).

Food group plan A diet-planning tool that groups foods together based on nutrient and/or kcalorie content and then specifies the amount of each group a person should consume based on their recommended kcalorie intake.

Food infection An illness resulting from ingestion of food containing large numbers of living bacteria or other microorganisms.

Food intoxication An illness resulting from ingestion of food containing a toxin.

Foodborne illness An illness transmitted to humans by food.

Forecast The amount of food that a food-service operation is predicted to require within a given time period.

Fortified Modified by the addition of nutrients that were not present in the original food.

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Free radical An unstable molecule that is extremely reactive and that can damage cells.

Freeze-dry To remove water from food when it is in a frozen state, usually in a vacuum.

Freezer burn White or grayish patches on frozen food caused by water evaporating into the package's air spaces and possibly recrystallizing as ice on the food's surface.

Freezing point The temperature at which a liquid changes to a solid.

Fruit The edible part of a plant that develops from a flower.

Fumet A flavorful fish stock made with white wine.

Functional food A food or beverage that imparts physiological benefits that enhance overall health, prevents or treats a disease or condition, and/or improves physical/mental performance.

Gaping The separation of fish flesh into flakes that occurs as the steak or fillet ages.

Gelatinization The increase in volume, viscosity, and translucency of starch granules are heated in a liquid.

Gene A unit of genetic information in the chromosome.

Generally Recognized as Safe (GRAS) list A list of compounds exempt from the food additive definition because they are generally recognized as safe based on "a reasonable certainty of no harm from a product under the intended conditions of use."

Genetically modified organisms (GMOs) Plants, animals, or microorganisms that have had their genes altered through genetic engineering using the application of recombinant deoxyribonucleic acid (rDNA) technology.

Germ The smallest portion of the grain, and the embryo for a future plant.

Glaze (1) A flavoring obtained from soup stock that has been concentrated by evaporation until it attains a syrupy consistency with a highly concentrated flavor. (2) A sugar-based icing poured over pies or pastries that hardens to provide flavor and structure.

Gluten The protein portion of wheat flour with the elastic characteristics necessary for the structure of most baked products.

Grading The voluntary process in which foods are evaluated for yield (a 1 to 5 grading for meats only) and/or quality (e.g., Prime, Choice, AA, A, Fancy, etc.).

Gram A metric unit of weight. One gram (g) is equal to the weight of 1 cubic centimeter (cc) or milliliter (mL) of water (at a specific temperature and pressure).

GRE The Graduate Record Examination®; a general test that measures verbal reasoning, quantitative reasoning, critical thinking, and analytical writing skills.

Gustatory Relating to the sense of taste.

HACCP Hazard Analysis and Critical Control Points System, a systematized approach to preventing foodborne illness during the production and preparation of food.

Halal An Arabic word meaning "permissible." Usually refers to permissible foods under Islamic law.

HARPC Hazard Analysis and Risk-Based Preventive Controls is a global set of required guidelines (evolving from and newer than HACCP) that addresses food safety through the analysis and control of hazards from farm to fork.

Health claim A statement that describes a relationship between a food, food component, or dietary supplement ingredient and reduced risk of a disease or disease-related condition.

Heat of solidification The temperature at which a substance converts from a liquid to a solid state.

Heat of vaporization The amount of heat required to convert a liquid to a gas.

Heat shock Repeated cycles of temperature fluctuations between cold and warm that cause larger ice crystal growth, reducing the quality of frozen desserts.

Herb A plant leaf valued for its flavor or scent.

High-conversion corn syrups Corn syrups with a dextrose equivalent over 58.

Homogenization A mechanical process that breaks up the fat globules in milk into much smaller globules that do not clump together and are permanently dispersed in a very fine emulsion.

Hops The dried fruit of the Humulus lupulus plant, which grows in the Pacific Northwest of the United States.

Humectant A substance that attracts water to itself. If added to food, it increases the water-holding capacity of the food and helps to prevent it from drying out by lowering the water activity.

Husk The rough outer covering protecting the grain.

Hydrogenation A commercial process in which hydrogen atoms are added to the double bonds in monounsaturated or polyunsaturated fatty acids to make them more saturated.

Hydrolysis A chemical reaction in which water (hydro) breaks (lysis) a chemical bond in another substance, splitting it into two or more new substances.

Hydrophilic A term describing "water-loving" or water-soluble substances.

Hydrophobic A term describing "water-fearing" or nonwater-soluble substances.

Hygroscopic Having the ability to attract and retain moisture.

Imitation milk A product defined by the FDA as having the appearance, taste, and function of milk (its original counterpart) but as being nutritionally inferior.

Incomplete protein A protein, usually from plant sources, that does not provide all the essential amino acids.

Induction The transfer of heat energy to a neighboring material without contact.

Interesterification A commercial process that rearranges fatty acids on the glycerol molecule within triglycerides so that they are more heterogeneous, result in smaller fat crystals, and produce a smoother-consistency fat.

Interfering agent A substance added to the sugar syrup to prevent the formation of large crystals, resulting in a candy with a waxy, chewy texture.

Internships Corporate internships are temporary job positions (usually for 3 months during the summer or for 6 months, which includes a summer and a semester) in industry, government, or academia. Dietetic internships are supervised practice experiences that average 12 months (6 to 24 months).

Invert sugar An equal mixture of glucose and fructose created by hydrolyzing sucrose.

Ionize To separate a neutral molecule into electrically charged ions.

Irradiation A food preservation process in which foods are treated with low doses of gamma rays, X-rays, or electrons.

Job description An organized list of job duties used for finding qualified applicants, training, performance appraisal, defining

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authority and responsibility, and determining salary.

Julienne To cut food lengthwise into very thin, stick-like shapes.

Kinetic energy Energy associated with motion.

Knead To work dough into an elastic mass by pushing, stretching, and folding it.

Kosher (From Hebrew) Food that is "fit, right, proper" to be eaten according to Jewish dietary laws.

Lamination The arrangement of alternating layers of fat and flour in rolled pastry dough. During baking, the fat melts and leaves empty spaces for steam to lift the layers of flour, resulting in a flaky pastry.

Larding Inserting strips of bacon, salt pork, or other fat into slits in the meat with a large needle.

Latent heat The amount of energy in calories per gram absorbed or emitted as a substance undergoes a change in state (liquid/solid/gas).

Legumes Members of the plant family *Leguminosae* that are characterized by growing in pods. Vegetable legumes include beans, peas, and lentils.

Maillard reaction The reaction between a sugar (typically reducing sugars such as glucose/dextrose, fructose, lactose, or maltose) and a protein (specifically the nitrogen in an amino acid), resulting in the formation of brown complexes.

Marbling Fat deposited in the muscle that can be seen as little white streaks or drops.

Marinade A liquid containing acids, aromatics, and/or oil in which meat, fish, or vegetables are soaked to enrich their flavor or tenderize them.

Masa A corn product made by cooking corn in water and then grinding it into a pourable slurry. *Masa* means "dough" in Mexico, and it is often used to make tortillas, tamales, and many commercial corn-based snacks.

Mealy Refers to a pastry with a grainy or less flaky texture, created by coating all of the flour with fat.

Medical food A food to be taken under the supervision of a physician and intended for the dietary management of a disease/condition for which distinctive nutritional requirements are established by scientific evaluation.

Medical nutrition therapy The provision of nutrition care in clinical settings to manage nutrition-related diseases such as heart disease, diabetes, cancer, renal disease, liver failure, and others. Registered dietitian nutritionists (RDN), as part of the health care team and often referred by a physician, contribute to the patient's care by providing this dietary therapy.

Melting point The temperature at which a solid changes to a liquid state.

Meniscus The imaginary line read at the bottom of the concave arc at the water's surface.

Methylxanthine A compound that stimulates the central nervous system.

Microorganism Plant or animal organism that can only be observed under the microscope—for example, bacterium, mold, yeast, virus, or animal parasite.

Milk solids-not-fat (MSNF) Federal standard identifying the total solids, primarily proteins and lactose, found in milk, minus the fat.

Mirepoix A collection of lightly sautéed, chopped vegetables (a 2:1:1 ratio by weight of onions, celery, and carrots) flavored with spices and herbs (sage, thyme, marjoram, and chopped parsley are the most common).

Modified starch A starch that has been chemically or physically modified to create unique functional characteristics.

Moist-heat preparation A method of cooking in which heat is transferred by water, any water-based liquid, or steam.

Mold A fungus (a plant that lacks chlorophyll) that produces a furry growth on organic matter.

Molecule A unit composed of one or more types of atoms held together by chemical bonds.

Mollusk An invertebrate animal with a soft, unsegmented body usually enclosed in a shell.

Monograph A summary sheet (fact sheet) describing a substance in terms of name (common and scientific), chemical constituents, functional uses (medical and common), dosage, side effects, drug interactions, and references.

Mother sauce A sauce that serves as the springboard from which other sauces are prepared.

Mycotoxin A toxin produced by a mold.

Myocommata Large sheets of very thin connective tissue separating the myotomes in fish muscle.

Myotomes Layers of short fibers in fish muscle.

No-observed-effect level (NOEL) The level or dose at which an additive is fed to laboratory animals without any negative side effects.

Noncrystalline (amorphous) candy A type of candy formed from sugar solution that did not crystallize.

Nonnutritive sweeteners Food additives requiring FDA approval that provide sweetness with no or insignificant amounts of energy (kcal). Also known as alternative sweeteners, artificial sweeteners, noncaloric sweeteners, very-low-calorie sweeteners, sugar substitutes, sugar replacers, and intense sweeteners.

Nontempered coating A coating resembling chocolate that is not subject to bloom because it is made with fats other than cocoa butter.

Nuclei Small aggregates of molecules serving as the starting point of crystal formation.

Nutraceutical A bioactive compound (nutrient or nonnutrient) that has health benefits.

Nutrient content claims Food label descriptions communicating the amount of a nutrient or dietary substance contained in a food or beverage.

Nutrients Food components that nourish the body to provide growth, maintenance, and repair.

Nutrigenomics A field of study focusing on genetically determined biochemical pathways linking specific dietary substances with health and disease.

Nutrition care process A standardized process for providing high-quality nutrition care implemented by registered dietitian nutritionists (RDN) and nutrition and dietetic technicians, registered (NDTR).

Objective tests Evaluations of food quality that rely on numbers generated by laboratory instruments that are used to quantify the physical and chemical differences among foods.

Ohmic heating A food preservation process in which an electrical current is passed through food, generating enough heat to destroy microorganisms.

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Oleogustus A proposed sixth taste for the unique flavor of fat; from the Latin for "taste for fat."

Olfactory Relating to the sense of smell.

Omega-3 fatty acids Polyunsaturated fatty acids in which the first double bond is three carbons from the methyl (CH_3) end; examples are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Organizational chart A descriptive diagram showing the administrative structure of an organization.

Osmosis The movement of a solvent through a semi-permeable membrane to the side with the higher solute concentration, equalizing the solute concentration on both sides of the membrane.

Osmotic pressure The pressure or pull that develops when two solutions of different solute concentration are on either side of a permeable membrane.

Outbreak As defined by the CDC, the occurrence of two or more cases of a similar illness resulting from the ingestion of a common food.

Oven spring The quick expansion of dough during the first 10 minutes of baking, caused by expanding gases.

Overrun The volume of a frozen dessert over and above the volume of the liquid mixture from which it was produced; this increase in volume results from the incorporation of air during freezing.

Parasite An organism that lives on or within another organism at the host's expense without any useful return.

Parboil To boil, but only partially cook, a food.

Pascalization A food preservation process utilizing ultrahigh pressures to inhibit the chemical processes of food deterioration.

Pasteurization A food preservation process in which liquids (milk, beer, soups, or juices) are heated to a specified temperature for a certain period of time to destroy most microorganisms (bacteria, yeasts, and molds) that could cause disease, spoilage, or undesired fermentation.

Patent flour Flour containing the finest streams produced during milling.

Pathogenic Causing or capable of causing disease.

Peptide bond The chemical bond between two amino acids.

Percentage yield The ratio of edible food to food as purchased. Edible food = food as purchased minus losses due to waste, inedible portions, and/or cooking (if applicable).

pH scale A scale used to measure the degree of acidity or alkalinity of a substance, with 1 the most acidic, 14 the most alkaline, and 7 neutral.

Phenolic A chemical term to describe an aromatic (circular) ring attached to one or more hydroxyl (–OH) groups.

Phytochemical A nonnutritive component ("chemical") in plants ("phyto") considered to have positive health benefits.

Plain pastry Pastry made for producing piecrusts, quiches, and main-dish pies.

Plant stanol esters Naturally occurring substances in plants that help block absorption of cholesterol from the digestive tract.

Plasticity The ability of a fat to be shaped or molded.

Polymerization A process in which free fatty acids link together, especially when overheated, resulting in a gummy, dark residue and an oil that is more viscous and prone to foaming.

Polymorphism The capability of solid fats to change into several crystalline forms, each with its own melting point, crystal structure, and solubility.

Polyphenol An organic compound with two or more phenols—carbon atoms structured into an aromatic ring with one or more hydroxyl (–OH) groups.

Pomes Fruits with seeds contained in a central core. Examples are apples and pears.

Prawn A large crustacean that resembles shrimp but is biologically different. Large shrimp are often called by this name.

Prebiotics Nondigestible food ingredients (generally fibers such as fructooligosaccharides [FOS] and inulin) that support the growth of probiotics.

Precipitate To separate or settle out of a solution.

Prime (season) To seal the pores of a pan's metal surface by coating the pan with a layer of oil and then heating it.

Prion An infectious protein material, called prion protein (PrP) that does not contain DNA or RNA, but that can lead to disease by misfolding other proteins.

Probiotics Live microbial food ingredients (i.e., bacteria) that have a beneficial effect on human health.

Process (processed) cheese A cheese made from blending one or more varieties of cheese, with or without heat, and mixing the result with other ingredients.

Processed Foods Any deliberate change to a food before it is available to eat, such as salting, fermenting, drying, canning, freezing, packaging, or other types of processing.

Product recall Civil court action to seize or confiscate a product that is defective, unsafe, filthy, or produced under unsanitary conditions.

Proof (1) To increase the volume of dough through fermentation, that is, to allow dough to rise. (2) Alcohol strength indicated by a number that is twice the percent by volume of alcohol present.

Proof box A large, specially designed container that maintains optimal temperatures and humidity for the fermentation and rising of dough.

Protein complementation Two incomplete-protein foods, each of which supplies the amino acids missing in the other, combined to yield a complete protein profile.

P/S ratio The ratio of polyunsaturated fats to saturated fats. The higher the P/S ratio, the more polyunsaturated fats the food contains.

Puff pastry A delicate pastry that puffs up in size during baking because of its many alternating layers of fat and flour.

Qualified health claim As defined by the FDA, a type of health claim that must be accompanied by a "qualifying" statement specifying the degree of scientific evidence that supports it. The FDA allows these statements to be made based on the "weight of the evidence," but does not consider them to be backed by significant scientific agreement.

Quality grades The USDA standards for beef, veal, lamb, and mutton.

Quick bread Bread leavened with air, steam, and/or carbon dioxide from baking soda or baking powder.

Radiation The transfer of heat energy in the form of waves of particles moving outward from their source.

Rancidity The breakdown of the polyunsaturated fatty acids in fats that results in disagreeable odors and flavors.

Reducing sugars Sugars such as glucose, fructose, maltose, and others that have a

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reactive aldehyde or ketone group. (Sucrose is not a reducing sugar.)

Reduction The process in which a liquid is simmered or boiled until the volume is reduced through evaporation, leaving a thicker, more concentrated, flavorful mass; or the product of this process.

Reference protein A standard against which to measure the quality of other proteins.

Registered Dietitian Nutritionist (RDN; old term was registered dietitian, RD) A health professional who counsels people about their medical nutrition therapy (carbohydrate-controlled, low-fat, low-sodium, etc.). Registration requirements consist of completing an approved 4-year college degree, exam, internship, and ongoing continuing education. Categories include generalists, specialists, and advanced practitioners.

Respiration rate The rate of carbon dioxide production from a given amount of produce over a certain unit of time.

Retail cuts Smaller cuts of meat obtained from wholesale cuts and sold to the consumer.

Retrogradation A phenomenon during the cooling of gelled starch when the amylose and amylopectin molecules "retrograde" and realign themselves. Staling in baked products and syneresis in gels may result.

