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Optimization mixing ratio of the brewery waste water sludge and coal as energy source for cement industry and fuel ash effect on the raw material composition

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ABSTRACT

Brewery waste water produces sludge with high organic content, which required proper treatment before disposal. The sludge is disposed to landfill creating contamination to the ground water and surface water due to high organic content. Also, it increases the salinity of crops and the environment. Since it has potential for energy production, it can be used in the country's coal-dependent cement industry due to its energy content. The objective of this study was to characterize brewery wastewater sludge and coal, to determine the optimum mix ratio and to see the effect of mixture fuel ash content on raw mix design. Characterization of coal using American Standard Testing Material 2009 and sludge using the World Health Organization method was done and also calorific value with different mixing ratio of coal and sludge determined by a bomb calorimeter in order to find the optimum mix. By using proportionating calculation, determining the effect of mixture fuel ash on the clinker and proportion of raw materials used is done. Brewery wastewater sludge has high moisture content and volatile matter compared to coal. Also, its ash content is higher than coal's. The caloric value of brewery wastewater sludge will not allow for using it without mixing. It is found that 70% coal and 30% sludge is the optimum mix ratio. Its high amount of SiO_2 (45%), Al_2O_3 (14%), and Fe_2O_3 (11%) makes it possible to substitute some portion of clay and sand stone while our lime feed increases as a result. Since mixture fuel ash content is similar with cement raw materials, brewery wastewater sludge is a good alternative for the cement industry.

1. Introduction

1.1. Background

Nowadays, energy and the environment are sensitive issue. Both are interlinked with one another and our energy consumption affects the environment since most of our energy sources are non-renewable. The byproduct of one industry can be used for various purposes including as an energy source.

The brewery industry is one of the industries that uses a lot of energy and produces multiple wastes. The industry produces the most polluted waste water (Ranade and Bhandari, 2014). The treatment plant contains the most famous industrial wastewater treatment methods, such as biological treatment with activated sludge process. Therefore, a large amount of brewery wastewater sludge was generated, which required proper management before disposal. Land disposal is the most common method of management of brewery sludge in the world and our country.

Studies show that beer sludge has many applications in energy generation. But none of them showed an application in the cement industry. One study in our country showed that brewery waste water sludge has potential for fertilizer that can be comparable to urea. The study

Abbreviations: AM, Aluminum Ratio/ Module; ASTM, American Standard Testing Material; BWS, Brewery Waste Sludge; $CaSO_4$, Calcium Sulphate; CO, Carbon Monoxide; COD, Chemical Oxygen Demand; GHG, Greenhouse gasses; HCl, Hydrochloric Acid; HFO, High Density Fuel Oil; LSF, Lime Saturation Factor; SM, Silica Module; TVOC, Total Volatile Organic Compound; Zn, Zink.

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tries to find an effect on the tomato plant. Based on the findings of this study, it was realized that for tomato plants an application of 10–25% and 100–200 mg/kg of brewery waste sludge (BWS) and Urea fertilizer respectively, is practically feasible for optimum yield. And high concentration of brewery waste sludge (BWS) also has a negative impact on the growth and yield of tomato plant (Ediget and Seyoum, 2016).

Another study tries to study the optimum condition for fuel briquettes produced from wastewater sludge of the beer industry and biodiesel production wastes. The study compares the heating value of pure brewery sludge and a mixture of brewery waste water sludge and bleaching earth. Unfortunately, it tries to come up with an optimum ratio of brewery wastewater sludge and biodiesel waste for better output of heating value. In addition, it comes up with the best process condition for carbonization of the mixture. The mixture showed better heat value than pure sludge (Nusong, 2018). Also, anaerobic co-processing of brewery waste water sludge with sewage sludge showed good application for bio gas and land application. The possibility of mixing brewery sludge with sewage sludge in different mixing ratios was investigated for anaerobic digestion so that energy can be generated as biogas and concurrently, digested sewage sludge can be used as an agricultural fertilizer. A discontinuous anaerobic reactor in the mesophilic state for 40 days of digestion was used in the lab. The experimental results showed that the sludge mixture at a ratio of 25:75% by weight (waste water: brewery) produced more biogas. A reduction in heavy metals and pathogens was observed at this ratio after the digestion indicating its safe use as fertilizer.

