New Perspectives: Sustainable Technological Development in Agriculture.

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ABSTRACT

New long term perspectives on fulfilling our (basic) needs for food and short term actions to work on these perspectives are necessary. In agriculture in The Netherlands and elsewhere there are currently many economic and environmental problems. This situation is further aggravated by trends towards liberalization of world trade, a demanding environmental policy, technological progress and fewer price subsidies for agricultural production. The next four decades will bring a considerable growth in the world's population and an increasing welfare. This will lead to a sharp increase in the demand for food.

If sustainable development is to become a reality, the environmental efficiency (i.e. the use of energy, space and raw materials) of current agricultural production methods must be increased with a factor of 20 by 2040. This is a challenge for a technological breakthrough.

In the contribution 'New Perspectives: Sustainable Technological Development in Agriculture' two sustainable perspectives and action agendas, which are studied at the Dutch research program Sustainable Technological Development (STD), will be discussed. The first perspective is the development of protein foods which are attractive to both consumers and manufacturers. These products must be able to meet in the future

consumer demands in the same way as meat does, but their production in environmental terms must be at least 20 times more environmentally efficient than current meat production in The Netherlands.. Research points out that in 2040 novel protein foods will occupy 40% of the meat market.

The second perspective, sustainable land use, is focusing on the rural area. The essentials of this perspective are the integration of "new" functions like the gaining of water and energy, the processing of organic waste and the management of nature and culture into the production of food and raw materials for industry. This should lead to new business opportunities both for farmers and other parties like energy and water companies and a production which in environmental terms is 10 times more efficient.

Market parties, research-institutes, government bodies and non governmental organizations are working together to realize the action agendas and try to achieve these perspectives.

1. INTRODUCTION

The next four decades will see a growth in the world's population from 6 billion to some 10 billion. Welfare will increase at the same time by an average of 2% per year in OECD countries and by 4-6% in Third World countries, the latter rise leading to a more evenly spread demand for food in the world as more people eat meat. And to produce one kilo of meat requires four kilos of plant food. The quotation of figure 1 shows the consequences.

	EB	=	EB/Pr	*	Pr/P	*	P
1990	1	=	1	*	1	*	1
2040	0,5	=	1/20	*	5	*	2

EB = Environmental Burden
EB/Pr = Environmental Burden per unit of prosperity
Pr/P = Prosperity per capita
P = Population

Figure 1.1. The relations that determine the environmental burden

Twice as many people, a five-fold increase in worldwide prosperity and a reduction in environmental pollution, all by the year 2040. This means that we are going to need to become twenty times as efficient in our treatment of energy, raw materials, space and other environmental factors. Thus we need to become twenty times as efficient in meeting our food supply needs. This amounts to a substantial technological challenge. (Weterings en Opschoor, 1992).

If in the twenty-first century we wish to be assured of an economically feasible and ecologically sustainable food supply, now is the time for us to be developing a new outlook, and daring to invest in the future. We need to be making long-term investments, in policy-making, in research and in development programs.

In the "Choosing the Opportunities" memorandum the government of The Netherlands puts a strong emphasis on technological development in order to harmonize economic and ecological objectives. In the memorandum and the subsequent debate reference is made to a three-way approach: continual improvement, redesign of products and processes, and reconsideration.

Continual improvement refers to the small forward steps like the catalysator or, in food terms, the reduction of the use of remedial substances. Redesign should draw our attention to plants which can themselves counter insects and fungi. Reconsideration is the rethinking of functions that products and services perform, for instance the obtaining of

necessary protein by means other than the eating of meat. The interdepartmental research program Sustainable Technological Development has targeted the route of reconsideration by formulating the future needs of society: a leap forwards not only in the technological sense but especially in terms of social change.

2. PROGRAM SUSTAINABLE TECHNOLOGICAL DEVELOPMENT

In the last four years, research in the context of interdepartmental research program Sustainable Technological Development (or STD) has been carried out with the aim of ascertaining (Jansen en Vergragt, 1992; Vergragt en Jansen, 1992):

> widely supported possibilities there are for becoming twenty times as efficient in meeting social needs;

> to what extent it is possible to halt current trends and initiate a long-term sustainable technological development.

At this stage, the program is clearly research-oriented, rather than being concerned with policy-making. Learning by doing. The process of carrying out research and learning from its results has been organized into twenty projects, which in turn fall under the sub-programs Food, Transport, Housing, Water and Chemistry.