Rhizome An underground (usually) stem that generates: (1) shoots that rise up and/or horizontally to propagate new plants, and (2) roots that grow down to the ground.

Rigor mortis From the Latin for "stiffness of death," the temporary stiff state following death as muscles contract.

Ripening The chemical and physical changes that occur during the curing period.

Rope The sticky, moist texture of breads resulting from contamination by Bacillus mesentericus bacteria.

Roux A thickener made by cooking equal parts of flour and fat.

Saturated solution A solution holding the maximum amount of solute that can be dissolved at its current temperature.

Scalloped Baked with milk sauce and bread crumbs.

Scampi A crustacean found in Italy and not generally available in North America. The term is often used incorrectly to describe a popular shrimp dish.

Score To use a sharp knife or a special blade called a "lame" to create ¼- to ½-inch-deep slashes on the risen dough's top surface just prior to baking.

Sear To brown the surface of meat by brief exposure to high heat.

Searing Cooking that exposes a meat cut to very high initial temperatures; this is intended to seal the pores, increase flavor, and enhance color by browning.

Seasoning Any compound that enhances the flavor already found naturally in a food.

Seed To create nuclei or starting points from which additional crystals can form.

Sensory (subjective) tests Evaluations of food quality based on sensory characteristics and personal preferences as perceived by the five senses.

Shortened cake A cake made with fat.

Shortening A fat that tenderizes, or shortens, the texture of baked products by impeding gluten development, making them softer and easier to chew.

Silence cloth A piece of fabric placed between the table and the tablecloth to protect the table, quiet the placement of dishes and utensils, and keep the tablecloth from slipping.

Simple syrup A liquid produced by boiling sugar and water together. The ratio of sugar to water determines whether it is a light, medium, or heavy syrup.

Slurry A thickener made by combining starch and a cool liquid.

Small sauce A secondary sauce created when a flavor is added to a mother sauce.

Smoke point The temperature at which fat or oil begins to smoke, due to the release of free glycerol, followed by breakdown of glycerol to acrolein.

Sol A colloidal dispersion of a solid dispersed in a liquid (see Chapter 3 for colloidal dispersions).

Solubility The ability of one substance to blend uniformly with another.

Solute Solid, liquid, or gas compound dissolved in another substance.

Solution A completely homogeneous mixture of a solute (usually a solid) dissolved in a solvent (usually a liquid).

Solvent A substance (usually a liquid) in which another substance is dissolved.

Specific gravity The density of a substance compared to another substance (usually water).

Specific heat The amount of heat required to raise the temperature of 1 gram of a substance 1°C.

Specifications Descriptive information used in food purchasing that defines the minimum and maximum levels of acceptable quality or quantity (i.e., U.S. grade, weight, size, fresh or frozen).

Spice A seasoning or flavoring added to food that is derived from the fruit, flowers, bark, seeds, or roots of a plant.

Spore Encapsulated, dormant form assumed by some microorganisms that is resistant to environmental factors that would normally result in their death.

Stabilizer A compound such as vegetable gum that attracts water and interferes with ice crystal formation, resulting in a smoother consistency in frozen desserts.

Standardized recipe A food-service recipe; that is, a set of instructions describing how a particular dish is prepared by a specific establishment. It ensures consistent food quality and quantity, the latter of which provides portion/cost control.

Standards of Fill The amount of raw product that must be put into a container before liquid (brine or syrup) is added.

Standards of Identity Requirements for the type and amount of ingredients a food should contain in order to be labeled as that food.

Standards of Minimum Quality Minimum quality requirements for tenderness, color, and freedom from defects in canned fruits and vegetables.

Starter A culture of microorganisms, usually bacteria and/or yeasts, used in the production of certain foods such as sourdough bread, cheese, and alcoholic beverages.

Sterilization The elimination of all microorganisms through extended boiling, heating to temperatures much higher than boiling, or the use of certain chemicals.

Stock The foundational thin liquid of many soups, produced when meat, poultry, seafood (and/or their bones), or vegetables are reduced (simmered) and strained.

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Storage eggs Eggs that are treated with a light coat of oil or plastic and stored in high humidity at low refrigerator temperatures very close to the egg's freezing point (29 to 32°F [–1.5 to 0°C]).

Straight flour Flour containing all the different types of streams produced during milling.

Stream A division of milled flour based on particle size.

Streusel topping A crunchy, flavorful topping that can be strewn over the top of pies; it is made by combining flour, butter or margarine, brown sugar, and possibly spices (cinnamon) and chopped nuts (pecans, walnuts, or almonds).

Structure/function claims Statements identifying relationships between nutrients or dietary ingredients and a body function.

Sublimation The process in which a solid changes directly into a vapor without passing through the liquid phase.

Substrate A substance that is acted upon, such as by an enzyme.

Superglycerinated Describes a shortening that has had monoglycerides and diglycerides added for increased plasticity.

Supersaturated solution An unstable solution created by cooling a saturated solution without disturbance; the solution contains more than the maximum amount of solute that can be dissolved at that temperature.

Surfactant A surface-active agent that reduces a liquid's surface tension to increase its wetting and blending ability.

Surimi Japanese for "minced meat"; a fabricated fish product usually made from Alaska pollock, a deep-sea whitefish, which is skinned, deboned, minced, washed, strained, and shaped into pieces to resemble crab, shrimp, or scallops.

Sweat The stage of cooking in which food, especially vegetables, becomes soft and translucent.

Syneresis (weeping) The seepage of water out of an aging gel because of the contraction of the gel (bonds tighten between the amylose molecules). Examples of liquid seeping out of foods include aging yogurt, puddings, and gelatins.

Tannins Polymers of various flavonoid compounds; some of the larger ones yield reddish and brown pigments.

Temperature danger zone The temperature range—considered to be 40 to 140°F (4 to 60°C) by the USDA for consumers, and 41 to 135°F (5 to 57°C) according to the FDA Food Code for retailers—that is ideal for bacterial growth.

Tempering The process of heating and cooling chocolate to specific temperatures, making it more resistant to melting and imparting a smooth, glossy, hard finish.

Tenure track The process in which new faculty members are hired as assistant professors and are on probation for approximately 5 years. If their yearly contract is renewed for 5 years in a row based on satisfactory performance, they may apply for tenure (permanent hire) and promotion to associate professor. The next and final step is promotion to full professor.

Test of English as a Foreign Language™ (TOEFL) A test that measures the ability of non-native speakers to understand English as it is spoken, written, and heard in colleges and universities.

Three-compartment sink A sink divided into three sections, the first for soaking and washing, the second for rinsing, and the third for sanitizing.

Truss To tie the legs and wings against the body of the bird to prevent them from overcooking before the breast is done and to enhance presentation.

Tuber Enlarged tip of a rhizome (underground stem) that stores food.

Turgor The rigid firmness of a plant cell resulting from being filled with water.

Ultrahigh-temperature (UHT) milk Milk that has been pasteurized using very high temperatures (280°F/138°C), is aseptically sealed, and is capable of being stored unrefrigerated for up to 3 months.

Ultrapasteurization A process in which a milk product is heated above 145°F (63°C), but below 280°F (138°C) for 0.01 to 15 seconds.

Unqualified health claim As defined by the FDA, a type of health claim that is supported by significant scientific agreement; also known as an authorized claim.

Unshortened cake A cake made without added fat.

Variety meats The liver, sweetbreads (thymus), brain, kidneys, heart, tongue, tripe (stomach lining), and oxtail (tail of cattle).

Verification form Documentation provided by the dietetic program director to an individual who has completed the undergraduate AND course requirements approved by the AND for that particular academic institution. This form is required for: (1) acceptance into an AND internship and (2) taking the AND examination.

Vinaigrette A salad dressing consisting of only oil, vinegar, and seasoning.

Vintage The year in which a wine was bottled; especially, an exceptionally fine wine from a year with a good crop.

Virus An infectious microorganism consisting of RNA or DNA that reproduces only in living cells.

Viscosity The resistance of a fluid to flowing freely, caused by the friction of its molecules against a surface.

Vitelline membrane The membrane surrounding the egg yolk and attached to the chalazae.

Volatile molecules Molecules capable of evaporating like a gas into the air.

Volume A measurement of three-dimensional space that is often used to measure liquids.

Water activity (a_w) A measurement of the amount of available (free) water in foods. Water activity ranges from 0 to the highest value of 1.00, which is pure water.

Weeping (syneresis) Extraction of liquid from a gel. An example is the escape of liquid to the bottom of a meringue or the formation of pores filled with liquid within a meringue.

Whey The watery component of milk removed from the curd in cheese manufacture. Consists primarily of water (93%), lactose, and whey proteins (primarily lactalbumin and lactoglobulin).

White sauce A mixture of flour, milk, and usually fat.

White stock The flavored liquid obtained by simmering the bones of beef, veal, chicken, or pork.

Whole Foods Foods as you find them in their natural state, minimally processed, and free from additives or artificial ingredients.

Whole grains As defined by the American Association of Cereal Chemists (AACC), "Foods made from the entire grain seed, usually called the kernel, which consists of the bran, germ, and endosperm."

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Wholesale (primal) cuts The large cuts of an animal carcass, which are further divided into retail cuts.

Winterizing A commercial process for vegetable oils that removes the high-melting point triglycerides that would otherwise crystallize during low-temperature storage (in a refrigerator) and make the oil appear cloudy.

Yeast A single-celled fungus (a plant that lacks chlorophyll) that is able to ferment sugars and that is used for producing food products such as bread and alcohol.

Yeast bread Bread made with yeast, which produces carbon dioxide gas through the process of fermentation, causing the bread to rise.

Yield grade A standard representing the amount of lean meat on the carcass in proportion to fat, bone, and other inedible parts.

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Index

A

À la meunière, 190–91. *see also* Fish and shellfish
Abalone, 188
Academy of Nutrition and Dietetics (AND), 8, 10
Acceptable Daily Intake (ADI), 419, 563
Accessories, table settings, 127–28
Acesulfame-k, 421
Acid coagulation, cheese, 223
Acidophilus milk, 211
Adaptation, odor, 2
Additives. *See* Food additives
Adenosine triphosphate (ATP), 134
Adipose (fatty tissue), 134
Aerated candies, 496
Affective (acceptance or preference) tests, 21–22
Agglomerate, 208
Aging
  dry aging, 142
  fast or wet aging, 143
  vacuum-packed aging, 143
AICR (American Institute for Cancer Research), 9
Al dente, 341
Albedo, 286
Alcoholic beverages, 531
  beer, 531–32
  overview of, 530–31
  spirits
    common spirits, 537
    proof, 537
  wine, 532–37
Allergens, food allergen labeling, 561
Allergic reaction prevention, 73
Allergies (GMOs), 15
Almond milk, 206–7
Altitude Adjustments for Shortened Cakes, 461
American Institute for Cancer Research (AICR), 9
American Medical Associations List of Allied Health Careers, 573
American service, 127
American Spice Trade Association, 108
Amino acids, 48–49
Amino acids, essential and non-essential, 47
Amphoteric, 51
Amylose and amylopectin in various starch sources, approximate, 371
Analytical (effective) tests, 20–22
Anchovies, 185
Ancient wheat grains, 331
Angel food cake
  definition of, 455
  mixing technique, 461
  overview of, 461
  temperature/timing, 462
Antibiotics and hormones, meats, 134–36
Antioxidants, 8–9, 53
Apples, 290–91
Applesauce preparation, 305
Approved Nonnutritive Sweeteners, 420
Apricots, 290
AquaAdvantage salmon, 16
Aromatic compounds, 304
Artichoke, 263–66
Artificial tendering
  acids, 143
  electrical stimulation, 143
  enzymes, 143
  mechanically tenderized beef (MTB), 143
  salts, 143
Asparagus, 266
Aspartame, 421
  aspartame side effects, 421
Aspic, 321
Astringency, 5
Atoms, 28
Au gratin, 275
Au jus, 380
Average pH Values for Selected Fruits, 285
Avocados, 290

B

Bacon, 152
Bacteria
  food infections, 63–64
  food intoxication, 64
  toxin-mediated infection, 64–65
Bacterial food infections
  Listeria monocytogenes, 65
  Salmonella, 65
  Shigella, 66
  Yersinia enterocolitica, 65–66
Bacterial Food Intoxications, 64
Bacterial food intoxications
  Clostridium botulinum, 66
  Clostridium perfringens, 66
  Staphylococcus aureus, 66
Bacterial toxin-mediated infections
  Campylobacter jejuni, 68
  definition of, 64
  Escherichia coli, 66–67
  molds, 68
  parasites, 69–70
  Vibrio, 68
  viruses, 68–69
Bagels, 407
Baked good, preparation of
  changes during heating, 365
  doughs and batters
    batters, 365
    doughs, 365
  high-altitude adjustment, 366
Baking, 94
Baking eggs
  shirred eggs, 247
  soufflés, 248
Baking fish
  baking shellfish, 191
  determining doneness, 190
Baking powder, 356
  acid in baking powder, 359
  types of baking powder, 359–60
Baking soda, 356
Baking vegetables
  overview of, 277
  potatoes, 277–78
Bananas, 291
Bar cookies
  brownies, 465
  lemon bars, 465
Barbecuing, 94–95
Barding, 153
Barley
  forms of barley
    barley grits, 332
    flaked barley, 332
    hulled barley, 331–32
    malt, 332
    pearled barley, 332
    pot barley, 332
Basic food chemistry: the six key atoms (CHNOPS), 27–28
Baste, 94
Batters, 109
  drop batters, 365
  pour batters, 365
Bayle, George, Jr., 466
Beading, 247
Beans, types of, 266
Beating techniques, eggs
  avoiding overwhipping, 243
  testing for doneness, 243
Beef, 131–32
  USDA grading, 140
Beef retail cuts
  ground beef, 144–45
  lean finely textured beef (LFTB), 145–47
  prime cuts, 146
Beer
  beer production
    brewing, 532
    fermenting, 532
    filtering or pasteurizing, 532
    lagering, 532
    malting, 531–32
  classifications of beer
    ales, 532
    lagers, 532
  serving beer, 532
  speciality beers, 532
  storing beer, 532
Beets, 266
Ben & Jerry's, 5
Berries
  blackberries, 292
  blueberries, 292
  cranberries, 292
  gooseberries, 292
  raspberries, 292
  red currants, 292
  strawberries, 291–92
Beurre manié, 378

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Beverages
  alcoholic beverage, 530–37
  carbonated soft drinks, 520–21
  coffee, 523–28
  dairy beverages, 530
  functional beverages, 521–23
  summary, 538
  tea, 528–30
  water, 518–20
Bibb tettuce (butterhead), 268
Bioengineering, 14
Biological hazards, 63
Biological hazards - living culprits
  bacteria: number-one cause of foodborne illness, 63–64
  intoduction to, 62–63
Biological value, 321
Biotechnology, 14
Biotechnology, history of
  acceptance/rejection of GM foods, 16
  clones: not GMO, 15
  concerns about GMO foods, 15–16
  foods created with biotechnology, 14–15
Biotechnology Industry Organization, 15
Bioterrorism Preparedness Act, 563–64
Biscotti di prato, 466
Biscuits, 391–92
Bisque, 314
Bitter, 3
Blanch, 93
Blind bake, 485
Bloom, 68, 498
Body, frozen desserts
  defintion of, 506
  heat shock, 510
  ice cream shrinks as it ages, 510
  overrun, 510
  overview of, 510
  recrystallization, 510
Boiling, 93
Boiling eggs
  cold-start method, 249
  hot-start method, 248–49
Boiling point, 31
Boiling point and elevation and, 31
Bone
  introduction to, 134
  marrow, 134
Boston brown bread, 389
Boston cream pie, 455
Boston Lettuce, 268
Bottled water
  sources of water
    artesian water, 519
    mineral water, 519
    P.W.S., 519
    spring water, 519
    well water, 519
Bouillon, 313
Bouquet garni, 312
Braising, 92, 158
Bran, 327
Breadings, 109
Breads. *See* Quick breads; tea breads; Unleavened breads; Yeast bread
Brief Summary of Hospital Diets, 115
Brioche, 472
British thermal unit (Btu), 6
Broccoli, 266
Broiling, 94
Broiling and grilling, 156–57
Broth, 311
Brown stock, 311
Browning
  enzymatic browning, 52
  Maillard Reaction, 51–52
Brussels Sprouts, 266
Buddhism, 12
Budgetary criteria, 17
Buffering, 51
Buffet service, 127
Bundt cakes, 454
Butter, 434–35
Butter cake, 454
Butter cookies, 466
Buttermilk, 209–10
Butters (fruit), 305
Buyers, 121