Mixing of brewery sludge with agricultural wastes such as cattle dung has allowed systems to produce hydrogen. Such a system was optimized to produce 43 ml of hydrogen per gram of COD. To achieve this, however, cattle manure had to be heat treated at 103 °C for 24 h to eliminate methanogen microorganisms and select them for hydrogenation Clostridia.

The economics of energy production from brewery sludge digestion is yet to be guaranteed as a variety of factors will influence the overall balance, not least waste water treatment charges. However, because they are likely to increase in the future, the on-site processing option will become increasingly attractive (Thomas and Rahman, 2006).

The brewing industry is growing rapidly in Ethiopia from time to time. Number of beer factories is increasing which shows the increase in production volume. As the same time there is generation of proportional amount of wastewater which requires proper treatment. Treatment of the wastewater produces sludge with high organic content, which required proper management before disposal. It is estimated from experience that the sludge production rate is approximately 0.5 kg/hl of beer produced. Ethiopian annual beer production was 11.5 million hector liters in 2017 G.C. It is estimated that 5.75 million kg (5750 ton) 75% wet sludge and approximately 2.01million kg (2010 ton) of sludge with 10% moisture content was produced. From onsite experience in the brewing industry the sludge is disposed to landfill. This will create contamination to the ground water and surface water due to high organic content. Also increase salinity of crops and environment.

In addition, there are number of cement industries in Ethiopia dependent on imported fuels specially coal. As it is known imported goods require foreign currency. Ethiopia is currently facing shortage of foreign currency. Coal import takes budgets which can be allocated for other development activities. Coal mining disrupts land escape and create respiratory health problem from coal dust and heavy metals. Burning coal will produce greenhouse gasses which create global warming, acid rain, respiratory health problem and other problems. Therefore, we need to substitute or decrease the consumption by using alternative energy sources like biomass.

The aims of this study was optimization of the mixing ratio of brewery wastewater sludge and coal as energy source for cement industry and fuel ash effect on the raw material composition.

2. Materials and methods

2.1. Study area

The study was conducted in Heineken breweries Share Company. The company has acquired 25 hectares of land at the southern part of Addis Ababa, in Akaki Kality Sub city, Woreda 26, and Kebele 06, specifically in Kilinto Area. This brewery has a capacity of 1.5 million hectoliter beer per year. Addis Ababa is a high terrestrial zone, situated at an altitude of 7446 feet. (2300 m) above sea level and is a prairie biome, it is situated at 9°1′48"N 38°44′24"E, with an average annual rainfall of 1800 mm and temperature of 14 to 21 °C average.

2.2. Raw materials

The sludge was collected from the Heineken brewery wastewater treatment plant after belt press and kept outside until it was dried. The coal sample was found from Derba cement factory.

The coal is grinded to mesh size 80 for characterization. First, characterization of sludge and coal were performed (proximate analysis and calorific value).

Then, the brewery wastewater sludge was dried with sun light for five days until reached 8% for further analysis. The mix ratio range is determined based on the assumption that mixture calorific value must be at least 5500 kcal/kg (Yoseph and Tassisa, 2004) and the mixing ratio sums to 1. The Calorific value of Derba cement factory coal is found from the company which is 6243 kcal/kg and the brewery sludge calorific value is found from literature which is 3045 kcal/kg (Nusong, 2018).

Based on this calculation the minimum amount of sludge that can give the desired heat value when mixed with coal is 23%. Then after milling the coal and the desired amount of dried brewery wastewater sludge, mixing was performed according to the proposed mixing ratio. The proposed mixing ratio is 30:70, 15:85, 20:80, 23:77 and 25:75. The result was analyzed after characterization of those samples.

2.3. Sample collection and preparation

Sample was taken after digging a pill of sludge to get wet and get a representative sample. The coal sample was found from Derba cement factory. The coal was crushed using disk crusher of mesh size 80. Then, the sludge and coal were characterized by proximate analysis and calorific value. This shows to what extent the sludge can be dried.

2.4. Experimental design

The methodology used to perform this research is through laboratory experiment and theoretical calculation. Here in this research proximate analysis and calorific value were used for characterization of individual and mixture of coal and sludge. And raw mix design proportionating calculation to determine fuel ash effect on raw mix design.