The ultimate goal of STD is to have started with sustainable technological development before the end of 1997 in order to give substance to the process of reconsideration. Based on a number of credible examples STD wants to demonstrate that it can be economically attractive to make provisions on the long term with much less pressure on the environment than is now the case. Other criteria for success are not only financial and other support but also the adoption of the results by companies, governmental organizations, research institutes and the government. A practical derivative of the program is a manual for the development of sustainable technology projects.

The program STD is intended to function as a starter motor: it is a question of looking at long-term goals, and with those in mind, taking the initial steps in the direction of sustainable technological development. This initial steps will include policy-forming, research activities and investment plans. In so doing a method, it is referred to as

Backcasting, is developed to ensure that the starter motor will work effectively.
The long-term goal, the social implications and the large number of parties involved in developing sustainable technology tend to mean in practice that it is the government which often has to take the initiative.

3. CURRENT SITUATION IN AGRICULTURE

The Food sub-program of the Sustainable Technology Development research program aims to contribute to the development of sustainable technology in food production. Sustainable in many respects.
Sustainable means for the consumer that he can count on an uninterrupted supply of healthy safe and tasty foods which fulfil his physiological and emotional needs. From the economic point of view sustainable means that food provision has a firm economic base and contributes to incomes. Ecologically, sustainable means that environmental pressure from food production is significantly reduced.
There are a number of problems inherent in the current food supply situation in The Netherlands. Not only environmental problems, but also socio-economic problems, such as a fall in the income of farmers and threats to the quality of rural subsistence. Table 2.1 shows the entire food production chain for various product groups. The vertical line shows the different product groups, and the horizontal line shows each link in the chain. The spots indicate the degree of environmental damage caused by a particular link. The more spots, the more serious the environmental problem.

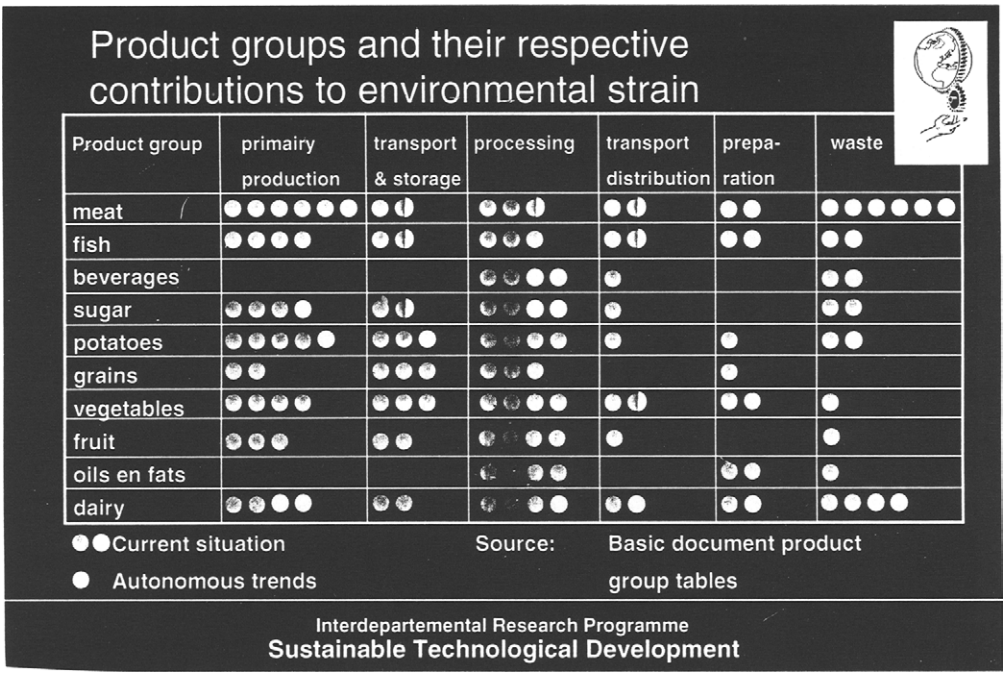

Table 2.1 Product groups and their respective contributions to environmental strain in The Netherlands

In the case of meat production, the problems related to matters such as the processing of manure and the amount of physical space required for feed production. Space, not only in The Netherlands, but also in foreign countries where cattle feed is grown. In the case of the production of greenhouse vegetables, the problems relate to energy use and related issues, such as the greenhouse effect. In primary production as a whole, problems include acidification and manure surpluses.