C

Cabbage, 266
Cabbage and carrots for salad, preparing, 319
Cacao tree with pods, 497
Caffeine, 57
Cake, 454
  chiffon cakes, 455
  shortened cakes, 448–49
  unshortened cakes, 455–56
Cake ingredients
  additional ingredients, food additives, 457–58
  eggs, 457
  fats, 457
  flour, 456
  leavening agent, 457
  milk, 457
  other factors, 458
  sugar
    overview of, 456–57
    Three Rules for "High-Ratio" Cakes, 457
Cake Problems and Their Causes, 460
Cakes, preparation of
  ingredients, 456–58
  preparing shortened cakes
    changes during baking, 459
    cooling sensation, 460
    high-altitude adjustment, 461
    microwave preparation, 461
    selection and preparation of pans, 458–59
    temperature/timing, 459
    testing for doneness, 460
  preparing unshortened and chiffon cakes
    angel food cake, 461
    chiffon cakes, 462
    selection and preparation of pans, 462–63
    sponge cake, 462
    temperature/timing, 463
    testing for doneness, 463
Cakes, storage of, 464
Cakes and cookies
  frosting/icings, 463–64
  preparation of cakes, 456–63
  preparation of cookies, 467–68
  selected food additives, 458
  storage of cakes, 464
  storage of cookies, 468
  summary, 468–69
  types of cake, 453–56
  types of cookies, 464–67
Calaza (pl chalazae), 237
CaliciNet, 88
Calorie, 6
Calorie Control
  alcoholic beverages, 531
  balanced energy and nutrient intakes, 119–21
  beverages, 523
  cakes, 458
  calorie balance, 7–8
  candy, 496
  choosing cheeses, 225
  choosing meats and meat substitutes, 138–39
  cookies, 468
  eggs, 245
  fat and fiber in salads, 317
  frozen desserts, 509
  fruits, 288
  grain and pasta calories quickly add up, 329
  lowering fat, 110
  Milk and Milk Products, 201
  Pastries and Pies, 477
  Poultry, 167
  quick breads, 389
  Sauces Hiding Sneaky Kilocalories, 382
  Sensible Fat Choices, 437
  Vegetables, 261–62
  Yeast Breads, 405
Campylobacter jejuni, 68
Candies, classification of
  coagulation, enzyme coagulation, 221–23
  crystalline versus non-crystalline (amorphous), 490
  curd treatment, 223–24
  syrup phase versus fat phase, 489–90
Candling, 238
Candy, 490
  chocolate, 496–502
  classifications of candy, 489–90
  preparation of candy, 490–96
  storage of candy, 502
  summary, 503
  syrup and temperatures and doneness tests, 492
Candy, preparation of
  confectionery preparation overview, 490–91
  crystalline candies, 491–95
  food additives in candy, 496
  noncrystalline candies, 495–96
Candy, storage of
  overview of, 502
  shelf life of chocolate, 502
Canned fluid milk, 207
Canned fruit
  canning liquids, 300
  grading of canned fruits, 300
  overview of, 299–300
Canning
  overview of, 545
  preparing foods for canning, 545–46
  two methods of canning, 545–46
Canning, meats, 150
Cannoli shell, 466
Capsaicin, 5
Caramels, 495–96
Carbohydrates
  composition of carbohydrates, 36–43
  foods high in carbohydrates, 36
Carbohydrates, composition of, 38
  disaccharides, 38
  introduction to, 36–37
  monosaccharides, 37–38
  polysaccharides, 38–43
Carbonated soft drinks
  diet soft drinks, 521
  early soft drinks, 520
  food additives in soft drinks, 521
  overview of, 520
  soft drink health concerns, 520–21
Career Corner

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Ben Cohen and Jerry Greenfield— cofounders of Ben & Jerry's, 5
food chemistry, Willie Byrd, 456
food safety inspector and food and drug branch supervisor, 174
food science, 303
Judy Thompson, 233
Kristen M. Gray and Jonathan Gray, 515
Liz Applegate, 581
Pamela Hays, 392
Careers in food and nutrition
food science, 577–79
food service, 579–80
graduate school, 580–83
nutrition science and dietetics, 571–77
summary, 584
three major food and nutrition areas, 570–71
Carmelization, 425
Carotenoids, 258
Carrot cake, 454
Carrots, 266
Carryover cooking, 155
Carver, George Washington, 466
Carving, 159
Carving poultry, 172
Casein, 199
Catechins, 529
Cauliflower, 266
CDC (Centers for Disease Control and Prevention), 7
Celery, 266
Cellulose, 40
Centerpieces, 128
Centers for Disease Control and Prevention (CDC), 7, 566–67
Cereal grains and pastas
cereal grains containing gluten, 330–34
composition of grains, 327–29
general types of cereal grains, 329–30
gluten-free cereal grains, 334–38
overview of, 326
pastas, 340–41
preparation of creal grains, 339–40
preparation of pasta, 341–42
storage of pasta, 342–43
summary, 344
uses of cereal grains, 329
Cereal grains, composition of
structure
bran, 327
endosperm, 327–28
germ, 328
husk, 327
Cereal grains containing gluten
ancient wheat grains, 331
barley, 331–32
oats, 332
rye, 332–33
triticale, 333
wheat, 330–31
Cereal grains, preparation of
food additives in grain products, 328–29
microwaving, 339
moist-heat preparation: boiling/simmering
cooking the grain, 338
determining doneness, 339
prepreparation, 338
standing time, 339
sautéing and baking, 339
Cereal grains, recommend liquid and heat times, 338
Cereal grains, storage of
dry, 339
frozen, 340
refrigerated, 340
Cereal-grain food sensitivites
baker's astema, 350
celiac disease, 350
nonceliac gluten sensitivity (NCGS), 350
wheat allergy, 350
Certified colors, 54
Changes in pH-acids and bases, 34
Chapatis, 391
Cheese
classification of
food preparation with cheese, 230–32
how some cheese flavors develop, 227
production, 219–21
purchasing cheese, 229–30
selected food additives, 229
storage of cheese, 232–33
summary, 234
Cheese, enzyme coagulation
acid coagulation, 223
chymosin, 222
coagulants, 222
coagulation process, 222–23
overview of, 221–22
Cheese, purchasing
forms of cheese, 230
grading, 229–30
Cheese, storage of
dry storage, 232
frozen, 233
refrigeration, 232
Cheesecake, 454
Cheeses, classification of
curing and ripening, 224–26
food additives in cheese, 229
milk selection, 220
moisture content, 219
overview of, 218–19
place of origin, 219
process (processed) cheeses, 228–29
whey and whey products, 226–28
Chemesthesis, 5
Chemical hazards
introduction to, 71–72
seafood toxins: chemicals from shellfish, 72–73
Chemical reations
changes in pH-acids and bases, 34
food preservation, 35
hydrolysis, 35
ionization, 34
osmosis and osmotic pressure, 36
salt formation, 35
water activity (aw), 35–36
Chemical tests, 24–25
Chemistry of food composition
basic food chemisty, 27–28
carbohydrates, 36–43
lipids (fats), 43–47
nonnutritive food components, 53–58
proteins, 47–52
summary, 59
vitamins and minerals, 52–53
water, 28–36
Chemist's Corner
1-1 Hot Peppers and Body Chemistry, 5
1-2 Other Units of Measurement for Energy, 6
2-1 Viscosity, 23
2-2 Analyzing Food with Chromatography, 23
3-1 Atomic structure, 28
3-2 Free or Bound Water, 29
3-3 The Chemical Structure and Properties of Water, 29
3-4 Calculating Freezing Point Depression and Boiling Point Elevation, 31
3-5 Temperature Increases Solubility, 33
3-6 The Logarithmic pH Scale, 34
3-7 Measuring Water Activity, 34
3-8 D and L Sugars, 37
3-9 Chemical Formation of Triglycerides, 43
3-10 Naming Chemical Compounds, 45
3-12 Protein Gels, 49
3-13 Enzyme Classification, 49
3-14 Proteins and Buffering, 51
3-15 The Maillard Reaction, 51
4-1 Testing for Contamination, 65
4-2 Bacteria-Killing Viruses, 65
4-3 Biofilms, 68
4-4 How Melamine Falsely Elevates Protein Content, 72
4-5 How Is the Protein in Foods Measured? 72
4-6 Acrylamide, 72
7-1 Collagen, 134
7-2 Antibiotic Resistance, 135
7-3 Superbugs in Food, 135
7-4 Meat Pigments, 136
7-5 Color Changes in Meat, 136
7-6 Passing of Rigor Mortis, 142
7-7 Color Changes in Cooked Meats: Nitrites, 151
7-8 Effect of Temperature on Meat Components, 153
7-9 Warmed-Over Meat Flavor, 154
8-1 Processing Poultry, 166
8-2 Aroma of Roasting Chicken, 171
8-3 How TSP Kills Bacteria, 174
8-4 Oxidation of Cooked Poultry, 174
9-1 Why Fish Mince Develops Bad Texture, 185
9-3 Lemon Juice and Fish Odor, 192
9-4 Effect of Freezing on Fish, 194
10-1 Casein and Whey Proteins, 200
10-2 Flavor Compounds in Yogurt, 210
11-1 Milk Coagulation Mechanism, 222
11-2 Caseins and Coagulation, 222
11-3 Cheese Ripening, 225
11-4 Bacteria and Cheese Flavor, 226
11-5 Enzymes and Cheese Flavor/Texture, 226
12-1 Egg Proteins, 237
12-2 Yolk Color in Boiled Eggs, 248
12-3 Egg Pasteurization, 252
13-1 Vitamin A Carotenoids, 258
13-2 Types of Chlorophyll, 259
13-3 Phytochemicals and Cancer, 260
13-4 Cancer and DNA damage, 261
13-5 The Chemistry of Pungent Odors, 276
13-6 Cream of Tartar and Potatoes, 277
13-7 French Fry Phenomenon, 278
13-8 Edible Films, 280
13-9 Legume Storage, 281
14-1 The Chemical Structure of Pectin, 285
14-2 Berry Power, 288
14-3 Measuring Antioxidant Power, 299
14-4 Enzymes Reduce Haze, 301
14-5 Calcium in Canned Fruits, 303
14-6 Pectins and Methoxylation, 305
15-1 Food Additives Used in Soups, Salads and Gelatins, 321
16-1 Malt Production, 332
16-2 Rye Proteins and Starches, 333
16-3 Cloudy Pasta Water, 342
17-1 Classifying Plant Proteins, 349
17-2 Cold Water and Yeast, 358
17-4 The Red in Chocolate Cake, 360
17-5 How Reducing Agents Work, 364

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Chemist's Corner (*Continued*)
17-6 Commercial Enzyme Additives, 364
18-1 Amylose and Amylopectin, 371
18-2 Testing for Starch, 372
18-3 Controlling Gelatinization, 372
18-4 Gelatinization under a Microscope, 374
18-5 Quantifying a Food's Resistant Starches, 375
18-6 Types of Resistant Starch, 375
20-1 Hydrocolloid Food Additives, 397
20-2 Enzymes in Yeast Dough, 399
20-3 Bread Flavors and Aromas, 402
20-4 The Chemistry of Staling, 408
21-1 Measuring Sugar Solutions, 415
21-2 Dextrose Equivalents, 416
21-3 HFCS Production, 416
21-4 Inversion, 418
21-5 Sugar Alcohol Production, 419
21-6 Stevia's Sweet Substance, 422
22-1 Monoglyceride and Diglyceride Emulsions, 431
22-2 Fatty Acid Melting Points, 432
22-3 Hydrogenation, 440
22-4 Hydrolytic Rancidity, 448
22-5 Oxidative Rancidity, 449
22-6 Measuring Oxidation, 450
22-7 Antioxidants in Action, 450
23-1 Cake Batters, 457
23-2 Chlorinated Cake Flour, 457
23-3 Surfactants in Cake Batter, 458
25-1 Liquid Fondant, 494
25-2 Tempering and Chocolate Melting Point, 498
26-1 The Chemistry of Ice Cream, 506
26-2 Salt's Effect on Freezing, 513
26-3 Measuring Sugar Concentration, 513
27-1 The Water in Soft Drinks, 520
27-2 Filtering Wines, 533
27-3 White Wine from Red Grapes, 534
28-1 Proteinases, 541
28-2 Glass Transition Temperature, 547
28-3 Irradiation and Softening of Food, 549
28-4 Irradiation Dosages, 550
Chemical Formation of Triglycerides, 43
Measuring Gelation Potential, 323
Cherries, 292
Chicken. *See* Poultry
Chicory, 268
Chiffon cakes, 455
Chlorophyll
blanching enchances green color, 259
overview of, 259
CHNOPS, 27–28
Chocolate
baking chocolate, 501
cacao tree, 496
chocolate liquor, 498–501
chocolate production, 497–98
cocoa, 501
cooling and manipulation of, 500
functional chocolate, 501–2
history of, 496–97
imitation chocolate, 501
milk chocolate, 501
semisweet or sweet chocolate, 501
white chocolate, 501
Chocolate chip cookies, 465
Chocolate liquor
conching, 498
tempering, 498–501
Chocolate milk, 204
Chocolate production
cocoa beans produce chocolate liquor
blending/roasting, 498
cacao bean selection, 497
drying, 497–98
fermentation, 497
grinding, 498
winnowing, 498
ChooseMyPlate, 118
Calorie Control, Calorie Balance, 7–8
Dietary Guidelines, 2010, 6–7
previous food group plans, 8
supertracker, 8
vegetarianism, 9
Choux pastry (pâte à choux), 472, 480
Chromatography, 23
Church of Jesus Christ of the Latter-Day Saints (Mormon Church), 12–13
Chymosis (rennin), 213
Cialde, 465
Ciambellone, 454
Ciguatera fish poisoning, 72–73
Cilantro, 268
Clams, 188
Clarified butter, 434
Clarify, 244
Classifications of fish and shellfish, lean or fat, 178
Cleaning salad greens, 317
Clones: not GMO, 15
Clostridium botulinum, 66
Clostridium perfringens, 66
Coagulation, 49
Coarse dispersions (suspension), 32, 34
Cod worms, 69
Coddling eggs, 249
Code of Federal Regulations, cheese, 219
Code of Federal Regulations, fruit, 300
CODEX Alimentarius Commission, 567
Coffee
brewing time increases with larger grind, 527
café au lait, caffè latte, or café con leche, 526
café brulot, 526
coffee purchasing
decaffeination, 524
grinding, 524
instant coffee, 524
removing the hull, 524
roasting, 524
composition of coffee
bitter substances, 525
methylxanthines, 525
volatile compounds, 524–25
flavored coffees, 526
iced coffee, 526
imitation coffee, 526
overview of, 523–24
preparation of coffee
brewing equipment, 527
brewing time, 526–27
coffee freshness, 526
holding time, 527
water temperature, 526
water type, 526
water-to-coffee ratio, 526
speciality coffees, 526
storage of coffee, 527–28
types of beans, 525
types of processing, 525
Coffee beans
blended coffees, 525
unblended coffees, 525
Coffee cakes, 390, 454
Coffee processing
decaffeinated, 525
espresso, 525
instant coffee, 525
Cohen, Ben, 5
Cold preservation
freezing
foods suitable for freezing, 546
four problems with frozen food, 547
freezer storage times, 546–47
overview of, 546
refrigeration
overview of, 546
refrigerating food, 546
refrigeration temperatures and times, 546
Cold shortening, 142
Collagen
effect of age on tenderness, 133
effects of collagen on tenderness, 133
effects of elastin on tenderness, 133
Colloidal dispersions, 32, 34
Color compounds, 54
Color in food, use of, 54–56
Commercial cheese production, 227
Commercial food-service organization
administrative positions, 115
Escoffier's System of Organization via Stations, 114–15
Common cheeses, 219
Complementary and integrative medicine, 9–10
Complete protein, 47
Compound, 28
Condiments, 110
Conduction, 95
Congener, 534
Connective tissue, 134
Conserves, 305
Consistency, 5
Consommé, 313
Consumer dietary changes
complementary and integrative medicine, 9–10
functional foods, 9–11
kcalories on menus, 9
Convection, 96
Convenience, poultry, 165
Conventional cakes. *See* Shortened cakes
Cookies
bar cookies, 465
cookies as functional foods, 466–67
dropped cookies, 465–66
icebox/refrigerator cookies, 466
molded cookies, 466
overview of, 464–65
pressed cookies, 465
problems and their causes, 468
rolled cookies, 466
selected food additives, 467
Cookies, preparation of
baking cookies
high-altitude adjustment, 468
microwave preparation, 468
selection and preparation of pans, 467–68
temperature/timing, 468
testing for doneness, 468
ingredients and mixing methods
food additives in cookies, 467
overview of, 467
Cookies, storage of, 468
Cooking grain, moist-heat preparation
adding seasonings, 339