The dried sludge was crushed to the same size as the coal to 80 mesh sizes. The mix ratio range is determined based on the requirement that the mixture calorific value must be at least 5500 kcal/kg (Yoseph and Tassisa, 2004) and the mixing ratio sums to 1. Calorific value of Derba cement factory coal is found from company laboratory analysis data which is 6243 kcal/kg (Ghalandari et al., 2019) and the brewery sludge calorific value is found from literature which is 3045 kcal/kg (Nusong, 2018).

$$X * 6243 + 3045 * Y = 5500 \tag{1}$$

$$X + Y = 1 \tag{2}$$

Where X: fraction of coal
Y: fraction of sludge

Based on this calculation, the minimum amount of sludge that can give the desired heat value when mixed with coal is 23%.

2.5. Characterization of sludge and coal

2.5.1. Characterization of sludge

Moisture content analysis: The experiment was done according to the WHO method for determination of moisture content. 5 gm of raw sludge was used for the analysis. The crucible containing the sample was placed in a drying oven and heated gradually until the temperature reached 105 °C for 24 h. Then, cooled in desiccators and weighed. The difference in weight was due to loss of moisture which was reported in percentage as its moisture content.

$$\%M = \frac{(C - A)}{5} * 100\% \tag{3}$$

Where A= weight of crucible, C= weight of sample after oven + crucible

Volatile matter analysis: The experiment was done according to the WHO method for determination of volatile matter. 5 g of the sample was weighed and put into the crucible. The volatile solid content of samples was determined by a muffle furnace, heating at 550 °C for 5 h and weighing after cooling in room temperature. Then cooled in desiccators and weighed. The loss in weight was reported as that of the volatile matter.

$$VS = \frac{D - A}{C - A} * 100\% \tag{4}$$

Where A= weight of crucible, C= weight of sample after oven + crucible and

D= weight of sample after furnace + crucible.

Ash content analysis: The ash content of the sludge is reported as measuring the sample which is left after burning the sample in the furnace. The procedure is similar to the determination of volatile matter. The mass of crucible is subtracted from the mass of the sample plus the mass of crucible to get the ash content.

$$A.C = D - A \tag{5}$$

Where, A= weight of crucible, D= weight of sample after furnace + crucible.

2.5.2. Characterization of coal

- Moisture content analysis: The experiment was done according to the ASTM-2009 (ASTM D5142-09 2009) method for determination of moisture content. One gram of sample was weighed and put into the crucible. The crucible containing the sample was placed in a drying oven and heated gradually until the temperature reached 105 °C for 24 h. Then cooled in desiccators and weighed. The difference in weight was due to loss of moisture which was reported in percentage as its moisture content and can be calculated by equation 3.
- Volatile matter analysis: The experiment was done according to the ASTM-2009 (ASTM D5142-09 2009) method for determination of volatile matter. One gram of sample was weighed and put into the crucible. The samples were inserted directly into the furnace chamber at a temperature of 950 °C for 7 min. Then they were cooled in desiccators and weighed. The volatile content can be calculated by equation 4.
- Ash content analysis: The experiment was done according to the ASTM-2009 (ASTM D5142-09 2009) method for determination of ash content. One gram of sample was weighed and put into the crucible. The crucible containing the sample was placed in a furnace at a temperature of 750 °C for two hours. Then they were cooled in desiccators and weighed. The loss in weight was reported as its ash content and calculated by equation 5.

2.6. Calorific value analysis

Calorific value was determined using ASTM-2009 (ASTM D5142-09 2009) procedure. The sample weight of 1 gram crushed to 80 mesh sizes was taken and made into a pellet by a piston press. The pellet contains 15 cm ignition wire. The pellet was inserted in the bomb reactor and charged with 2 MPa oxygen. Then the reactor was put in a bomb calorimeter vessel containing 2 L of water. After ignition, the temperature rise was recorded to determine calorific value.

The gross calorific value was calculated as

$$Q_{Vad(gross)} = \frac{\left[(tEe) - e_1 - e_2 - e_3 - e_4\right]}{m} \tag{6}$$

Q_{vad} (gross) = gross calorific value at constant volume as determined, J/g (cal/g);
Ee = the heat capacity of the calorimeter, J/ °C (cal/ °C);
t = corrected temperature rises according to 10.7, °C;
e_1 = acid correction according to 10.6.1, J;
e_2 = fuse correction according to 10.6.2, J;
e_3 = sulfur correction determined in accordance with point 12.4, J;
e_4 = combustion aid correction determined according to 12.7, J; and
m = mass of the sample, g.