Taking into account forecasts of consumer demands in 2040 and the current environmental and economic problems for which a solution has to be found, the sub-program Food has developed the possible options Sustainable Land Use, High-Tech Agroproduction and Novel Protein Foods.

4. WHAT WILL BE EATEN IN 2040?

To develop technology for sustainable food and the associated networks we have to gain a picture of where we are heading. Not a blueprint but a charcoal sketch of the needs of society in forty years. This assumes that these needs can be fulfilled while environmental pressure is substantially reduced. However, to prevent the perspective from being pie in the sky, we first have to see the attraction of the first step before we invest.

In the area of food supply, a vital factor in developing a sketch of the needs of society is the anticipation of consumer behavior. Much is known about current consumer behavior in the Western world. Certain aspects of consumer behavior are extremely difficult to predict, since it is subject to capricious, spur-of-the-moment decisions. But it is possible to pick out a number of general trends.

Consumer research has shown that the consumer of the twenty first century will be increasingly inclined to demand high quality food which tastes good, and is safe, healthy and reliable. Any food which is considered to be either unhealthy or unreliable will be forced out of the western dietary package. Health, and therefore products promoting good health, will become increasingly important. In The Netherlands, the rising number of older people in the population will make this trend even more marked.

Demands regarding the way in which food is produced will also play an increasingly important role in purchasing decisions. These demands relate, for example, to environmental and Third World concerns. Consumers will wish to be supplied with information regarding where products come from and the production methods used. Information technology and extensive knowledge of the entire production chain will therefore become extremely important.

Alongside an increase in the consumption of ready-to-eat meals, it is also reasonable to assume that demand will increase for quality products such as locally produced, ecologically grown products.

5. PERSPECTIVES ON SUSTAINABLE TECHNOLOGICAL DEVELOPMENT IN AGRICULTURE

5.1. Sustainable Land Use

In the Sustainable Land Use project a perspective has been developed for the rural area, the core of which is the integration of "new" functions like the gaining of water and energy, the processing of waste and the management of nature and culture with the production of food and produce for industry.

In the Sustainable Land Use project several main functions per plot have been targeted. Multiple land use saves space and benefits both nature and the environment. Moreover, it gives the land user more possibilities to earn income. The integration begins at plot level but has consequences for other levels too. Corporate structures and control mechanisms will change as investors other than farmers and conservationists vie for the rural areas.

Multiple land use makes the rural areas attractive for new investors like drinking water and energy companies. If ground and surface water is no longer subject to contamination and if this can be maintained, it will become possible to obtain more and cleaner water, on top of which incidence of drought will decrease. Gaining energy can also have its place in multifunctional land use. Think of the biomass crop and solar and wind energy. A further function of the rural area is waste processing that offers the farmer savings (less fertilizer) and is a compensation for the reduction of residues. In terms of the value of nature the quality of the countryside will increase as pressure on the environment and the threat of drought are reduced. A more varied landscape is also more interesting from a recreational point of view.

The Sustainable Land Use vision is currently being applied to an area of just under twenty thousand hectares around the town of Winterswijk in the eastern part of The Netherlands. Ten practical projects are being worked in order to stimulate the acquisition of the knowledge and technology we currently lack, and also to implement new forms of cooperation. Fundamental research questions will be imbedded in research programs in the knowledge infrastructure.

It is expected that by combining existing functions, total environmental pollution could be reduced by a factor of ten, and the environmental problems related to primary

production could be alleviated. At the same time is expected that there will be more rural incomes then autonomous developments predict. (IP-DL 1997, p.m.).

5.2. High Tech Agroproduction

The High Tech Agroproduction project fits in with the knowledge and experience of the Dutch horticulture sector. Various interested parties, including the farming community, the processing industry and providers of energy from the growing base of the project. The focus of the project is on the demand-focused production of fresh vegetables in enclosed production units, under controlled conditions and in close geographical proximity to the consumer. It will be possible in the future, for example, for sprouts to be produced in this type of 'factory', the advantages being that production will be more than twenty times more environmentally friendly than is currently the case within glasshouse horticulture and that it will be possible to respond to the precise demands of the consumer.