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factors influening grain cooking, 339
grain consistency, 338–39
hot breakfast cereal, 339
overview of, 338
Cooking Time for Beans (after a 10-hour soak), 279
Co-op, 578
CORE Network, 88
Corn, 266
classification of corn
dent corn, 334
flint corn, 334
flour corn, 335
pod corn, 335
popcorn, 334
sweet corn, 335
forms of corn
corn oil, 336
corn on the cob and kernal corn, 335
corn syrup, 336
cornmeal, 335
hominy, 335
hominy grits, 335
Corn bread, 389–90
Corn syrup, 35, 37–38, 54–55, 149–51, 206, 229, 252, 336, 352, 415. *see also* Glucose; High-fructose corn syrup; Sweeteners
Cost control, purchasing
bread/grains, 122
dairy, 122
fish, 122
fruits and vegetables, 122
meats, 122
price comparisons, 122–24
Country of origin labeling, 564
Court bouillon, 191
Cover, 127
Cover and linens, 127
Crackers, 392
Crayfish, 190
Cream and substitutes
cream, 212
cream substitutes, 212
Crepes, 386–87
Crisp flatbreads, 391
Critical Control Points, 88
Croissant pastry, 473
Cross-contamination, 73–74
Cruciferous, 259
Crumb, 347, 403
Crumbling, 125
Crustacean, 178
Crystalline candies
candies start with a syrup solution, 491
cooling and beating
cooling is crucial, 493
stirring during cooling, 493
heating the syrup
avoiding agitation druing heating, 493
cold water test, 493
overheating and underheating, 492
overview of, 491–92
thermometer test, 492–93
types of
divinity, 495
fondant, 494
fudge, 494–95
Crystalline candy, 490–92
Crystallization, 416
Cucumbers, 266–67
Cultural criteria
cultural influences on manners, 12
ethnic influences, 11
geography and climate, 12
place of birth, 11–12
Cultured milk products
cultures added to milk
acidophilus milk, 211
buttermilk, 209–10
curd formation, 208–9
functional foods - probiotics, 211
kefir, 211
lactic acid bacterial, 209
microorganisms for food lists, 209
sour cream, 211–12
yogurt, 210
Cupcake, 454
Curd, 209
Cure, 543
Curing, 149–50, 224
Current Good Manufacturing Practices (cGMPS), 74
Custards
baked custard, 250
stirred custard (soft custard or custard sauce), 250
sweet and savory custards, 250
Cuticle (bloom), 238
Cutlery techniques
cutting styles, 98–100
handling knives, 97–98
Cutting styles, 98–100
Cycle menu, 117

D

Dacquoise, 455
Dairy, 122
Dairy beverages
cocoa beverages, 530
overview of, 530
Danish pastry, 473–74
Dates, 292
Deep-frying, 95, 158
problems and causes, 446
Deglaze, 381
Degorge, 276
Dehydrate, 542
Delaney Clause, 563
Denaturation, 49
Denaturation/Coagulation, 49
Density, 23
Descriptive tests, 21
Desired spread of drop cookie, 465
Detecting aroma, mouthfeel, and taste, 3
Detrinization, 374
Devil's food cake, 454
Dextrinization, 374
Dextrose equivalent (DE), 370, 415
DHHS (U.S. Department of Health and Human Services), 6
Dietary fiber, 40
Dietary Guidelines, 2010, 6–8
Dietary Guidelines for Americans, 6, 9, 117
Dietitian (registered dietitian [RD] or registered dietitian nutritionist [RDN]), 116
Difference tests, 21
Disaccharides
maltose, 38
sucrose, 38
Discriminative tests, 21
Dispersion destabilization, 34
Dispersions, 32
Distillation, 33
Diverticulosis, 40
Divinity, 495
Dough, 365
Dough conditioners
emulsifiers, 364
enzymes, 364
mixing time reducers, 364
oxidizing agents, 364
reducing agents, 364
DPDx (CDC network), 88
Drawn fish, 181–82
Dressed fish, 181–82
Dressed poultry, 165
Dried
fruit leather, 300
rehydrating, 300
Dried beans, 274
Dropped cookies
chocolate chip cookies, 465
cialde, 465
Florentines, 465
fortune cookies, 465
macarons, 465
macaroons, 465
madeleines, 465
meringues, 465
wafers, 465
Drug, 562
Dry aging, 142–43
Dry-heat preparation, 93
baking
pan color, 94
rack position, 94
barbecuing, 94–95
broiling, 94
frying
deep-frying, 95
pan-broiling and pan-frying, 95
sautéing and stir-frying, 95
grilling, 94
roasting, 94
Drying, foods
commercial drying
conventional drying, 542
drum drying, 542
freeze-drying, 543
microwave drying, 543
osmotic drying, 543
pretreatments, 543
spray drying, 542
vacuum drying, 543
overview of, 542
sun-drying, 542
Drying, meats, 150
Dumplings, 390

E

E. coli. See Escherichia coli
EAFUS (Everything Added to Foods in the United States), 54
Edible coating, 545
Edible flowers, 317
Edible portion (EP), 123
Efficient meal preparation, 124
Egg storage safety tips
consumption, 253
overview of, 252–53
preparation, 253
purchasing, 253
storage, 253
Eggnogs, 204

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Eggplant, 267
Eggs, 241–42
  composition of eggs, 236–38
  functions of eggs in food, 241–44
  measuring, 102
  number of eggs equivalent to 1 cup, 240
  number of eggs used to replace eggs of other sizes, 240
  preparation of eggs, 244–51
  purchasing eggs, 238–41
  storage of eggs, 251–53
  summary, 254
  types of eggs, 241
Eggs, coagulation temperatures, 245
Eggs, composition of
  air cell, 237–38
  albumen, 237
  shell, 238
  shell membranes, 237
  yolk, 236–37
Eggs, preparation of, 248
  changes in prepared eggs, 245
  color changes, 245–46
  dry-heat preparation
    baking, 247–48
    frying, 246–47
  effects of added ingredients, 245
  meringues, 247–48
  microwaving
    fried eggs, 250
    omelets, 250–51
    poached, 250
    quiche, 250–51
    scrambled eggs, 250
    shirred eggs, 250
  moist-heat preparation
    coddling, 249
    custards, 250
    hard or soft "boiling," 248–49
    poaching, 249–50
  overview of, 244–45
Eggs, purchasing
  appearance, 239
  egg substitutes, 240
  grading
    grading methods, 238–39
    overview of, 238
  inspection
    eggs failing USDA inspection, 238
    overview of, 238
  sizing, 240
  value-added eggs, 240–41
Eggs, storage of
  dried eggs
    overview of, 252
    rehydrating dried eggs, 252
  frozen, 251–52
  refrigerator
    pasteurized eggs, 251
    shelf life of refrigerated eggs, 251
    storage eggs, 251
    whole eggs, 251
  safety tips, 252–53
EHS-Net (Investigators in the Environmental Health Specialists Network), 88
Electrolyte, 34
Electronic noses, 25
Emulsions
  definition of, 33–34
  emulsifiers, 430–31
  overview of, 430
  stability of emulsions
    permanent emulsions, 431
    semipermanent emulsions, 431
    temporary emulsions, 430–31
Endosperm, 327
English muffins, 407–8
English service, 127
Enriched, 53
Environmental Protection Agency, product labeling, 566
Enzymatic browning, 52
Enzyme, 38
Equipment. *See* Coffee; Cutlery; Food safety; Sanitation, foodborne illness
Escarole, 268
Escherichia coli, 66–67
Escoffier, Georges Auguste, 114
Essential oil, 304
Estimated Salaries for Various Jobs in Dietetics, Food Science, and Food Service, 583
Ethnic influences, 11
European Food and Food Cultures Association (EFFCA), 209
European Food Safety Authorities (EFSA), 209, 422
Evaporated milk, 207–8
EverSweet, 422
Eviscerate, 165
Examples of foods containing starches, 370
Examples of Processed Meats, 149
Excessively Firm or Soft Dough Problems, 398
Exotic Vegetables
  Adzuki bean, 267
  Amaranth, 267
  Belgiun endive, 267
  Breadfruit, 267
  calabaza, 267
  Chayote, 267
  Chinese long beans, 267
  Daikon, 267
  Jerusalem artichoke, 267
  Jicama, 267
  Kohlrabi, 267
Extractives, 137

F

Factors influencing gel formation
  added ingredients
    acid, 323
    enzymes, 323
    salts, 323
    solid ingredients, 323
    sugar, 323
  whipping, 323
Fahlberg, Constantin, 421
Family service, 127
Fat, in flour mixtures
  functions of fat
    delays staling, 362
    improves flavor and color, 362
    improves strength, crub, and flakiness, 362
    improves volume, 362
  lower-fat alternatives, 363
  overview of, 361–62
  temperature of fat, 363
  too much/too little fat, 363
  types of fat used in baked goods, 362–63
Fat, in pastry
  flakiness, 475–76
  tenderness, 476
Fat, measuring, 102
Fat replacers, 442
  types of fat replacers
    lipid-based fat replacers, 441–42
    olestra, 442–43
    overview of, 441
    protein-based fat replacers, 441
Fat-free or nonfat milks, 204
Fats
  butter, 434
  cocoa butter, 441
  lard/tallow/suet, 441
  margarine
    composition of margarine, 434–35
    types of margarine, 435
  oils, 436–41
  shortenings, 436
Fats, composition of, 447
Fats, storage of
  overview of, 446–47
  rancidity, 447–50
Fats and oils, 451
  fat replacers, 441–43
  food preparation with fats, 443–46
  functions of fats in foods, 429–34
  overview of, 428–29
  summary, 446–50
  types of, 434–41
Fatty acids
  differ in saturation and length, 432
  fatty acid nomenclature, 45
  fatty acid structure, 43–44
  fatty acids in foods, 44–45
Fatty ingredients in recipes, placing, 447
FDA enforcement and its laws
  allowable contaminants, 558
  food fraud, 557
  overview of, 557
FDA Food Code, 86–87
FDA inspections
  allowable contaminants, 558
  FDA enforcement and its laws
    food fraud, 558
    overview of, 557–58
Federal food laws
  Federal Food, Drug, and Cosmetic Act (1938), 556
  Numerous Government Agencies, 556–57
  overview of, 555
  Pure Food and Drug Act (1906), 556
Federal Register, 16–17
Fermentation, 328, 541, 544
Fibers
  common fibers and food industry uses
    cellulose, 40
    hemicelluloses, 40–41
    inulin, 43
    lignin, 43
    pectic substances, 41
    vegetable gums, 41–43
  as indigestible polysaccharides, 40
  measuring dietary fiber, 40
  soluble vs. insoluble fiber, 40
"fight-or-flight" response, 5
Figs, 292–93
Filled milk, 205
Fillets, 181–82
Finfish, 178
Finfish, selection of
  canned fish
    salmon, 185
    sardines, 185

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FOR REFERENCE PURPOSES ONLY

tuna, 184–85
cavier, 186
cured fish, anchovies, 185
fabricated fish
food additives, 186
overview of, 185–86
surimi, 186
fresh and frozen fish
determining freshness of fish, 182
how much fish to buy, 184
mercury contamination, 183–84
phosphate treatment of fresh finfish, 182
processed fish products, 184
rigor mortis, 182
signs of decay in fresh finfish, 182–83
variety of finfish, 181
Fire point, 443
Fish, 122
Fish, composition of
pigments, 179–80
structure of finfish
amino acid content, 179
collagen, 179
muscle structure, 179
overview of, 178
Fish and shellfish
classification of fish and shellfish, 177–78
composition of fish, 178–80
grouped by flavor and textures, 179
purchasing, 180–90
storage of fish and shellfish, 193–94
summary, 195
Fish and shellfish, classification of
overview of, 177
saltwater or freshwater, 178
vertebrate or invertebrate
invertebrates, 178
vertebrates, 177–78
Fish and shellfish, preparation of
dry-heat preparation
baking, 190–91
broiling, 191
frying, 191
grilling, 191
moist-heat preparation
microwaving, 192–93
poaching, 191–92
simmering, 192
steaming, 192
overview of, 190
raw fish preparation
ceviche, 193
food safety concerns, 193
sashimi, 193
sushi, 193
Fish and shellfish, purchasing
inspection/grading, 181
overview of, 180
selection of finfish, 181–86
shellfish classification, 181
Fish and shellfish, storage of
fresh finfish
refrigerated, 194
spoilage factors, 194
storing caviar, 194
fresh shellfish, 194
frozen
overview of, 194
thawing, 194
overview of, 193
Fish sticks, 181–82
Flash point, 443
Flat Parsley, 268
Flatware, 127
Flatware/dinnerware/glassware, 127
Flavor, 4
Flavor compounds, 56
Flavor enhancers, 108
Flavor profile, 21
Flavor reversion, 448
Flavorings. *See* Seasonings and flavorings, 104
Flavorings, in pastry
alcohol, 477
essences, 477
extracts, 477
flavored oils, 477
Flocculation, 34
Florentines, 465
Flour
presifted or instantized flours, 103
white flour, 103
whole grain or graham flour, 103
Flour and flour mixtures
dry storage, 366
frozen, 366
Flour compression test, 366
Flour mixture ingredients
commercial additives
aging or maturing agents, 363
dough conditioners, 363–64
eggs
overview of, 363
too much/too little eggs, 363
fat, 361–63
flavorings, 361
flood additivies in flours, 364–65
leavening agents, 356–60
liquid
milk, 361
too much/too little liquid, 361
salt
purpose of, 361
salt controls yeast growth, 361
too much/too little salt, 361
sugar
functions of sugar, 360
too much/too little sugar, 360
types of sugar, 360
Flours
cereal-grain food sensitivities, 350
gluten, 347–50
milling, 350–52
nut-based flours, 355
overview of, 346
starch, 347
summary, 367
treated wheat flours
aged flour, 355
bleached flour, 355
enriched flour, 355
instant or agglomerated flour, 355
phosphated flour, 355
self-rising flour, 355
types of gluten-free grain flours
amaranth, 354
buckwheat flour, 354
cornmeal flour, 354
rice flour, 355
sorghum flour, 355
types of nongrain, gluten-free flours
legume-based flours, 355
tuber-based: potato flour, 355
types of nonwheat grain flours containg gluten
rye flour, 354
triticale flour, 354
types of wheat flour, 352–56
what does gluten-free mean, 350
wheat flour classifications
mineral content, 352
percent protein content, 352
Flours and flour mixtures
flour mixture ingredients, 356–65
flours, 347–56
preparation of baked goods, 365–66
storage of flour and flour mixtures, 366
Fluctose, 38
Foam, 33, 323
Foaming
additives
acid, 244
fluid, 244
salts, 244
sugar, 244
beating techniques, 243
bowl selection, 244
separation of eggs, 244
temperature, 243–44
Fondant, 494
Food additive, 557
Food additives
ingredients not defined as additives
GRAS supplements, 563
sustances with prior sanction, 563
Food additives in processed meats, 150–51
Food additives, purposes of
additives that extend storage life, 56
additives that improve appeal
certified colors, 54
color compounds, 54
flavor compounds, 56
natural colors, 54
texture compounds, 56
use of color in foods, 54–56
additives that maximize performance, 56
additives that protect nutrient value, 56
Food allergy, intolerance and sensitivity
allergic reaction prevention, 73
cross-contamination, 73–74
labeling of common food allergens, 73
Food and Drug Administration (FDA)
Bioterrorism Preparedness Act, 563–64
the code of federal regulations, 557
the Delaney Clause, 563
FDA inspections, 557–58
FDA standards
Standards of Fill, 559
Standards of Identity, 558–59
Standards of Minimum Quality, 558–59
food additives, 563
food labeling, 559–63
research/education, 557
Food code, 557
Food cost, 118
Food evaluation
sensory/subjective evaluation, 20–23
summary, 26
Food fraud, 558
Food group plan, 8
Food Guide Pyramid, 8
Food industry uses, 110
Food infection, 63
Food intoxification, 64