2.7. Determination of optimum mix ratio

The optimum mix ratio is found by calorific value analysis for each mix ratio of the sample. The mix ratio was determined based on the requirement that the mixture calorific value must be at least 5500 kcal/kg (Yoseph and Tassisa, 2004) and the mixing ratio sums to 1. The optimum mixing ratio was found from calculation to be 77:23 coals and sludge respectively. In order to find the actual optimum mixing four ratios above and below the theoretical optimum ratio were selected. Mixing ratio of 30:70, 15:85, 20:80, 23:77 and 25:75 is proposed. This ratio is selected based on calculation of that the ratios give calorific value around the minimum heating value required for heating in a cement kiln.

2.7.1. Raw mix proportionating

Mineral composition was adjusted using standards. The mineral composition depends on the type of cement to be produced. There are formulas that relate mineral composition with oxide composition of clinker and can use them to calculate the oxide compositions of clinker.

$$\%\ \text{Tetra calcium alumino ferrite}\ \left(C_4AF\right) = 3.043*\left(\%\ Fe_2O_3\right) \tag{7}$$

$$\%\ \text{Tricalcium aluminate}\ \left(C_3A\right) = 2.650*\left(\%\ AI_2O_3\right)\ -\ 1.692*\left(\%\ Fe_2O_3\right) \tag{8}$$

$$\begin{aligned}\%\ \text{Dicalcium silicate}\ \left(C_2S\right) &= -30710CaO\ +\ 8 - 6024SiO_2\\ &+\ 5 - 0683Al_2O_3\ +\ 10785Fe_2O_3 = 2.867*\left(\%\ SiO_2.\right)\ -\ 0.7544*\left(\%\ C_3S\right)\end{aligned} \tag{9}$$

$$\begin{aligned}\%\text{Tricalcium silicate}\ \left(C_3S\right) &= -4.071(\%\ CaO)\ -\ 7.600\left(\%\ SiO_2\right)\\ &-\ 6.718\left(\%\ Al_2O_3\right)\ -\ 1.430\left(\%Fe_20_3\right)\ -\ 2.852\left(\%\ SO_3\right)\end{aligned} \tag{10}$$

Where, the%CaO and%Al_2O_3, etc. Terms being the mass percentages of the component oxides.

Based on the above formulas, the following steps are taken into consideration:

- All the SO_3 present is combined with CaO to give $CaSO_4$, and the equivalent

  CaO = 0.70(% SO_3), is subtracted from the total CaO present.

$$\%\ \text{CaO Combined} = \%\text{CaO}\ -\ \text{SO3}*0.7\ -\ \text{Free CaO} \tag{11}$$

- All the Fe_2O_3 present is combined as 4CaO-$Al_2O_3Fe_2O_3$ and the quantities of Al_2O_3 = 0.64(% Fe_2O_3) and CaO = 1.40(% Fe_2O_3) are subtracted from the appropriate totals.