The aim of the High Tech Agroproduction project is to design an enclosed production system. It is important to develop systems in which the only raw materials are sunlight, water and residues. All other materials must be recyclable. This will require the acquisition of a broad international knowledge base, which can then be coordinated by the Dutch centers of expertise. To this end contact has been made with research organizations and businesses in the United States, Japan, Germany, Australia and the United Kingdom. (IP-HTA 1997, p.m.).

5.3. Novel Protein Foods

In this project, research has been carried out into the future development of new protein foods which are attractive to both consumer and producer, and which meet the same requirements as meat, but the production of which is twenty times as environmentally efficient as current meat production. It is not the intention to replace meat altogether, but to achieve a significant market share for environmentally friendly new protein foods (Novel Protein Foods or NPF's) by the year 2035. These products should be able to occupy their own position in the food market. In the next chapter the case Novel Protein Foods will be worked out more in detail.

6. THE NOVEL PROTEIN FOODS CASE

At the moment, meat is a very important source of protein in our diet, and it meets a wide range of requirements in such areas as taste, habit and status. Unfortunately production places a heavy strain on the environment in The Netherlands through a surplus of manure, harmful emissions from pesticides and large use of energy, space and raw materials. Apart from the growing problem of manure disposal and recent discussions surrounding diseases like BSE and swine fever, the Dutch meat sector is also under pressure from increasing foreign competition and a growing demand on the part of the consumer for new meat-replacement products. The latter in particular is proving a challenge to Dutch businesses. They are faced with a choice: either they can remain passive, and leave foreign competition to capture and develop these new markets, or they can decide to take up the challenge and exploit the opportunities presented by these developments. In real terms, there is no choice: the challenge must be taken up.

In order to achieve a significant market share for Novel Protein Foods instead of meat, a research and development plan was drawn up. This plan had to be attractive to both consumers and producers and must be accepted as feasible by scientists and technology developers, if the relevant market parties are to continue down the path set by this project (STD, 1996). In order to develop such a plan for NPF's in the twenty-first century research was carried out in five different lines environmental aspects, consumer, technology, business economics and macro-economics. Therefore, five research questions have been posed as an integral part of this project (see Figure 6) (De Haan et al, 1995).

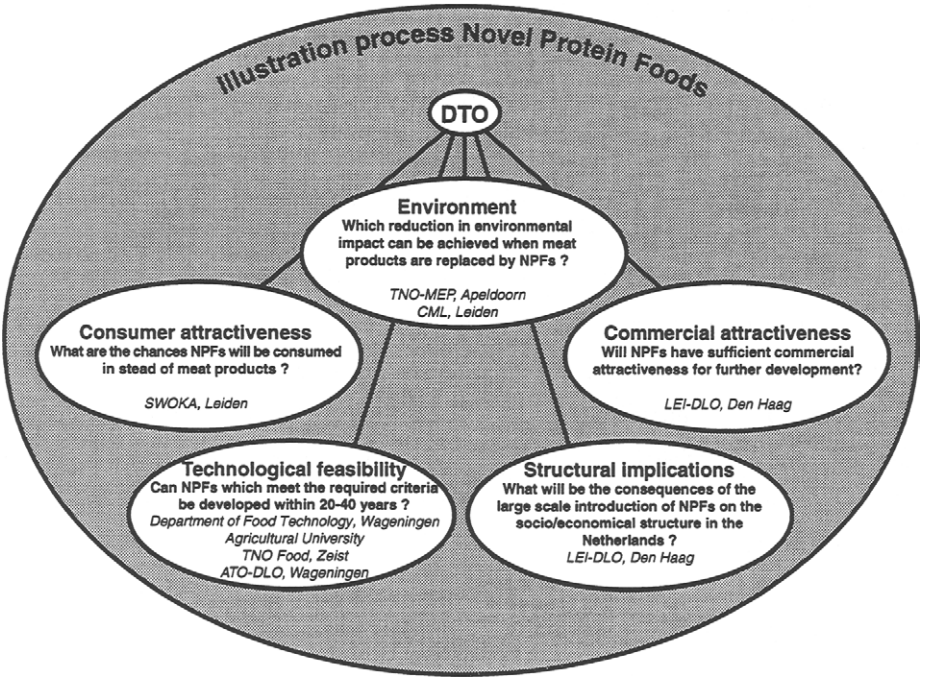

Figure 6. The research questions and structure of the Novel Protein Foods project

In the following paragraphs the main results of the Novel Protein Foods project and the next steps in NPF-development are discussed.