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Food labeling
  dietary supplements, 562–63
  FDA claims allowed on labels
    health claims, 561
    nutrient content claims, 562
    qualified health claims, 561–62
  food allergen labeling
    gluten-free products, 561
    overview of, 560–61
  food labeling exemptions, 560
  genetically modified organisms (GMOs), 561
  nutrition facts label
    kilocalories, 560
    nutrients, 560
    overview of, 559
    serving size and serving number, 559–60
  other nutrition facts information, 559
Food preparation basics
  cutlery techniques, 97–101
  heating foods, 91–92
  measuring heat, 96–97
  measuring ingrediants, 101–4
  mixing ingrediants, 104
  seasonings and flavorings, 104–10
  summary, 111
  types of dry-heat preparation, 94–95
  types of heat transfer, 95–96
  types of moist-heat preparation, 92–94
Food preparation with cheese
  cutting cheese, 232
  selecting a cheese, 230–31
  temperatures, 231–32
Food preparation with fats
  lower-fat preparation techniques
    fats preferred for health, 445
    modifiying recipes to reduce fat, 445–46
    pretreatments to reduce absorbed oil, 446
    reducing fat by healthy methods, 445
  selection and care of frying fats, 443–45
Food preservation, 35
  cold preservation, 546–48
  food preservation methods, 542–46
  food spoilage, 540–42
  heat preservation, 548
  nutrient retention, 552
  other preservation methods, 548–52
  summary, 553
Food preservation methods
  aseptic packaging
    controlled-atmosphere packaging (CAP), 552
    modified-atmosphere packaging (MAP), 552
    vacuum packaging, 552
  canning, 545–46
  curing, 543
  drying, 542–43
  edible coatings
    commonly coated foods, 545
    composition of, 545
    micro-encapsulation, 545
  fermentation, 544
  high-pressure processing, 551
  irradiation (cold pasteurization), 548–51
  overview of, 542
  ozonation, 551–52
  pickling, 544–45
  pulsed light, 551
  radio frequency, 551
  smoking cured meat, 543–44
Food safety
  bacterial food infections, 65–66
  bacterial food intoxications, 66
  bacterial toxin-mediated infections, 66–71
  biological hazard - living culprits, 62–65
  chemical hazards - harmful chemicals in foods, 71–73
  introduction to, 61
  preventing foodborne illness, 74–81
  proper use of thermometers, 82–83
  summary, 89
  What is a foodborne illness, 62
Food safety monitoring
  health department inspectors
    FDA Food Code, 86–87
    foodborne illness surveillance, 88
    HACCP, 87–88
    HARPC, 88
  World Health Organization, 88
Food science
  food science technician, 579
  food scientist, 577–79
Food scientist
  academic requirements
    contacting companies, 578
    internship or co-op experience, 578
    overview of, 577–78
  overview of, 577
  types of food scientists, 578–79
Food selection
  cultural criteria, 11–12
  introduction to, 1
  nutritional criteria, 6–11
  psychological and sociological criteria, 14–17
  religious criteria, 12–14
  sensory criteria, 1–6
  summary, 18
Food service
  academic preparation for culinary arts, 579
  food-service certifications, 580
  overview of, 579
  types of food service positions
    chef, 580
    dietary manager, 580
    food-service manager, 580
    overview of, 579–80
    sales and marketing, 580
Food spoilage
  biological changes, 540–41
  chemical changes, 541
  overview of, 540
  physical changes, 541–42
Food stores and vendor/suppliers
  co-ops, 122
  food-service vendors, 122
  smaller outlets, 122
  supermarkets, 121–22
  warehouse stores, 122
Foodborne Disease Outbreak Surveillance System (FDOSS), 88
Foodborne illness
  causes of, 62. *see also* food safety
  introduction to, 61–62
Foodborne illness, preventing
  food flow, 75–77
  personnel, 74–75
  preparation, 79–81
  prevention factors overview, 74
  vulneralbe foods, 78–79
Foodborne illness surveillance
  additional surveillance systems, 88
  Foodnet, 88
Foodbourne illness, prevention
  cooking (heating)
    minimum internal temperatures, 80
    temperature-time monitoring program, 80
  cooling, 84
  food flow
    inspection, 76
    proper refrigerator and freezer use, 77
    purchasing: written specifications, 75–76
    storage, 76
    storage times, 77
    temperature, 76–77
  holding
    preventive barriers, 80
    time limit, 80
  introduction to, 74
  personal hygiene habits
    avoid hand-to-mouth, 74–75
    Food-service personnel checklist, 75
    handwashing, 75
    proper gloving, 75
    uniforms, 75
  pre-preparation
    cross-contamination, 80
    thawing, 79
  reheating, 84
  serving, 84
  training, 74
Foodnet (Foodborne Diseases Active Surveillance Network), 88
Foods approved for irradiation in the United States, 549
Foods for Specified Health Use (FOSHU), 10
Foods high in carbohydrates, 36
Foods high in lipids, 43
Foods high in vitamins and minerals, 52
Food-service organization
  commercial food-service organization, 114–15
  hospital food-service organization, 115–16
  introduction to, 113–14
Forecast, 121
Fortified, 53
Fortune cookies, 465
FOSHU (Foods for Specified Health Use), 10
Free radicals, 53
Freeze-dry, 542
Freezer burn, 547
Freezing, problems with
  cell rupturing, 547
  fluid loss, 547
  freezer burn, 547
  recrystallization, 547–48
Freezing point, 30
French service, 127
Fricaseeing. *See* Braising
Frostings/icings
  cooked frosting, 463
  decorating frosting, 463
  flat frostings, 463
  ganache, 463
  garnishes, 463
  whipped cream frosting, 463
Frozen desserts
  frozen yogurt, 508
  gelato, 507
  ice cream, 506–7
  imitation ice cream, 507
  overview of, 505
  preparation of frozen desserts, 508–14
  sherbet, 507–8
  sorbet, 508
  still-frozen desserts, 508
  storage of frozen desserts, 514–15
  summary, 516
  types of frozen desserts, 505–8
Frozen desserts, preparation

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- factors influencing quality
  - body, 510–11
  - flavor, 508
  - texture, 508–10
- mixing and freezing
  - frozen yogurt, 513
  - ice cream, 511–13
  - sherbet, 513
  - sorbet, 513–14
  - still-frozen desserts, 514
  - water ices, 514

Frozen desserts, storage of
- scooping frozen desserts, 514–15
- texture changes, 514–15

Frozen fruit
- overview of, 300
- signs of refrozen fruit, 300

Frozen meat storage, 160
Frozen yogurt, 507, 513
Fructose, 415
Fruit, changes during ripening and heating
- color changes
  - ethylene gas, 302
  - metal salts, 302
  - pH, 302
  - texture, 302
- flavor
  - overview of, 304
  - zest, 304
- texture, osmosis, 303

Fruit fillings
- cooked juice methold, 483
- cooked-fruit method, 483
- old fashioned method, 483

Fruit Juice Beverage Names Depend on the Percentage of Actual Juice, 300
Fruit juices, 454
- fruit/vegetable juice processing, 300–301
  - clarification, 301
  - concentration/additives, 302
  - deaeration, 301
  - juice extraction, 301
  - pasteurization, 301–2
- overview of, 300

Fruit spreads
- ingredients
  - acid, 306
  - fruit, 306
  - pectin, 305–6
  - sugar, 306
- preparing, 306–7

Fruit sugar. *See* Natural sweeteners, fructose
Fruits
- classification of fruits, 284–85
- composition of fruits, 285–89
- preparation of fruits, 302–7
- purchasing fruits, 289–302
- storage of fruits, 307
- summary, 308

Fruits, classification of
- aggregate fruits, 284
- classification exceptions, 285
- multiple fruits, 284
- simple fruits, 284

Fruits, composition of
- acidity of fruits, 285
- food additives in fruits, 288–89
- fruits as functional foods
  - antioxidants, 287
  - polyphenols (phenolics), 287–88
- organic acids, 285
- overview of, 285
- pectin substances, 285–86
- phenolic compounds, 286

Fruits, preparation of
- Carving, 159
- changes during ripening and heating, 302–4
- dry-heat preparation
  - baking, 304
  - broiling, 304
  - frying/sautéing, 304
- fruit spreads
  - ingredients, 305–6
  - preparing, 306–7
  - types of, 305
- limiting enzymatic browning
  - adding antioxidants, 302
  - coating fruits with sugar or water, 302
  - denaturing enzymes, 302
  - lowering temperature, 302
  - reducing pH, 302
- moist-heat preparation
  - applesauce preparation, 305
  - preparing dried fruit, 305
  - stewing/poaching, 304–5

Fruits, purchasing
- fruit juices, 300–302
- grading fruit, 289–90
- processed fruits, 299–300
  - dried, 300
  - frozen, 300
- selecting fruit, 290–98
- superfruits
  - blueberry, 299
  - cranberry, 299
  - goji and acai, 298–99
  - pomegrante, 299

Fruits, storage of
- olives, 307
- overview of, 307
- storing canned fruit, 307
- storing fresh fruit, 307

Fruits and vegetables, 122
Frying, 95, 157–58
Frying eggs
- fried eggs, 246
- omelets, 246
- scrambled eggs, 246

Frying fats, selection and care of, recommended equipment, 444
Frying fish
- deep-frying, 191
- sautéed fish variations, 191

Frying oils, preserving, 445
Frying vegetables
- deep-frying, 278
- stir-frying, 278

Fudge, 494
Fumet, 191
Functional beverages
- energy beverages and shots, 523
- nutraceutical beverages
  - nutraceutical trends, 522
  - overview of, 521–22
- overview of, 521
- smart beverages, 522–23
- sports beverages, 522

Functional foods
- conventional foods, 10–11
- culture, 11
- definition of, 9
- modified foods, 11
- nutrigenomics, 11
- synthesized foods, 11

Functional foods - probiotics
- benefits of probiotics, 211
- future research, 211
- mechanisms of health benefits, 211
- probiotic foods, 211
- probiotic foods and supplements, 211

Functions of eggs in foods
- binding, 241
- clarifying, 244
- color, 244
- emulsifying, 241
- foaming, 241–44
- interfering, 244

Functions of fats in food
- appearance, 433–34
- emulsions, 430–31
- flavor, 433
- heat transfer, 429
- melting point, 431–33
- plasticity, 433
- satiety or feeling full, 434
- shortening power, 429–30
- solubility, 433
- texture, 433

Functions of milk in food, 198
Functions of proteins in foods
- browning, 51–52
- buffering, 51
- denaturation/coagulation, 49
- enzymatic reactions
  - enzyme nomenclature, 50
  - factors influencing enzyme activity, 50
  - food industry uses, 50–51
  - introduction to, 49–50
  - structure of enzymes, 50
- hydration, 49

Functions of sugars in foods
- browning reactions, 424
- caramelization, 425
- crystallization, 424
- fermentation, 425
- leavening, 425
- moisture absorption (hygroscopicity), 425
- other uses, 425
- preservation, 425
- solubility, 424
- sweetness, 423–24
- texture, 425

Functions of water in food
- heat transfer: moist-heat cooking methods, 32
- introduction to, 31–32
- solvent, 32–34

G

Galactose, 38
Gaping, 182
Garlic, 267
G.D. Searle Company, 421
Gel, 33
Gelatinization
- critical temperatures, 372
- definition of, 372
- factors influencing gelatinization
  - acid, 373
  - fat, 373
  - heating time, 373
  - stirring, 373
  - sugar, 373
  - temperature, 372
  - water, 372
- problems and their causes, 306
- temperature, 372

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Gelatins
factors influencing gel formation
added ingredients, 323
gelatin concentration, 322
temperature, 322–23
is gelatin nutritious, 321
overview of, 321
phases of gel formation
phase 1 - hydration, 321
phase 2 - dispersion, 321–22
phase 3 - gelation, 322
preparation of a gel, 321
storage of gelatin, 323
summary, 325
unmolding a mold, 322
what is gelatin, 321
Gelation potential, measuring, 323
Gelato, 507
Gene, 14
Gene contamination (GMOs), 15–16
General classification of cakes, 454
Generally Recognized as Safe (GRAS), 422, 563
Genetically modified organisms (GMOs), 14
Génoise, 455
Geography and climate, 12
Germ, 327–28
Ginger, 268
Gingerbread, 466
Glacé. *See* Water ices
Glaze, 378, 473, 484
Glucose, 37, 415
Gluten, 330, 347
dried gluten, 349–50
purpose of gluten
bake product sets, 348
gases are trapped, 347–48
gases rise, 348
separating gluten from flour, 348
tender textures, 348
steps to gluten formation
hydration, 348
kneading, 348–49
Gluten-free cereal grains
amaranth, 334
buckwheat, 334
chia seeds, 334
corn, 334–36
Indian rice grass, 336
millet, 336
quinoa, 336
rice, 336–37
sorghum, 337
teff, 337
Glycogen, 40
GM foods, acceptance/rejection, 16
GMO foods, concerns about
allergies, 15
gene contamination, 15–16
religious/cultural concerns, 16
GMOs (Genetically modified organisms), 14
Government food regulations
Environmental Protection Agency, 566
federal food laws, 555–57
Food and Drug Administration (FDA), 557–64
summary, 568
U.S. Department of Agriculture (USDA), 564–66
Grading, 564
Grading meat
quality, 139
yield, 140–41
Grading methods, eggs
candling, 238–39
Haugh units, 239
Grading poultry, 165
Graduate school
academic requirements
examination requirements, 581–82
overview of, 581
graduate-degree jobs
pharmaceutical and nutraceutical Industries, 583
professor, 582–83
researcher, 582
prerequisites, 580–81
professional schools, 582
Grains. *See* Cereal grains and pastas
Grains into cereal, processing, 329
Gram, 28
Grapefruit, 293
Grapes, 293
GRE, 580
Green Cabbage, 268
Green Leaf Lettuce, 268
Green meat, 142
Greenfield, Jerry, 5
Greens
Collards, 268
Dandelion, 268
Kale, 268
Swiss Chard, 268
Grilling, 94
Guavas, 293
Guide to Acceptable Market Names for Seafood Sold in Interstate Commerce and, 177
Guide to Rounding Off Weights and Measures, 102
Gustatory, 3

H

HACCP (Hazard Analysis and Critical Control Points System)
history of, 88
introduction to, 87–88
seven principles of, 88
Halal, 13
Halal meats, 149
Ham, 152
Handling phyllo dough, 483
Hard vs. soft water, 31–32
HARPC, 88
Haugh units, 239
Health claim, 561–62
Heat energy, measuring, 30
Heat of solidification, 30
Heat of vaporization, 31
Heat preservation
boiling, 548
ohmic heating, 548
pasteurization, 548
Heat shock, 510
Heat transfer
conduction, 95
convection, 96
induction, 96
radiation, 96
Heating foods
moist heat preparation, 91–93
types of moist-heat preparation, 91–93
Hedonic tests, 21
Hemicelluloses, 40–41
Hemp milk, 207
Hepatitis A virus, 68–69
Herb, 107
Herbs add interest and flavor to salads and other foods and beverages, 316
Herbs and spices
herbs, 107
introduction to, 106–7
purchasing herbs and spices, 108
spices, 107–8
storing herbs and spices, 108
Herring worms, 69
High-conversion corn syrups, 415
High-fructose corn syrup
HFCS and obesity controversy, 416
overview of, 416
High-pressure processing, 551
Hinduism, 12
Hippocrates, 11
Histamine food poisoning, 73
Hollandaise sauce, 381
Hominy and hominy grits, 335
Homogenization, 203
Honey
honey composition, 417
overview of, 416–17
removing honey from the comb, 417
safety concern, 417
storing honey, 417
substituting honey for sugar in recipes, 417
whipped, creamed, granular, and infused honeys, 417
Hops, 532
Hormones and Antibiotics, 134–36
Hospital menu patterns, 117
cycle menus, 117
nutrition, 118
Humectant, 419
Hush puppies, 390
Husk, 327
Hydration, 49
Hydrolysis, 35
Hygroscopic, 415