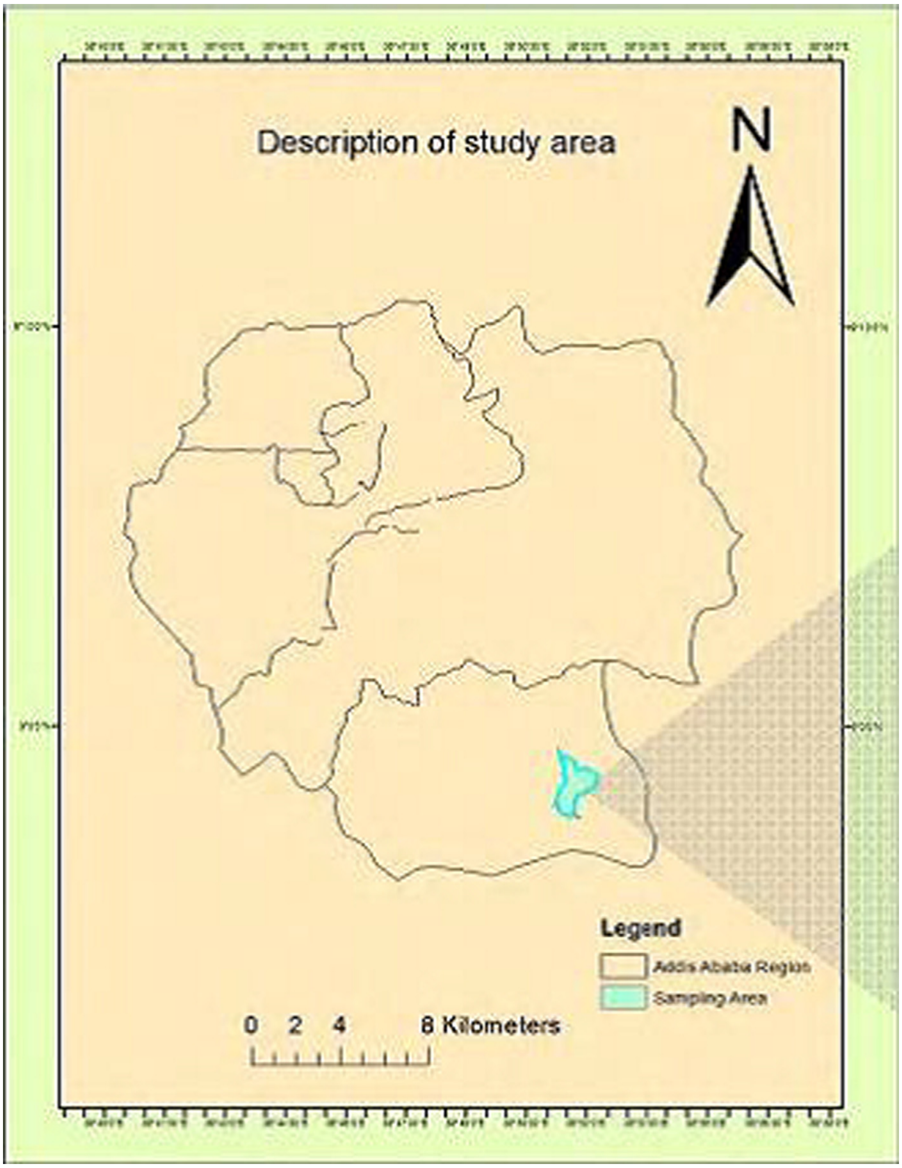

Fig. 1. Map of Addis Ababa and Heineken brewery share company.

- The remaining Al_2O_3 is combined as $3CaOAl_2O_3$ and a further quantity of CaO = 1.65(% Al_2O_3) is subtracted from the total remaining CaO.

$$\%CaOSilicates = \%CaOCombined - Fe_2O_3 \times 1.40 - (Al_2O_3 - 0.64{*}\ Fe_2O_3)\ x1.65 \quad (12)$$

4. The SiO_2 combines initially with CaO to form $2CaOSiO_2$, giving a provisional dicalcium silicate figure. The CaO combination with SiO_2 = 2.87 (% SiO_2) is subtracted from the total CaO number and the remaining CaO is then combined which a portion of C_2S = 4071 (% CaO) to form C_3S. Fig. 1

The remaining CaO and the SiO_2 are then partitioned between C_3S and C_2S and the proportions of C_3S and C_2S can be found by solving simultaneous equations; and so

Rearranging gives us:

$$\text{a. } \%\ CaOSilicates = C_3Sx0.7368 + C_2Sx0.6512 \quad (13)$$

$$\text{b. } \%\ SiO_2 = C_3Sx0.2632 + C_2Sx0.3488 \quad (14)$$

Rearranging those formula gives:

$$\%\ C_3S = 4.07\ x\ CaOSilicates - 7.60\ x\ SiO_2 \quad (15)$$

$$\%\ C_2S = 8.60\ x\ SiO_2 - 3.07\ x\ CaOSilicates \quad (16)$$

Solving Eq. (15) and 16 simultaneously, the value of SiO_2 can be known. From Eq. (7) the value of Fe_2O_3 composition can be determined. Substituting the Fe_2O_3 composition into Eq. (8), the amount of Al_2O_3 can be obtained. After that, the composition of CaO can be calculated from Eq. (9). After determining the clinker oxide composition, we get LSF, SM and AM to calculate the raw material feed composition. The proportions or mixture of the different raw materials which must be used are dependent on the targets for LSF, SM and AM, plus the oxide composition of the individual raw materials. The oxide composition of the raw material data is determined from laboratory analysis of the raw materials.