6.1. The consumer: the deciding factor is taste

It became evident in the course of consumer research that it is the taste of NPF's which will determine whether they are purchased and consumed or not (Hamstra en Verhoeven, 1995; Baggerman en Hamstra 1995; Fonk en Hamstra 1996). In addition a trend analysis was carried out including a prediction of consumption and purchasing behavior in 2035. An important assumption in this trend analyses is that in the future it will be possible to manufacture NPF products the taste, smell and structure of which are considered by the consumer to be as good as, or better than meat.

Consumer research also revealed that consumers will be reluctant to give up quality cuts of meat. NPF's are therefore most likely to function as a replacement for compound

meat products and in the processed sector as opposed to the unprocessed sector, which consists of straight cuts of meat (see Table 6.1). This led to forecasts that the processed sector will grow from its present 45% to 75% in 2035, whilst in the same period the share of straight cuts of meat will fall from 55% to 25% (Baggerman en Hamstra 1995).

meal category	NPF products
meal component	burgers, nuggets, fingers, cordon-bleu, souffles, patties, schnitzels, frankfurters & sausages
meal ingredient	frying meat mix, strips, cubes
ready-to-eat-meals	hearty soups, vegetables, rice and noodle dishes
savory snacks	filled sandwiches, hot dogs, dried sausages
sandwich fillings	pates, pastes, spreads, cold cuts
appetizers	meatballs, sticks, croquets

Table 6.1. A number of possible product concepts in which NPF's could be included as an ingredient (Quist et al. 1996).

On the basis of these same consumer trends and assumptions, it has been predicted that it must be possible for NPF's to gain more than half of the processed segment, reducing consumption of products such as sausage meat and minced meat in particular. This represents a market share of 40%. Our assumptions regarding the behavior of the consumer of the future were of course of crucial importance in carrying out trend analysis and making predictions about diet and purchasing behavior in the future.

Several parties were involved in seminars lasting several days, extensive desk studies and interviews with consumers, the results of which helped us to draw up a picture of the consumer of the future. These parties included representatives of the business world (both research and marketing), research organizations (both institutes and universities), government and non governmental organizations (representing the interests of the environment and the consumer) (Fonk and Hamstra, 1996).

In the short-term, there are plenty of options for the inclusion of NPF's in main meals. In the longer term, changing eating patterns will lead to an increase in the importance of meat substitutes in snacks and ready-to-eat products (Fonk and Hamstra, 1996; STD

1996) In actual fact, NPF's will not be introduced onto the market as meat substitutes, but as new protein products. Products which meet the demands of the consumer of the future: healthy, easy to prepare and reliable!

6.2. New technologies make NPF's possible

In principle hundreds of different NPF's could be produced from around 20 protein-source/technology combinations. A stepwise selection process was followed to identify those NPF's most likely to succeed in the market. These NPF's scored well in areas such as technological attractiveness, consumer attractiveness, commercial attractiveness, the degree to which they would reduce environmental damage and macro-economic and institutional effects (de Haan et al., 1995).

The selection process finally led to the identification of 3 ingredients which can be produced in 7 different ways (referred to as the 7 options) from peas, lucernelupin, the fungus *Fusarium* and the cyanobacteria *Spirulina*.

The three ingredients which have been given fancy names, are Protex, Fibrex and Fungopie. Protex is a product resembling to minced meat in structure and made from either Spirulina, Pea or Lucerne. Fibrex is a fibrous ingredient and made by the continuous fermentation of *Fusarium*. Fungopie is a fermented ingredient and resembling temper in structure. It can be made from either Pea or Lupin by fermentation with the fungus *Rhizopus*. In Table 6.2 is shown the 7 high-potential options, each representing the combination of a particular protein source with a particular technology.

Ingredients	Protein source	
Protex	1	Spirulina (cyano bacterium)
an ingredient resembling	2	Pea
can be made form bacteria,	3	Genetically modified pea
yeasts and plants	4	Lucreme
Fibrex		
a fibrous ingredient		
produced by continuous	5	Fusarium
fermentation of fungi		
Fungopy		
an ingredient produced by	6	Pea with the fungus Rhizopus
fermenting plants with fungi	7	Genetically modified lupin with the fungus Rhizopus

Table 6.2 The selection of 7 high-potential NPF-options, each representing the combination of a particular protein source with a particular technology

Although most of the technologies involved are already being used in current production techniques, it has not been possible yet to produce products which are sufficiently attractive to the consumer to cause a significant reduction in the amount of meat consumed. By relating consumer demands to product quality demands it was possible to identify the areas in which new - and in some cases, basic - knowledge must still be gained (Sijtsma et al 1996a). This areas are sensory sciences (Sijtsma et al, 1996b), nutritional value (Jansen et al., 1996a), an increase in scale to large-scale production (Jansen et al., 1996b) and a further reduction in environmental strain (Linnemann et al., 1996). Research programs have been planned to fill these gaps. They are to be carried out between now and the year 2010.