I

Ice Cream, food additives, 514
Ice cream
churning and freezing, 511–12
cooked versus uncooked ice cream, 511
flavorings, 511
heating and aging, 511
ice cream as functional food, 507
ingredients, 506–7
low-fat ice cream, 507
overview of, 506
speed of churning/freezing, 512–13
storing and hardening, 513
structure of, 510
Ice cream cake, 455
Iceberg lettuce, methods of preparing, 319
Imitation milk, 204, 206
Incomplete protein, 47
Indian Rice Grass, 336
Induction, 96
Inferfering agent, 491
Infused Honey Recipe, 417
Inspection, meat, 137–39
Inspection, poultry, 164–65
Instant milk, 208
Institutional Meat Purchases Specifications (IMPS), 144
Integrated Pest Management (IPM) program, 86
Interesterification, 441
International agencies, 567
European regulation, 567
Food and Agriculture Organization, 567
International Dairy Federation (IDF), 209

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Internships, 574
Inulin, 43
Invert sugar, 418
  invert sugar in foods, 418
  invert sugar production, 418
Ionization, 34
Ionize, 34
Irradiation, 548
Irradiation (cold pasteurization)
  effects of irradiation on food, 549–50
  the irradiation process, 549
  irradiation pros and cons, 550–51
  overview of, 548–49
Irradiation inhibits mold formation in strawberries refrigerated for 17 days., 550
Islam, 13

J
Jams, 305
Jellies, 305
Job description, 113
Joule, 6
Judaism, 13

K
Kcalories on menus, 9
Kefir, 211
Kilocalories, 7, 28
Kinetic energy, 96
Kiwifruit, 293
Knead, 348
Knives, handling, 97–98
Kosher, 13
Kosher meats, 149
Kraft, James L., 228
Kraft Foods, 228
Kumquats, 293

L
Labeling of common food allergens, 73
Lactose, 414
Ladyfingers, 466
Lamb and mutton, 132
Lamb retail cuts, 147
Lamination, 471
Larding, 153
Lard/Tallow/Suet
  interesterification, 441
  overview of, 441
Latent heat, 31
Leading Examples of Food Fraud, 558
Lean versus Fatty Fish: Fat Content of 3-Ounce Cooked Portions of Fish and Shellfish, 179
Leavening agents
  air and steam, 356
  bacteria, 358
  baking powder, 359–60
  baking soda, 358–59
  overview of, 356
  potassium bicarbonate, 359
  too much/too little flour, 360
  too much/too little leavening, 360
  yeast
    dry (active yeast), 357–58
    fresh yeast, 358
    instant, quick-rising, or fast-acting yeast, 358
    overview of, 356–57
Leeks, 268
Legume-based flours
  garbanzo flour (gram flour or besan), 355
  soy flour, 355
Legumes, 260
  fermented soybean foods
    miso, 274
    natto, 274–75
    soy sauce (shoyu or soya sauce), 275
    sufu, 275
    tamari, 275
    tempeh, 275
  meat analogs, 274
  overview of, 273
  textured vegetable protein, 274
  tofu, 274
Legumes, preparing
  indigestible carbohydrates, 279–80
  no-soak method, 279
  overnight soak method, 279
  short-soak method, 279
Lemons, 293
Lettuce, 268
Levulose. *See* Fructose
Lignin, 43
Limes, 293
Linzer cookies, 466
Lipid-based fat replacers
  Olestra, 442–43
  overview of, 441–42
Lipids (fats)
  composition of lipids, 43
  fatty acids, 43–45
  foods high in lipids, 43
  triglycerides, 43
Lipids (fats), composition of, 43
Listeria monocytogenes, 65
Lobsters, 188
Loin, 146
Lower-fat preparation techniques, 445–46
Lower-fat processed meats, 152
Low-sodium milk, 206
Luo han guo, 422–23

M
Macarons, 465
Macaroons, 465
Madeleines, 465
Maillard Reaction, 51
Maize. *See* Corn
Major U.S. federal agencies involved in food regulation, 556
Major Varieties of Lettuce, 269
Major Vitamins and Minerals in Foods, 52
Making a Tender, Flaky Pastry, 476–77
Malt, 332
Malt breads, 406
Malt sugar. *See* Maltose
Maltose, 38, 414
Mandarins, 293
Mandelbrot, 466
Mangoes, 294
Manners, cultural influence on, 12
Manufacture of processed (process) cheese, 228
Maple syrup
  maples syrup colors, 418
  overview of, 417–18
  "real" vs. blended maple syrups, 418
Marbling, 134, 141
Margarine, 434–35
Marinades, 108, 143
Marmalades, 305
Marrow, 134
Masa, 334–35
Material Safety Data Sheets (MSDS), 85
Matzo, 391
Meal management
  food-service organization, 113–16
  purchasing, 118–24
  summary, 129
  table settings, 127–28
  time management, 124–25
  type of, 125–27
  types of meal planning, 116–18
Meal planning
  hospital menu patterns, 117
  types of menus, 117
  USDA menu planning, 116–17
Meal service
  American service, 127
  buffet service, 127
  English service, 127
  family service, 127
  French service, 127
  Russian service, 125–27
Mealy, 475
Measuring equivalents, 102
Measuring heat, 96–97
Measuring ingredients
  selecting the right measuring utensil, 101
  using an accurate measuring technique, 101–4
  using scales, 101
  weight vs. volume, 101
Measuring techniques, accurate
  approximating food requirements
    how much should be purchased, 103
    standard can sizes, 103
    substitutions, 104
  eggs, 102
  fat
    fractional measuring cups, 102
    glass measuring cups, 102
    water displacement method, 102
  flour, 103
  liquids, 101–2
  other ingredients or substitutions, 103
  sugar, 102–3
Measuring utensil, selecting the right, 101
Meat
  beef, 131–32
  composition of meats, 132–37
  Dark-cutting (dark, firm, dry condition), 142
  lamb and mutton, 132
  percentage yeild edible protein per pound, 124
  pork, 132
  purchasing, 137–53
  storage of meats, 159–60
  summary, 161
  types of meats, 131
  veal, 132
  yield, 140–41
Meat, cuts of
  beef retail cuts, 144–49
  halal meats, 149
  kosher meats, 149
  lamb retail cuts, 147
  organic meats, 149
  pork retail cuts, 146–47
  terminology of retail cuts, 144
  variety meats, 147–49
  veal retail cuts, 146
Meat, structure of
  adipose (fatty tissue), 133–34
  bone, 134
  connective tissue, 133
  muscle tissue, 132–33
The Meat Buyer's Guide, 144

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Meat pigments
  effects of heat on color, 137
  effects of oxygen on color, 136–37
  introduction to, 136
Meat storage, refrigerated
  packaging
    fas-flashed tray, 160
    polystyrene tray, 160
    vacuum packaging, 160
  refrigerated times, 159–60
  wrapping meat, 159
Meats, 122, 141
  choosing meats and meat substitutes, 138–39
  composition of meats, 132–37
  internal temperatures recommended for, 155
  preparation of meats, 153–59
  purchasing meats, 137–53
Meats, composition of
  antibiotics and hormones, 134–36
  extractives, 137
  pigments, 136–37
  structure of meat, 132–34
Meats, dry-heat preparation
  broiling and grilling, 156–57
  frying
    deep-frying, 158
    pan-broiling, 157
    pan-frying, 158
    sautéing, 157
  pan-broiling, 157
  roasting, 156
Meats, preparation of
  changes during heating
    flavor changes, 154
    searing, 153–54
    tenderness and juiciness, 153
  determining doneness
    color changes, 155–56
    internal temperature, 154–55
    time/weight charts, 155
    touch, 156
  dry-heat preparation, 156–58
  introduction to, 153
  moist-heat preparation, meats, 158–59
Meats, processing methods
  canning, 150
  curing, 149–50
  drying, 150
  smoking, 150
Meats, purchasing
  cuts of meat, 144–49
  grading, 139–41
  inspection, 137–39
  processed meats, 149–53
  tenderness of meat, 141–44
Meats, storage of
  frozen, 160
  refrigerated, 159–60
Mechanically deboned meats, 152–53
Mechanically tenderized beef (MTB), 143
Medical food, 198
Medical nutrition therapy, 571
Medium meat, 155
Mehtylxanthine, 525
Melons
  cantalope, 294
  honeydew, 294
  overview of, 294–95
  Persian, 294
  watermelon, 294
Melting point
  cis-trans configuration, 432–33
  crystalline structure, 433
  degree of saturation, 431–32
  elevation and boiling point, 31
  introduction to, 31
  length of fatty acids, 432
Meniscus, 102
Meringues, 247–48, 455, 465
"Microorganisms & Microbial- Derived Ingredients Used in Food," U.S. Food and Drug Administration, 209
Microorganizsm, 35
Microparticulation. The process of reducing the original size of a substance to numerous tiny particles, 442
Microwaving, 93, 159
Milk. *see also* Beverages, dairy beverages
  almond milk, 206–7
  canned fluid milks
    evaporated milk, 207–8
    sweetened condensed milk, 208
    whole milk, 207
  coconut milk, 207
  composition of milk, 198–202
  cream and substitutes, 212
  cultured milk products, 208–12
  dry milk
    instant milk, 208
    nonfat dry milk, 208
  filled milk, 206
  flavored fluid milks
    chocolate milk, 205
    eggnog, 205
    overview of, 204–5
  fresh fluid cow milks
    fat-free or nonfat milk, 204
    reduced-fat and low-fat milks, 204
    whole milk, 204
  fresh fluid milks from other animals, 204
  function of milk in foods, 198
  grain milk, 207
  hemp milk, 207
  imitation milk, 206
  ingredients used by food industry, 198
  low-sodium milk, 206
  milk products in food preparation, 212–15
  nut milks, 207
  nutritionally altered fluid milks, 205–6
  purchasing milk, 202–4
  reduced-lactose milk, 206
  rice milk, 206
  storage of milk products, 215
  summary, 215–16
  types of, 204–11
  ultrahigh-temperature processing (UHT), 205
Milk, coagulation and precipitation
  acid
    overview of, 212
    polyphenolic compounds, 213
  enzymes, 213
  heat, 212
  salts, 213
Milk, composition of
  color compounds, 200–201
  food additives, 201
  minerals, 200
  nutrients
    carbohydrates, 198–99
    cholesterol, 200
    fat, 199
    fat and kilocalorie content of milks, 200
    protein quality in foods, 199
  vitamins
    overview of, 200
    vitamins A and D fortification, 200
Milk, purchasing
  grades, 202
  homogenization, 203
  pasteurization, 202
  ultrahigh-temperature processing (UHT), 202–3
  ultrapasteurization, 202
Milk, reduced-fat and low-fat, 204
Milk, reduced-lactose, 206
Milk products in food preparation
  coagulation and precipitation
    acid, 212–13
    heat, 212
  flavor changes, 212
  whipped milk products
    whipped cream, 213–14
    whipped evaporated milk, 214–15
  whipped reconstituted nonfat dry milk, 215
Milk products, storage of
  dry storage, 215
  refrigerated, 215
Milk solids-not-fat (MSNF), 204
Millet, 336
Milling
  five steps of milling
    1 - breaking, 351
    2 - purifying, 351
    3 - reducing, 351
    4 - sifting, 351
    5 - classifiying, 351
  overview of, 350–51
  wet milling, 352
Minimum Internal Temperatures (for 15 Seconds), 81
Mirepoix, 172, 312. *see also* Poultry, dry-heat preparation; Soups
Miso, 52, 274, 314. *see also* Soups
Mixing Methods for Baked Products, 105–6
Mixing techniques, baked products, 104
Modified foods, 11
Modified starch, 372
Moist-heat preparation
  boiling, 93
  braising, 92
  microwaving, 93
  poaching, 92
  scalding, 92
  simmering, 92
  steaming, 93
  stewing, 92
Moist-heat preparation, meats, 158
  braising, 158
  microwaving, 159
  simmering or stewing, 158–59
  steaming, 159
Moist-heat preparation, poultry, 173
Molasses, 417
Molded cookies
  almond cookies, 466
  biscotti di prato, 466
  peanut butter cookies, 466
Molds, 68
Molecule, 28
Mollusk, 178
Monographs, 9
Monosaccharides
  fluctose, 38
  galactose, 38
  glucose, 37
  ribose and arabinose, 37
Mooncake, 455

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Mother sauce, 376, 378. *see also* Sauces
Mouries, Hippolyte Mege, 434
Muffin breads
  Boston brown bread, 389
  drop batters
    corn bread, 389–90
    hush puppies, 390
    tea breads, 390
Muffins
  added ingredients, 388
  avoid overmixing, 388
  avoid undermixing, 388
  baking, 388–89
  shortened cakes, 455
Muscle tissue
  introduction to, 132–33
  muscle contraction and release, 133
Mushrooms, 268
Mussels, 188
Mutton. *See* Lamb and mutton
Mycotoxin, 68
Myocommata, 179
Myotomes, 179
MyPyramid, 8

N

NARMS (National Antimicrobial Resistance Monitoring System), 88
National Academy of Sciences, 16
National Notifiable Diseases Surveillance System (NNDSS), 88
National Organic Program, 16
National Outbreak Reporting System (NORS), 88
National Sanitation Foundation (NSF), 85
National Surveillance for Enteric Disease, 88
Natural colors, 54
"Natural" foods, 17
Natural sweeteners
  corn syrup, 415
  fructose, 415
  glucose, 415
  high-fructose corn syrup, 416
  honey, 416–17
  invert sugar, 418
  lactose, 414
  maltose, 414
  maple syrup, 417–18
  molasses, 417
  overview of, 412–13
  sugar alcohols, 418–19
  sugars
    overview of, 413
    sucrose, 413–14
  syrups, 415
Natural tenderizing
  aging, 142–43
  animal's age, 141
  cut, 141
  diet, 141
  heredity, 141
  marbling, 141
  slaughtering conditions, 142
Nectarines, 294
Neotame, 422
Noncrystalline candies
  concentrating the sugar solution
    aerated candies, 496
    caramels, 495–96
    hard and brittle candy, 495
    taffy, 496
Noncrystalline candy, 490
Nonfat dry milk, 208
Nonnutritive food components
  food additives, 54
  introduction to, 53
  plant compounds
    beneficial, 57
    caffeine, 57
    harmful, 57
    introduction to, 56
Nonnutritive sweeteners, 411
  acesulfame-k, 421
  aspartame, 421
  food functions, 421
  luo han guo, 422–23
  neotame, 422
  other nonnutritive sweeteners
    brazzein, 423
    cyclamates, 423
    dihydrochalcones, 423
    glycyrrhizin, 423
    isomaltulose, 423
    L-sugars, 423
    mabinlin, 423
    miraculin, 423
    neohesperidin, 423
    tagatose, 423
    thaumatin, 423
    trehalose, 423
  saccharin, 421
  safety, 419
  stevia and its derivatives, 422
  sucralose, 421–22
  use in foods and beverages, 419
Nontempered coating, 500
No-observed-effect-level (NOEL), 421–22
Norovirus, 69
NOSB (U.S. National Organic Standards Board), 16
Nuclei, 491
Nut milks, 207
Nut-based flours
  almond meal flour, 355
  coconut flour, 355
Nutraceuticals, 9
Nutrient Comparison: Fruit and Vegetable Beverages vs. Soda, 301
Nutrient Content
  breads, 404
  cakes, 458
  candy, 495
  cheese, 223–24
  Cookies, 468
  cookies, 468
  eggs failing USDA inspection, 241
  fats, 436
  fish, 182–83
  meats, 137
  poultry, 166
  reducing salt, 107
  sugars, 414
  vegetables, 260–61
Nutrient content
  grains, 328
  pastas, 342
  quick breads, 388
Nutrient content claims, 561–62
Nutrient Content Claims Allowed for Food Labeling, 562
Nutrient content, fruits, 287
Nutrient groups, 27
Nutrient retention, food, 552
Nutrients, 28
Nutrition, 118
Nutrition certification routes, 574
Nutrition science and dietetics
  dietetics
    overview of, 572
    registered dietitian nutritionist (RDN), 572–75
  nutrition science
    nutritionist, 572
    overview of, 572
  overview of, 571–72
  types of registered dietitian nutritionists
    Dietary Clerk or Dietary Aide, 577
    Dietetic Technician, Registered (DTR), 576–77
    licensure, 575–76
    listing of, 575–76
Nutritional criteria
  ChooseMyPlate, 6–9
  Dietary Guidelines for Americans, 6
  introduction to, 6
  weight management, 6
Nutritional criteria, food selection, 9–11
Nutritionally altered fluid milks, 205–6