The proportioning of the raw materials by ratio of: X-parts of limestone, Y-parts of clay, Z-parts of sand stone.

$$X + Y + Z = 100 \quad (17)$$

The calculation is performed by applying the formula of the oxide component of the raw mix as:

$$\%CaO = Cm = \frac{X.CaOl + Y.CaOc + CaOs}{X + Y + z} \quad (18)$$

$$\%SiO2 = Sm = \frac{X.SiO2l + Y.SiO2c + Sio2s}{X + Y + Z} \quad (19)$$

$$\%Fe2O3 = Fm = \frac{X.Fe2O3l + Y.Fe2O3 + Fe2O3s}{X + Y + z} \quad (20)$$

$$\%Al2O3 = Am = \frac{X.Al2O3l + Y.Al2O3c + Al2O3s}{X + Y + z} \quad (21)$$

$$LSF = \frac{Cm}{2.8Sm + 1.1Am + 0.7Fm20} \quad (22)$$

By using the chemical analysis of raw materials data from the laboratory to calculate them using LSF:

From the SM equation:

Sm=SM (Am +Fm)

$$\mathrm{SM} * (\mathrm{Am} + \mathrm{Fm}) - \mathrm{Sm} = 0 \quad (23)$$

By solving equations simultaneously, the proportion of raw materials can be obtained.

considering fuel ash effect

In order to consider the effect of fuel ash on clinker consumption of the fuel, the consumption of the fuel is calculated first as:

Fuel consumption = kiln fuel consumption /fuel calorific value

$$M_f = \frac{K_f}{C_f} \quad (24)$$

Where, Mf = fuel consumption, Kf = kiln fuel consumption and Cf = fuel calorific value

The contribution of the fuel ash in the clinker is calculated as

$$(\mathrm{Ac}) = \frac{K_f kiln\ fuel\ consumption}{\text{fuel consumption Mf}} * \text{ As fuel ash content} \quad (25)$$

Where Mf = Fuel consumption, As = Fuel ash content

Fuel ash content is found by proximate analysis of fuel. The oxide contribution of the ash to clinker can be calculated by multiplication of the ash contribution by the percentage of oxide in the ash.

Oxide contribution of the ash to clinker (Oc) = Ac ∗ O%

O% = percentage of oxide in the ash

Percentage of oxide in the ash is determined by analyzing the ash of the fuel in XRF.

To calculate the contribution of the kiln feed to the clinker composition, subtract the oxide composition of the ash from clinker oxide composition which is obtained from mineral composition calculation:

Contribution of the kiln feed to the clinker composition (Kc) = Co – Oc

Co = clinker oxide composition

Then to calculate the kiln feed composition at the moment

$$Feed\ Composition = \frac{\text{kiln feed to the clinker composition}}{\text{kiln feed to the clinker composition1} - \text{ash contribution to clinker}}$$

Then new LSF, SM and AR are calculated and based on that and raw materials oxide composition, the raw material proportion that considers fuel ash effect can be obtained.

Table 1
Proximate analysis results.

	Coal (%)	Sludge (%)
Moisture	5.1	85.32
Volatile mater	27	52.26
Ash content	17	36.01

Table 2
Mixture calorific value of coal and sludge.

Coal (%)	Sludge (%)	Calorific value of mixture (Kcal/Kg)
70	30	5529
75	25	5727
77	23	5785
80	20	6152
85	15	6185

3. Results and discussions

3.1. Proximate analysis results

The proximate analysis of coal and brewery wastewater sludge were summarized in the Table 1 below.

When compare the moisture content of coal and sludge, the raw sludge has a high amount of moisture content than coal. Since, the sludge found directly after the belt press is 85% water, a large amount of sludge is needed in order to get the desired amount of sludge quantity.

The volatile matter of the sludge is almost twice that of the coal. Mixing the sludge with coal increases the volatile matters which increase the combustion behavior of the fuel.

The volatile matter is an important property in combustion reactions, providing a rough indication of the reactivity or combustibility of the coal. Important steps in combustion are the DE volatilization, ignition and burning of the volatiles. As the volatile matter decreases, the ignition temperature rises, ignition becomes more difficult. In order to assist the flame stability, volatile matter yield should preferably be at least 22%. The volatile matter also affects the length of the flame. Fuel mixture can only be fed to the kiln system from the main burner, kiln inlet and pre calciner for environmental point of view based on the concern that fuel mixture has high organic volatile matter. It would help for complete combustion and decomposition of the volatile organic matter resulting in good burning characteristics. Feeding the fuel with the raw material is not an option, due to high volatile matter it would vaporize and escape the killer with gas emission resulting in an environmental problem.