6.3. NPF's are far more environmentally friendly than meat

Life Cycle Analysis (LCA) was carried out in order to be able to calculate and compare the environmental strain imposed by the production of NPF's on the one hand and pork on the other (Van den Berg et al, 1996). This method takes into account and quantifies - as far as is possible - all the factors in the entire production process which are in any way damaging to the environment.

For every environmental theme in the result was standardized in relation to the world situation. All standardized effects were added together to produce an environmental index. It was then possible to determine the degree of environmental damage caused by each of the selected NPF options, and to compare them with the environmental damage caused by the production of pork, based on current technological conditions. In Table 6.3. the result is shown of the environmental register for the selected NPF options compared to pork.

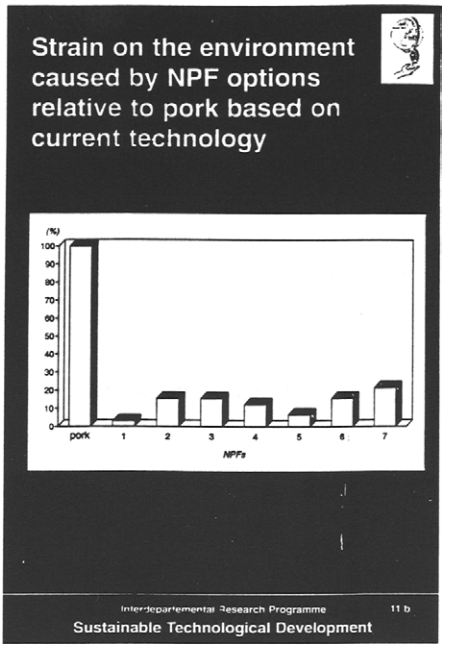

Table 6.3. The environmental register for the selected NPF options compared to pork as an ingredient (pork is 100%) based on the production processes prevailing in 1995 (Van den Berg et al, 1996).

In Table 6.3. the numbers 1, 2, 3 and 4 refers to options for the Protex ingredient, with respectively a cyanobacteria, a normal pea, a genetically manipulated pea and alfalfa as protein sources. The option 5 refers to a Fibrex ingredient, using a fungus as protein source and 6 and 7 are options for the Fungopie ingredient, with respectively, a pea and a genetically manipulated lupin as the protein sources, both in combination with a fungus.

According to the latest estimates, the NPF options Spirulina for Protex (option 1) and Fusarium for the ingredient Fibrex (option 5) are expected to achieve a reduction factor of more than 20, whilst the remaining options are expected to achieve a reduction factor of between 6 and 13.

6.4. NPF's are commercially attractive

Research in the area of business economics has revealed that NPF's are far less expensive to produce than meat (Reinhard et al., 1996). Depending on the precise NPF, production is expected to be between 20% and 50% less expensive (See Table 6.4. Estimated costs per ton NPF in 2035). These relatively low production costs, combined with the fact that the market share is expected to increase from 5% in 2005 to 40% in 2035 make NPF's an extremely attractive business proposition. Especially for those food companies which are already active in that part of the chain which leads from protein source to end product.