O

Oats
  forms of oats
    oat bran, 332
    oat groats, 332
    rolled oats, 332
    steel cut oats, 332
Obesity, 6–9
Objective evaluation
  chemical tests, 24–25
  physical tests, 23–24
Objective tests, 20
Odor
  classification of odors, 2
  detecting odors, 2–3
Ohmic heating, 548
Oil and vinegar salad dressings
  oils, 320
  vinegars, 320
Oil extracts, 108
Oils
  hydrogenated oils, 440–41
  oil production
    extraction, 437–38
    refining, 438–39
  overview of, 436–37
  types of
    oils as functional foods, 440
    tropical oils, 439–40
  types of oils
    olive oil, 439
    overview of, 439
  winterized oils, 440
Okra, 269
Oleogustus, 3
Olestra, 442–43
Olfactory, 2
Oliogosacharides
  food industry uses, 38
  introduction to, 38
Olive oil, 439
  variations according to acidity, 440
Olives, 295–96
Omega-3 fatty acids, 183, 437
Omelets, 246–47
Onion varieties, 270
Onions
  green onions, 269–70
  Leeks, 270
  overview of, 269
  Shallots, 270

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Oranges, 295
Organic certification, 16–17
Organic foods
  introduction to, 16
  organic certification, 16–17
Organic Foods Production Act, 1990, 16
Organic meats, 149
Origin of Selected Cheeses, 219–21
Osmosis, 36
Osmotic pressure, 36
Outbreak, 61
Oven spring, 402
Overrun, 511
Oxidative Rancidity, 449
Oysters, 187

P

Pan-broiling, 157
Pan-Broiling and Pan-Frying, 95
Pancakes, 386
Pan-frying, 158
Papayas, 296
Parasites
  advanced techniques for detecting contamination, 71
  new virulent biological hazards, 71
  prions - mad cow disease, 70–71
  protozoa, 69–70
  roundworms, 69
  that cause foodborne illness, 70
  Toxoplasma gondii, 70
Parboil, 93
Parchment cones and pastry bags, 484
Parechyma cells
  chloroplasts and chromoplasts, 257–58
  leucoplasts, 257
  vacuoles, 258
Parsley, 270
Parsnips, 270
Pascalization, 551
Pasta, preparation of
  microwaving, 342
  moist-heat preparation, 341–42
Pasta, storage of, 342–43
Pasta shapes, 341
Pastas
  Asian noodles, 340
  couscous, 341
  fanciful, 340
  flavored, 340
  fresh, 341
  high-protein pasta, 340–41
  noodles, 340
  overview of, 340
  whole wheat, 340
Pasteurization, 202
  high-temperature pasteurization, 548
  overview of, 548
  sous-vide, 548
  temperature for grade A milk, 203
Pastries and pies
  preparation of pastry, 474–85
  storage of pastry, 485–86
  summary, 487
  types of pastry, 471–74
Pastry
  Danish pastry, 473–74
  dough compared to bread dough, 474
  flakiness, 475–76
  laminated pastries
    croissant pastry, 473
    phyllo (filo) pastry, 473
    puff pastry, 473
    quick (blitz) pastry, 473
  nonlaminated pastries
    brioche, 472
    choux pastry (pâte à choux), 472–73
    plain pastry, 471–72
  pastry classification, 471
  problems and their causes, 486
Pastry, preparation of
  baking
    pan selection and preparation, 485
    temperature and timing, 485
    testing for doneness, 485
  fillings
    chiffon pies, 484
    cream fillings, 483
    custard fillings, 483–84
    fruit fillings, 483
    meringue pies, 484
    pastry fillings, 484
  ingredients in pastry
    eggs, 477
    flavorings, 477
    liquid, 476–77
    salt, 477
    sugar, 477
  ingredients of pastry
    fat, 475
    flour, 475
    overview of, 474–75
  mixing methods
    plain (pie) pastry, 478
    puff pastry, 478
  rolling
    chilling the dough, 479–80
    general technique, 480
    rolling plain pastry, 480
    rolling puff pastry, 481
    rolling surface, 480
  thickeners (for fillings)
    adding thickeners, 478
    arrowroot, 478
    ClearJel®, 478
    cornstarch, 478
    overview of, 477–78
    tapioca, 478
  toppings
    crumb toppings, 484–85
    glazes, 484
Pastry, storage of, 485–86
Patent, 351
Pathogenic, 63
Patient Protection and Affordable Care Act, 2010, 118
Peaches, 296
Pears, 296
Peas, 270
Pectic substances, 41
Pectin substances
  overview of, 285–86
  pectin formation and ripening fruit, 286
  pectin substances and juice cloudiness, 286
  use of pectin by the food industry, 286
Peppers, Hot, 270
Peppers, Sweet, 270
Peptide bond, 48
Percentage Yield, 123
Persimmons, 296
Personal preference, 21
Pesticide residues (GMOs), 16
Petit four, 455
Pharmaceutical and nutraceutical industries, 583
Phenolic, 43
Phenolic compounds
  overview of, 286
  phenolic compounds and enzymatic browing, 286
Phyllo (filo) pastry, 473
Physical tests, 23–24
Phytochemical, 56, 259, 287–88
Pickling
  overview of, 544
  weak organic acids, 544
Pies, 472
  and modified cornstart, 376
Pineapple, 296–97
Pita bread, 406–7
Pizza crust, 408
Place of birth, 11–12
Plain pastry
  alternative piecrusts, 481
  hot-water crust pastry, 472
  overview of, 471–72
  short or sweet dough pastry, 472
Plasticity, 102
Plums, 297–98
Poaching, 92
Poaching eggs, 249–50
Polymerization, 444
Polymorphism, 433
Polyphenol, 525
Polysaccharides, 38–43
  common fibers and their food industry uses, 40–43
  fiber - indigestible polysaccharides, 40
  glycogen - digestible polysaccharide from animal sources, 40
  measuring dietary fiber, 40
  soluble vs. insoluble fiber, 40
  starch - digestible polysaccharide from plant sources, 38–39
Pomegranates, 298
Popovers, 387
Pork, 132
Pork retail cuts, 146
Portion guide, 125
Potatoes
  choosing the right potato, 272
  other, 271
  overview of, 270–72
  reduced-lactose milk, 271
  russet, 271
  white, 271
Pots and pans, washing, 85
Poultry
  classification of poultry, 163
  common labeling terms, 168
  composition of poultry, 163
  preparation of poultry, 168–74
  purchasing, 163–68
  ready-to-cook, 165
  storage of poultry, 174
  summary, 175
Poultry, classification of, 163
Poultry, composition of, 163
Poultry, dry-heat preparation
  broiling or grilling, 172
  frying
    deep-frying, 173
    pan-frying, 173
    sautéing, 173

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stir-frying, 173
roasting or baking, 170–71
Poultry, preparation of
changes during preparation, 169–70
determining doneness
color changes, 170
internal temperature, 170
touch, 170
dry-heat preparation, 170–73
moist-heat preparation
braising, 173
microwaving, 173–74
poaching, 173
stewing, 173
overview of, 168
preparation safety tips
brining, 168–69
stuffing, 168
thawing frozen poultry, 168
time/weight charts, 170
Poultry, purchasing
grading, 165
how much to buy, 167–68
inspection, 163–65
labeling, 166
standarized poultry buying, 166–67
types and styles of
labeling, 168
processed poultry, 165–66
Standardized Poultry Buying, 166–67
Poultry, storage of, 174
frozen, 174
overview of, 174
refrigerated, 174
Poultry, types and styles of
overview of, 165
processed
additives, 166
hormones and antibiotics, 165–66
The Poultry Buyer's Guide, 167
Pound cake, 455
pH scale, 34
Prawn, 189
Prebiotics, 211
Precipitate, 33
Preservation. *See* Food preservation methods
Preserved fish/roe, 185
Preserves, 305
Pressed cookies
ladyfingers, 466
Russian tea cookies, 466
Price comparisons, 122
Prion, 70
Prions, 70–71
Probiotics, 211
Process (processed) cheese, 228
cold-pack cheese, 228–29
imitation cheese, 229
process cheese, 228
process cheese food, 229
process cheese spread, 229
tofu and other nondairy cheeses, 229
Process of photosynthesis, 412
Processed foods, 1, 17
Processed meats
bacon, 152
food additives in processed meats, 150–51
ham, 152
lower-fat processed meats, 152
mechanically deboned meats, 152
processing methods, 149–50
restructured meat, 153
sausage, 152
types of processed meats, 152–53
Product recall, 557
Proof, 364, 399, 537
Proof box, 399–400
Proofing
avoid overfermentation, 400–401
changes during fermentation, 400
optimal fermentation conditions, 400
overview of, 399–400
punching down and second proofing, 400–401
Protein complementation, 47
Proteins
amino acids, 48–49
composition of proteins, 47–48
functions of proteins in food, 49–52
protein quality in foods, 47
PSE condition, 142
Psychological and sociological criteria
bioengineering, 14
Budgetary criteria, 17
history of biotechnology, 14–15
introduction to, 14
"natural" foods, 17
organic foods, 16–17
processed foods, 17
Puff pastry
cream puffs and éclairs, 479
definition of, 473
overview of, 478–79
rolling
frozen rolled phyllo dough, 482–83
laminating puff pastry dough, 481–82
Puffer fish poisoning, 73
Pulsed light, 551
PulseNet (National Molecular Subtyping Network for Foodborne Disease Surveillance), 88
As purchased (AP), 123
Purchasing
buyers, 121
cost control, 122–23
food stores and vendors/suppliers, 121
introduction to, 118–21
reading label product codes, 123
reducing waste saves costs, 123
Pure Via, 422

Q

Qualified health claim, 561–62
Qualified Presumption of Safety (QPS), 209
Quality, meat
influence of fat content on grading, 140
introduction to, 139–40
USDA beef quality grades, 140
Quality grades (meat), 139
Quick (blitz) pastry, 473
Quick Bread
ingredients proportions, 386
problems and their causes, 389
Quick breads
drop batters, coffee cakes, 390
overview of, 346–47
pour batters, pancakes, 386
preparation of quick breads, 385–86
summary, 393
varieties of quick breads, 386–92
Quick breads, preparation of
additives used in quick breads, 386
muffin method, 386
overview of, 385–86
Quick breads, varieties of, 405
doughs
biscuits, 391
crackers, 391
scones, 391
unleavened breads, 390–91
drop batters
dumplings, 390
muffin breads, 389–90
muffins, 388–89
overview of, 387
pour batters
crepes, 386–87
popovers, 387
waffles, 387
Quinoa, 336

R

Radiation, 96
Radicchio, 268
Radio frequency, 551
Radishes, 271
Rancidity, 546
preventing
antioxidants, 448
avoid oxygen and heat, 448
types of rancidity
flavor reversion, 448
hydrolytic rancidity, 447
oxidative rancidity, 448
Rare meat, 155
Rebiana, 422
Red Leaf Lettuce, 268
Red tide, 73
Reducing agents, how they work, 364
Reducing sugars, 424
Reducing waste saves costs
percentage, 123
portion control, 123–24
as purchased vs. edible portion, 123
Reduction, 381
Reference proteins, 241
Registered Dietitian Nutritionist (RDN; old term was registered dietitian, RD), 575
academic requirements, 572–74
overview of, 572
supervised practice programs
internships, 574–75
professional developmental portfolio, 575
Regulatory agencies
Federal Trade Commission, 567
state agencies, 567
U.S. Department of Commerce, 567
Religious criteria
Buddhism, 12
Church of Jesus Christ of the Latter-Day Saints (Mormon Church), 12–13
Hinduism, 12
introduction to, 12
Islam, 13
Judaism, 13
Seventh-Day Adventist Church, 12
Religious/cultural concerns (GMOs), 16
Resistant starches (RS)
overview of, 375
RS4 modified (chemically) starches, 375–76
cross-linked starch, 376
oxidized starch, 376
Respiration rate, 280
Retail cuts, 144
Retrogradation, 374

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Rhizome, 107
Rhubarb, 298
Ribose and arabinose, 37
Rice
  classification of rice, 336–37
  forms of rice
    black rice (purple or forbidden rice), 337
    brown rice, 337
    converted rice, 337
    glutinous rice, 337
    instant rice, 337
    red rice (red rice koji), 337
    rice bran, 337
    specialty rice, 337
    white rice, 337
    wild rice, 337
Rice milk, 206
Rigor mortis, 141–42
Ripening, 224
"R-Month Rule." *See* Fish and Shellfish
Roasting, 94, 156
Roasting or baking poultry
  basting, 171–72
  carving, 172
  stuffing, 172
Rolled cookies
  butter cookies, 466
  cannoli shell, 466
  gingerbread, 466
  linzer cookies, 466
  mandelbrot, 466
  shortbread, 466
  sugar cookies, 466
Rolls, 406
Romaine lettuce, 268
Rope, 408
Roulade, 455
Roundworms
  Herring worms *(Anisakis simplex) and* Cod Worms *(Pseudoterranova decipiens)*, 69
  Trichinella spiralis, 69
Roux, 378. *see also* Sauce, preparing from roux; Sauces, thickened and unthickened
Rubs and pastes, 108–9
Russian service, 125–27
Rutabagas, 271

S

Saccharin, 421
Saddleback a Lobster Tail, how to, 193
Salad dressings
  adding dressing to salads, 321
  emulsified dressings, 320
  other dressings, 320–21
Salads
  overview of, 315–16
  principles of salad preparation, 316–17
  salad dressings, 319–21
  salad ingredients, 316
Salmon, 185
Salmonella, 65
Salt, 4
  adding salt in food preparation, 104–6
  other dietary salt source, 106
  processed foods, 106
  types of, 104–5
Salty, 3
Sanitation, foodborne illness
  dishes, 84–85
    chemicals, 85
    drying, 85
    heating, 85
    three-compartment sink, 85
  equipment, 85
  facilities, 85–86
  pest control
    blocking access to food, 86
    blocking entrances, 86
    integrated pest management (IPM) program, 86
  scheduling, 85
Sardines, 185
Saturated solutions, 33
Sauce, preparing from roux
  adding seasonings and flavorings, 379
  cheese sauce, 379
  combining the liquid and the roux, 379
  heating the sauce, 379
Sauces
  for beef, 154
  functions of sauces in foods, 376
  mother sauces, 377
  preparation of thickened sauces, 377–79
  small sauces, 377–78
  thickened and unthickened, 377
Sausage
  cooked, 152
  dry/semidry, 152
  raw fermented, 152
  uncooked, 152
Sautéing, 157
Sautéing and Stir-Frying, 95
Savoy, 268
Scalding, 92
Scalloped, 275
Scallops, 188
Scampi, 189
Schlatter, James, 421
Scones, 392
Score, 402
Seafood toxins
  ciguatera fish poisoning, 72–73
  histamine food poisoning, 73
  puffer fish poisoning, 73
  red tide, 73
Sear, 94
Searing, 153
Seasonings, 104
Seasonings and flavorings
  batters, 109
  breadings, 109
  condiments, 110
  flavor enhancers, 108
  herbs and spices, 106–8
  marinades, 108
  oil extracts, 108
  pepper, 106
  rubs and pastes, 108–9
  salt, 104–6
  salt substitutes, 106
  types of, 104–10
Seasonings and flavorings, adding
  food industry uses, 110
  how much to add, 110
  when to add, 110
Seasons for vegetables, 264–65
Seed, 493
Selecting a cheese
  blistering, 231
  browning, 231
  meltability, 230–31
  oiling off, 231
  shreddability, 230
  stretchability, 231
Selecting a Refined Cooking Oil, 438
Selection and care of frying fats
  controlling the temperature of frying foods
    avoid too-low temperatures, 444
    optimal frying temperatures, 444
    perfect browning of fried foods, 444
  fats suitable for frying, 443
  flash point and fire point, 443–44
  optimal frying condition
    avoid water, 444
    cool the frying fat, 444–45
    remove food particles, 444
    when to discard the used frying fat, 444–45
  smoke point, 443
A selection of cookies, 464
Sensitivity tests, 21
Sensory criteria
  hearing, 6
  odor, 2–3
  sight, 1–2
  taste, 3–4
  touch, 4–6
Sensory impressions of food provided by five senses, 2
Sensory testing, two types, 20–22
Sensory/subjective evaluation
  analytical (effective) tests, 22
  introduction to, 20
  sample preparation, 23
  two types of sensory testing, 20–22
Sensory/subjective tests, 20
Seventh-Day Adventist Church, 12
Several of the many varieties of grain, 327
Shellfish, selection of
  abalone, 189
  clams, 189
  crab
    canned crab, 190
    overview of, 189
  crayfish, 190
  lobsters, 189
  mussels, 189
  oysters, 187
  purchasing live shellfish
    "R-Month Rule," 187
    selecting live mollusks, 187
  purchasing processed shellfish, 187
  scallops, 189
  shrimp, 189
  shucking shellfish, 187
Sherbet, 507–8, 513
Shigella, 66
Shirred eggs, 247
Shortbread cookies, 466
Shortened cakes
  bundt cakes, 454
  butter cake, 454
  carrot cake, 454
  cheesecake, 454
  ciambellone, 454
  coffee cakes, 454
  cupcake, 454
  devil's food cake, 454
  fruitcake, 454
  German chocolate cake, 454
  ice cream, 455
  mooncake, 455
  muffin, 455
  overview of, 453
  pound cake, 455
  selection of shortened cakes, 455
  upside-down cake, 455