The ash content of the sludge is almost twice that of the ash content of coal. When mixing the coal and sludge, it was increased the ash content as compared to using only coal. This would change the raw mix design of the cement and affect feed composition.

3.2. Calorific value determination of coal and sludge

There is a bomb calorie meter in the lab. The caloric value of the coal and sludge were tested by a bomb calorie meter in Ethiopian geological survey geochemical laboratory.

Coal calorific value = 7318 Kcal/Kg

Sludge calorific value = 2169 kcal/Kg

Calorific value determination of coal and sludge mixture

Similarly, the calorific value of the mixture is determined in the Ethiopian geological survey geochemical laboratory. Based on the mix ratio, preparation of the sample to be tested was done. Then, it was given to the laboratory, and the results were reported as shown in the Table 2 below.

Table 3
Clinker oxide composition.

Oxides	Composition (%)
SiO_2	21.04
CaO	66.21
Al_2O_3	5.703
Fe_2O_3	3.614

It was found the calorific value of the coal to be 7318 Kcal/Kg and Sludge calorific value 2169 kcal/Kg. For the coal higher calorific value was obtained than got from the source and lower calorific value of sludge was obtained than got from the source. This would give the advantage of mixing a higher proportion of sludge with coal. Substituting most of the coal with the sludge has a greater impact on economical as well as environmental.

From the calorific value we get

$7318^{*} X + 2169^{*} Y = 5500$ kcal/ kg

$X + Y = 1$

Theoretically, based on the above calculation, it was possible to mix up to 35% of sludge with the coal. Based on the experiment conducted, the calorific value mix ratio of 70% coal with 30% sludge gave as 5529 kcal/kg, which is almost similar to the minimum calorific value required for heating.

3.3. Comparison of ash effect

3.3.1. Proportioning the raw materials without fuel ash

The definition of LSF (lime saturation factor) is theoretically based and the formula applies to clinkers; if corrected by subtracting $0.7SO_3$ from CaO, it may be applied to cement. It largely rules the relationship between a lite and belite and also shows whether the clinker is likely to contain an unacceptable amount of free lime, a value of 1 or above stating that the latter would be presented in balance clinkering temperature and thus likely to persist in the product. In practice, values up to 1.02 can be acceptable; typical values for modern clinkers are 0.920, & 0.98. The SM and AR, also respectively called silica modulus and alumina modulus are empirically based. For normal types of Portland cement clinker, SR is usually 2–0–3–0, and AR 1–0–4.0, but these ranges do not apply to special types, such as sulfate-resisting or white cement clinkers.

Alite (Tri calcium silicate) and belite (Di calcium silicate) account for about 75% by weight of modern cements and dominate the development of properties such as setting time and strength development. Although both are calcium silicates, alite reacts much more quickly than belite when mixed with water. Both alite and belite react to form calcium silicate hydrate (known in cement chemists' shorthand as (C-S-H), which is the primary binding material in cement paste, mortar, and concrete (Masacusate Institute of Technology CSH. 2013).

Calculation of the composition of oxides in the clinker was summarized in the Table 3 below.

The next stage is to select the raw material and determine their feed proportion. The chosen three component raw materials and chemical analysis were given as:

Based on the calculation formulating the LSF, SM and summation of raw material lime stone composition is 90.67%, clay composition 6.49%, and sand stone composition of 2.83% were found.

3.3.2. Proportioning the raw materials including fuel ash

The majorities of the ashes during the burning of fuel enter the clinker and modifies its chemical composition. On coal furnaces, it was not only important to maintain a uniform feed furnace, but also to operate it with a uniform coal composition. In plants where coal originates from several different suppliers' provisions, efforts should be made to blend these coals before was fired in the kiln. A typical analysis of coal and sludge ash were shown in the following.

Kiln fuel consumption =3100 MJ/ t clinker

Table 4
Raw materials oxide composition.