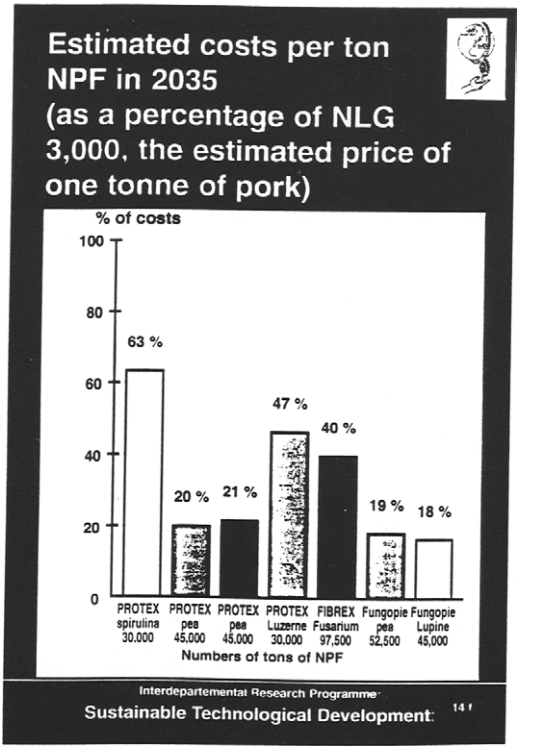

Table 6.4. Estimated costs per ton NPF in 2035 (as an percentage of DFL 3,000 the estimated price of one ton of pork), (Reinhard et al., 1996)

The development costs entailed in meeting the high quality standards and building up the expertise required in the areas of sensory sciences, nutritional value, upscaling and a reduction in environmental strain make it impossible for any one business to develop any given option single-handed. But where the development costs relate to more than one option and can be carried by a number of businesses throughout the chain working together, investment in NPF development can be a commercially attractive option.

Research has shown that if 40% of the meat will be replaced by NPF's that will not have a dramatic effect on future economic structure compared to possible autonomous developments. There will be nevertheless a negative effect on part of the meat sector. On the other hand, the environmental benefits will be considerable (Jahae et al., 1996, De Vlieger et al., 1996).

6.5. Next steps: First NPF's on the market

The NPF project has shown that the development and large-scale introduction of NPF's would be possible in the future, and would contribute to sustainable development. NPF's are attractive to both consumers and producers; the structural effects are relatively limited and if they cause large-scale reduction in meat consumption they will lead to a significant reduction in environmental damage.

A process to replace meat as an ingredient to a large extent with alternative protein products has now been initiated. It is now up to the market parties involved to ensure that the process is carried through. Fortunately that does appear to be happening as the following three examples will show.

The first example is that most elements of the research program have been taken on board by the recently founded Technological Top Institute for Food Sciences in Wageningen. Within this institute, companies such as Unilever and Gist-brocades are working together with those research organizations which were also involved in the Novel Protein Foods project to increase the level of basic knowledge concerning Novel Protein Foods.

The second example is that two companies are working together with research organizations on the development of NPF products. Their aim is to develop knowledge to a sufficient extent to allow the introduction of NPF products onto the market within the foreseeable future. The last example is the cooperation between research bodies such as TNO-Nutrion, the DLO-institute for Agrotechnological Research and Wageningen Agricultural University in a number of follow-up research projects. Next to these joint projects, the various institutes have also started work on individual projects. TNO-Nutrion, for example, has embarked on an extensive six-year research project into Future Protein Foods.

These and other follow-up activities which fit within the development plan being carried out are supporting the supposition that the program STD has succeeded in fulfilling its role as a starter motor. Research, development work and the introduction of new products can now proceed through existing channels.

7. CONCLUSION

This article leads to the following three conclusions. The first conclusion is that sustainable technological development is not a luxury but a necessity, if we wish to avoid problems in the future and if we wish to ensure that in the twenty-first century the world's environmental problems and other problems related to food supply are not as great as they are now. The second conclusion we would like to draw is that STD has development and tested a method by which concrete steps can be taken towards the initiation of sustainable technological development. Now Sustainable technological development has become possible. The third and final conclusion is that projects carried out within the STD framework have demonstrated that there are a number of high-potential visions. These and other visions point the way to an economically feasible and ecologically sustainable means of supplying food.

In order to ensure that the initiatives taken by STD are carried through the organizations involved, such as businesses, government, social organizations and centers of expertise must be prepared to invest in and become involved in long-term development. There must be also an organization which can initiate and facilitate new projects independent from existing structures, until such time as they are strong enough to be incorporated into existing research or investment programs - this comes down once more to the starter motor function. And there must be sufficient funding for the carrying out of new projects.

The learning time is now over, and the time for harvesting has arrived. The government would be wise to make use of the lessons learned within the context of the STD program. The STD program should in fact be continued, not in the form of an experimental learning program but as a long-term policy program. A program aimed at the continuous development and stimulation of new ideas and the stimulation of technical and social research. It is a tool for redesigning products and processes and for reconsideration of the way we fulfill our needs. The result of the NPF and other projects shows it will be an effective and efficient program to realize more synergy between environment and economy.

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