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Shortening, 429
Shortenings, 436
Shrimp, 188–89
  canned shrimp, 189
  how much to buy, 189
  peeling and cleaning shrimp, 189
Sight, 1–2
Silence cloth, 127
Simmering, 92
Simmering or stewing, 158–59
Simmering vegetables
  amount of water, 278
  overview of, 278
Simple syrup, 489
Six taste stimuli, 3
Slurry, 379
Small sauce, 377
Smoke point, 443–44
Smoking, meats, 150
Soda. *See* Beverages
Sodium, 53
Soft Drinks, selected food additives, 521
Sol, 322
Solubility, 33
Solute, 30
Solutions
  food applications, 33
  saturated solutions, 33
  solubility, 33
  supersaturated solutions, 33
Solvent, 31
  coarse dispersions (suspensions), 33
  colloidal dispersions, 33
  dispersion destabilization, 34
  dispersions, 32
Sorbet
  overview of, 508
  preparation of
    churning, 514
    overview of, 513
    sorbet syrup preparation, 513–14
Sorghum, 337
Soufflés, 248
Soups
  clear and thin soups
    bouillon, 313
    consommé, 313
    thin soups, 313
  overview of, 310
  stocks, 311–13
  summary, 325
  thickened soups
    cream soups, 314
    how to avoid curdling, 315
    keeping cream soups safe, 315
    lower-fat cream soups, 315
    overview of, 313–14
    preparation of cream soups, 314–15
  types of, 310–11
Soups, Salads, and Gelatins, 324
  salads, 315–21
  soups, 310–15
  summary, 325
Sour, 3
Sour cream, 211–12
Sourdough bread, 406
Spare ribs, 146
Specialty breads
  ingredient variation, 406
  nutrient modifications, 406
  preparation technique, 406
Specific gravity, 277
Specific heat, 30
Specificiations, 121
Spice, 107
Spinach, 271
Spirits, 537
Sponge cake, 462
Spore, 77
Sprout Preparation, 280
Sprouts, 271
Sprouts, preparing
  growing sprouts, 280
  storing sprouts, 280
Squash
  Summer Squash, 272
  Winter Squash, 272
Squash selections, 273
Stabilizer, 505
Standardized recipe, 125
Standards of Fill, 559
Standards of Identity, 558
Standards of Identity for Milk Products, 204
Standards of Minimum Quality, 558
Staphylococcus aureus, 66
Starch, 38–39
Starch characteristics
  sources of starch
    cornstarch, 370
    overview of, 369–70
Starch in food products
  dextrose, 370–71
  edible films, 370
  starch syrups, 371
  thickening agent, 370
Starch structure, 371
Starch transformations
  dextrinization, 374
  gel formation, 373–74
  gelatinization, 372–73
  instant or pregelatinized starches, 375
  resistant starches (RS), 375–76
  retrogradation, 374
Starches and Sauces
  sauces, 376–82
  starch characteristics, 369–72
  starch transformation, 372–76
  summary, 383
Starches and sauces, storage of starches and sauces, 376–82
Starches and sauces, storage of, 382
Starter, 358
Steaks, fish, 181–82
Steaming, 93, 159
  clambakes are underground steaming, 192
  steaming shellfish, 192
Steaming vegetables
  foil-wrapped vegetables, 279
  overview of, 278–79
Steps to refining edible vegetable oils, 439
Sterlization, 545
Stevia and it's derivatives
  overview of, 422
  safety of, 422
Stewing, 92
Still-frozen desserts, 508, 514
Stocks
  fish stocks
    overview of, 312–13
    shellfish stocks, 313
  flavoring ingredients, 312
  meat stocks
    adding meat and bones, 312
    adding vegetables, 312
    overview of, 312
  overview of, 311
  poultry stocks, 312
  vegetable stocks, 313
  water: the main ingredient, 311–12
  white and brown stocks, 311
Straight flour, 351
Stream, 351
Streusel topping, 480
Structure/function claims, 561–62
Sublimation, 543
Substrate, 50
Sucralose, 421–22
Sucrose, 38
  different forms of, 413
  forms of sucrose, 413–14
  sucrose extraction, 413
Sugar, measuring
  brown sugar, 103
  confectioners' sugar, 103
  granulated white sugar, 103
  introduction to, 102
Sugar alcohols
  sugar alcohols in foods
    cariostatic, 419
    cooling sensation, 419
    humectant, 419
    reduced calories, 418–19
Sugar cookies, 466
Superglycerinated, 437
Supersaturated solutions, 33
Surfactant, 430
Surimi, 186
Sushi, 193
Sweat, 110
Sweet, 3
Sweet Potatoes, 272–73
Sweetened condensed milk, 208
Sweeteners, 412
  functions of sugars in foods, 423–25
  natural sweeteners, 412–19
  nonnutritive sweeteners, 419–23
  overview of, 411–12
  summary, 426
Sweet'N Low, 421
Syneresis (weeping), 323, 374
Synthesized foods, 11

T

Table settings
  accessories, 127–28
  centerpieces, 128
  cover and linens, 127
  flatware/dinnerware/glassware, 127
Taffy, 496
Tangerines, 298
Tannins, 529
Taste
  definition of flavor, 4
  factors affecting, 4
  interactions, 4
  mechanism of, 3
  six taste stimuli, 3
Tea
  black tea, 528
  composition of tea
    health benefits of tea, 529
    overview of, 529
  flavored teas, 529
  grades of tea, 529
  green tea, 528
  herbal teas, 529

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Tea (*Continued*)
oolong, 528–29
overview of, 528
preparation of tea
brewing tea, 530
iced tea, 530
instant tea, 530
microwaving, 530
overview of, 529
speciality teas, 529
storage of tea, 530
tea processing
firing, 528
oxidizing, 528
rolling, 528
withering, 528
white teas, 529
Tea breads, 390
Teff, 331, 334, 337, 354. *see also* Ancient wheat grains
Temperature danger zone, 76
Tempering
cold-water method, 500
commercial chocolate coating, 500
enrobing, 499
factors influencing
overview of, 499
seeding method, 500
tabliering method, 499–500
nontempered coatings, 500–501
overview of, 498–99
seeding method, 500
tempering for chocolate dipping, 500
Tender young lettuces and other greens add variety to salads, 317
Tenderizers and Tougheners in Flour Mixtures, 475
Tenderness of meat
artificial tenderizing, 143–44
cuts of meat, 144–49
natural tenderizing, 141–43
rigor mortis, 141–42
Tenure track, 582
Test of English as a Foreign Language (TOEFL), 582
Texture profiles, 21
Textures
astringency, 5
consistency, 5
Textures compounds, 56
Thaw rigor, 142
Thawing a Turkey, 168
Thermometers, proper use of, 82–83
calibration of, 83–84
care of, 83
testing temperatures, 82–83
Thickened sauces, preparation of
ingredients
liquid, 377–78
seasonings and flavorings, 378
thickening agent, 378
preparing a sauce from a roux, 379
preparing thickeners
beurre manié, 378–79
roux, 378
slurry, 379
prevening lumps, 379
Three major food and nutrition areas, 570–71
Three Rules for "High-Ratio" Cakes, 457
Three-compartment sink, 85
Threshold concentration, 4
Time management
efficient meal preparation, 124–25
estimating time, 124
recipes, 124–26
Tiramisu, 455
Tomatoes, 273
Tortillas
corn tortillas, 390–91
flour tortillas, 390
Touch, 4–6
Trichinella spiralis, 69
Triticale, 333–34
Tropical fruits
cherimoya, 298
guavas, 298
kumquats, 298
lychee, 298
passion fruit, 298
plantains, 298
pummelos, 298
red banana, 298
Tropical oils, 439–40
Truss, 171
Truvia, 422
Tuber, 275
Tuna, 184–85
Turgor, 258
Turnips, 273
Typical freeze-drying process, 543

U

Ultrahigh-temperature (UHT) milk, 203, 205
Ultrapasteurization, 202
Umami, 3, 25
Unleavened breads
chapatis, 391
crisp flatbreads, 391
Génoise, 455
matzo, 391
tortillas, 390
Unqualified health claim, 561–62
Unshortened cake, 455
Unshortened cakes
angel food cake, 455
Boston cream pie, 455
dacquoise, 455
meringues, 455
petit four, 455
roulade, 455
tiramisu, 455
Unthickened sauces, preparation of
barbecue sauce, 381
butter sauce, 381
fruit sauce, 381
gravy, 381
deglazing, 381
degreasing, 381
overview of, 380–81
reduction, 381
seasoning, 381
straining, 381
hollandaise sauce, 381
tartar sauce, 381
tomato sauce, 382
U.S. Department of Agriculture (USDA), 6
product labeling
Country of Origin Labeling (COOL), 565–66
irradiated foods, 565
organic acids, 565
USDA grading
quality grades, 565
quantity grades of yields, 565
USDA inspections, 564–65
U.S. Department of Health and Human Services (DHHS), 6
U.S. Dietary Guidelines, 520
U.S. National Organic Standards Board (NOSB), 16
USDA (U.S. Department of Agriculture), 6
USDA Agricultural Marketing Service, 16
USDA Center for Nutrition Policy and Promotion, 118
USDA Grades for Vegetables and Fruits—Processed and Fresh, 263
USDA menu planning, 116–17
USDA Quality Grades for Beef, Veal, Lamb, and Mutton from Highest to Lowest, 140
Uses of cereal grains
alcoholic beverage, 329
animal feeds, 329
breakfast cereal, 329
flour, 329
pasta, 329

V

Varieties of cultivated mushrooms, 269
Varieties of oats, 333
Variety meats, 147–49
Veal, 132
Veal retail cuts, 146
Vegetable gums, 41–43
Vegetables, classification of, 256
Vegetables, composition of
additives, 261
flavonoids
anthocyanins, 259
anthoxanthins, 259
betalains, 259
plant pigments
carotenoids, 258
chlorophyll, 258–59
plants as functional food, 259–61
structure of plant cells
cell wall, 256–57
intercellar air spaces, 258
storage structure in parechyma cells, 257–58
Vegetables, preparation of
changes during heating
color, 276–77
flavor, 275–76
odor, 276
texture, 275
dry-heat preparation
baking, 277–78
frying, 278
roasting, 278
general guidelines
buying, 275
cooking liquid, 275
cooking time, 275
storing, 275
washing, 275
moist-heat preparation
braising, 279
microwaving, 279
simmering, 278
steaming, 278–79
nutrient retention, 277
preparing legumes, 279
preparing sprouts, 280
Vegetables, purchasing
grading vegetables, 263
selecting vegetables, 263–73
Vegetables, storage of
controlled-atomsphere storage, 281
dry storage
overview of, 281

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storing potatoes, 281
freezing, 281
overview of, 280–81
refrigerated
maintaining moisture, 281
special storage requirements, 281
Vegetables and legumes
classification of vegetables, 256
composition of vegetables, 256–63
legumes, 273–75
pigments color changes, acid, alkali, heat and metals, 277
preparation of vegetables, 275–80
purchasing vegetables, 263–73
storage of vegetables, 280–81
summary, 282
Vegetarianism, 8–9
Verification form, 574
Veterinary Feed Directive, 135
Vibrio, 68
Vinaigrette, 320
Vinegars, 320
Vintage, 534
Virulent biological hazards, new, 71
Virus, 68
Viruses
foodborne illness, 69
hepatitis A virus, 68–69
norovirus, 69
Vitamins and minerals
composition of vitamins and minerals, 52
foods high in vitamins and minerals, 52
functions of vitamins and minerals in foods
antioxidants and their food industry uses, 53
enrichment and fortification, 53
sodium and its food industry uses, 53
Vitamins and minerals in foods, function of
antioxidants and their food industry uses, 53
enrichment and fortification, 53
sodium and its food industry uses, 53
Vitelline membrane, 237
Volatile molecules, 2
Volume, 23
Vulnerable foods, foodborne illness
exception to the high-protein/water/pH rules, 78–79
foods with high water activity, 78
foods with low acidity, 78–79
high-risk foods, 78
oxygen and food, 79

W

Wafers, 465
Waffles, 387
Water
boiling point, 31
bottled water, 518–19
composition of water, 29
freezing point, 30–31
functions of water in food, 31–32
hard vs. soft water, 31
introduction to, 28–29
measuring heat energy, 30
melting point, 31
soft drinks marketed as "water," 519–20
specific heat, 30
treatment methods
distilled water, 519
purified water, 519
reverse osmosis water, 519
Water activity (aw), 35
Water ices, 514
frappé, 508
granitas and granités, 508
popsicles, 508
Watercress, 268
WCRF (World Cancer Research Fund), 9
Weeping (syneresis), 247
Weight management, 6
Well done meat, 155
Wheat
classification of wheat
color, 331
growing season, 330–31
forms of wheat
bulgur, 331
cracked wheat, 331
farina, 331
rolled wheat, 331
wheat berries, 331
wheat bran, 331
wheat germ, 331
Wheat (white) bread, 405
Wheat flour
ancient flour grains, 353
bread flour, 352–53
graham flour, 353
white flour
all-purpose flour, 353
cake flour, 353
durum flour, 353
pastry flour, 353
semolina, 353
whole-wheat flour
as a functional food, 352
overview of, 352
Whey, 199
Whey and whey products, cheeses, 226–28
dry whey, 228
modified whey products, 228
whey cheeses, 228
Whipped cream
age, 214
fat content, 214–15
sugar, 214
temperature-time monitoring program, 214
whipping time, 214
Whipped evaporated milk, 214–15
Whipped reconstituted nonfat dry milk, 215
White sauce, 248
White stock, 311
Whole fish, 181–82
Whole foods, 1
Whole grains, 328
Whole milk, 204
Whole wheat bread, 406
Wholesale (primal) cuts, 144
Wholesale and retail cuts of beef, 145
Wine
evaluating wines, 533–34
overview of, 532–33
selecting a wine
the colors of wine, 534
food additives in wines, 537
types of win, 534
wine production
aging, 533
fermentation, 533
racking, 533
Wines, 535–36
World Cancer Research Fund (WCRF), 9
World Health Organization, 135
Wrapping meat for freezing (apothecary or drugstore method), 160

Y

Yeast, 348, 540
Yeast breads
bagels, 407
English muffins, 407–8
ingredients and functions, 396
loaf breads
malt breads, 406
sourdough bread, 406
specialty breads, 406
wheat (white) bread, 405
whole wheat bread, 406
pita bread, 406–7
pizza crust, 408
preparation of yeast breads, 395–405
pretzels and bread sticks, 408
problems and causes, 404
raised doughnuts, 408
rolls, 406
summary, 409
types of yeast breads, 405–8
Yeast breads, storage of
fresh
fresh bread additives, 408
preventing staling, 408
staling, 408
frozen, 408–9
refrigerated, 408
Yeast breast, preparation of
baking
changes during baking, 402–3
crumb development, 403
problems with texture, 403
testing for doneness, 403–4
decorating, 402
food additives in baked goods, 396–97
high-altitude adjustment, 405
ingredients, 395–96
kneading, 398–99
microwave preparation, 404
mixing methods
batter method, 398
overview of, 397–98
rapid mix, 398
sponge method, 398
straight dough method, 398
proofing: fermentation causes the dough to rise, 399–401
selecting a baking pan, 402
shaping, 401–2
Yogurt
active yogurt cultures, 210
other ingredients added to yogurt, 210
overview of, 210
yogurt definition, 210

Z

Zest, 103, 270, 304. *see also* Fruits

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