	Raw materials composition				
	Raw materials	SiO_2	CaO	Fe_2O_3	Al_2O_3
X	Limestone	9.11	46.77	1.16	2.01
Y	Clay	42.92	0.99	16.21	27.74
Z	Sandstone	85.36	2.10	2.99	6.02

Table 5
Composition of coal and sludge mixture ash content.

Coal and sludge mixture ash	
Oxides in ash	Oxides in ash
SiO2	45.4%
Al2O3	14.83
Fe2O3	11.13
CaO	8.07

Table 6
Compiled data of raw mix without fuel mix ash and with fuel mix ash.

	Raw mix without fuel mix ash	Raw mix with fuel mix ash
SiO_2	21.04%	20.4%
CaO	66.21%	67.74%
Al_2O_3	5.703%	5.46%
Fe_2O_3	3.614%	3.42%
LSF	97.77%	102.95%
SM	2.25%	2.3%
AR	1.58%	1.6%
Lime stone	90.67%	92.39%
Clay	6.49%	5.37%
Sand stone	2.83%	2.23%

Coal and sludge mixture, CV = 23,150 MJ/t

Ash = 19%

The consumption of the fuel was calculated:

Fuel consumption = kiln fuel consumption

Using the above data's, the composition of raw materials feed considering fuel ash was calculated and found to be lime stone composition 92.93%, clay composition of 5.37% and sand stone composition of 2.23%.

According to the standards specification, AM ranges from 1.3 to 2.5, if it exceeds the upper limit, the viscous slag and high early strength was exhibited. Similarly, if it is less than 1.3, then fluid slag, low early strength and low heat of hydration occur. The recommended and acceptable range of SM is 2–3. If SM goes below this range, burning becomes very easy, but excessive liquid phase and low strength cement was obtained. At the upper limit of SM, the high strength cement was obtained but the burning becomes very difficult, if it crosses the upper limit, then no clinkerization take place at all. The normal and acceptable range of LSF was 0.90–0.98. Table 4, Table 5, Table 6

From the above summarized table, it was observed that the SiO_2 of the feed composition decreased by 0.6% when fuel ash was considered. Also, Fe_2O_3 and Al_2O_3 composition were decreased almost by 0.2% when fuel ash was considered. But lime (CaO) composition was increased by 1.5%. It was observed that the LSF of the cement considering mixture fuel is greater than the one that doesn't consider the fuel mixture. This was the result of fuel ash effect, and the ash of the fuel mixture contains a high amount of Fe_2O_3, SiO_2 and Al_2O_3. Since the fuel increased, the Fe_2O_3, SiO_2 and Al_2O_3 consumption in the raw mix increased almost by 2%. In order to compensate for that, the lime stone consumption in the raw mix increased almost by 2%. Clay and sand stone consumption decreased by 1% and 0.5% respectively. Since, it could be got Fe_2O_3, SiO_2 and Al_2O_3 from fuel ash. Over all it is shown that because of fuel ash an additional amount of lime stone was added, and clay plus sand stone composition decreased but the effect on final clinker composition is unchanged.

4. Conclusions

Based on the result, calorific value allow as of coal gives as to mix a large amount of brewery wastewater sludge. There is deviation of calorific value from the source and a determined one that the calorific value of sludge was low. Comparing the result between the determined and the references sludge calorific value shows that the deviation. Since the moisture content of the sludge is high, a large amount of brewery wastewater sludge was needed in order to have a continuous supply. The sun drying was the best method for conserving energy used for drying; it has its own limitation on rainy days.

Managing industrial waste is a headache these days. Using brewery wastewater sludge mixed with coal gives us a great advantage in solving this problem. It was found that 70% by 30% of coal and sludge mixture gives us an optimum mixing ratio in order to fulfill the calorific value requirement of the cement kiln. The high volatile matter content of sludge would support the combustion behavior of the fuel mixture. Substituting 30% of the coal would be saved for foreign currency spent on purchase of the coal was reduced. In the current foreign currency shortage, this would have been a great impact on the country's economy.

In addition, it would be solved the land disposal problem breweries are facing. It would be also reduced the greenhouse gas emission of the cement industry. More importantly, it would be created an opportunity for investigation of wastes to be used in the cement industry. The idea of using wastewater sludge with coal would be an ice breaker and may leads cement industry to explore and use other waste fuel sources. The ash content of the fuel adds up in the raw mix, it was incorporated into the clinker.

Declaration of Competing Interest

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