Biomass pellets produced from filler cake as waste to energy in sugar industry

Biomass pellets produced from filler cake as waste to energy in sugar industry

K Pajampa[1], T Wongwuttanasatian[1,2*]

1 Department of Mechanical Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, Thailand
2 Center for Alternative Energy Research and Development, Khon Kaen University, Thailand
E-mail: *tanwon@kku.ac.th

Abstract. In the sugarcane and sugar industry, there is a waste produced from the manufacturing process called "Filter cake". It is a black solid sludge with the moisture content of 70-75%. In general, this waste is about 4% of the sugarcane mass input to the process. In every year, there are a large amount of filter cake resulting in high waste management costs. Therefore, the idea of conversion this waste to energy was proposed. The filter cake was dried off to the moisture contents of 40%, 45%, 50%, 55% and 60% and then fed into a pelletizer for the 5 different initial moistures. Then filter cake pellets were dried off by sun drying for 3 days. Dried pellets from different initial moistures were analyzed for physical properties. It was found that the pellet with initial moisture content of 40% has the best physical properties at the diameter of 4.0 mm and 68.4% of pellets felt into 30-40 mm of length. In addition, it has the highest bulk density, highest durability and lowest dust content of 222.03 kg/m^3, 96.13% and 0.54% respectively. The proximate analysis and heating value were also determined for the dried pellets. The results showed that dried pellets contained 5.33% moisture, 35.67% ash, 51.33% volatile matter, 7.67% fixed carbon and the heating value of 11.71 MJ/kg. These properties were compared to other pellets and standard and it was suggested that the filter cake pellets can be used together with bagasse as fuel for a boiler in a sugarcane industry.

1. Introduction

Currently, there are 55 sugar mills with a total capacity of 100 million tons per year in Thailand [1]. The sugarcane bagasse, molasses and filter cake are economically significant by-products in sugarcane and sugar industry. The plant can produce 13% of sugar, 52% of waste water, 28% of bagasse, 3% of molasses and 4% of filter cake as seen in Figure 1[2]. The filter cake is a by-product produced from manufacturing process, which is a black solid sludge with moisture content of about 70-75%. It is the sludge from a sugar clarifier which composes of clay sediment, contaminants from sugarcane juice and fine bagasse. The filter cake is conveyed through the conveyor belt to the truck and being dumped into a provided area far from the plant buildings. Filter cake is generally produced about 4% of total sugarcane input to the mill. Thus, with a big amount of sugarcane used in this industry, millions ton of filter cake are found to be a problem in waste management.

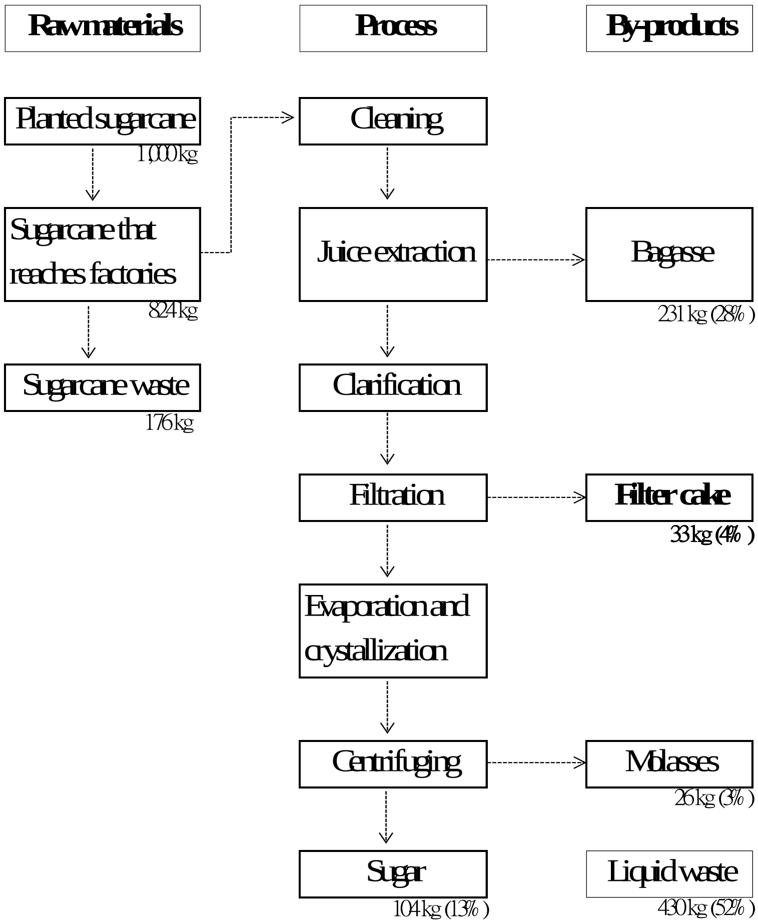

Figure 1. Manufacturing process of sugar and wastes [2].

According to the sugarcane milling information throughout Thailand in 2016-2017, there are 147.40 million tons of sugarcane fed into milling process, the total amount of filter cake is accounted for 5.89 million tons [1]. The conversion of waste to energy was proposed in this study to eliminate the cost of waste management and also to obtain a kind of biomass fuel complying with the Thai national renewable energy plan so called Alternative Energy Development Plan: AEDP2015 2015-2036. There have been many attempts to utilize filter cake, for example, the properties of compressed cement (SCC) mixed with combusted filter cake (ISFC) instead of Portland concrete (OPC**)** was investigated [3]. The mixing of filter cake together with soil and cow manure as ground-support material for the earthworm farming [4]. The filter cake mixed with distillery slop has also been used as a soil amendment agent for farmers [5]. In addition, the agricultural residues have been used to produce pellet fuels such as pellets from pineapple peels with cassava starch as a binder [6], pellets from olive branches [7], pellets from pine cones and reed canary grass (RCG), from timothy hay (H) and switchgrass (SW) [8], from eucalyptus bark, from mangosteen shell and papaya peel with different binders (dammar, Perseakurzii kosterm powder, and cashew nut shell liquid) [9]. Moreover**,** pellet fuels have been from the community waste water treatment sludge, coal powder mixed with tapioca flour as binder [10]. Therefore, the aim of the work is to produce pellet fuel from the filter cake and examine the physical properties of the pellets. It is expected that the filter cake pellets can be used with bagasse for a boiler in a sugar industry.

2. Material and methods

2.1. Raw material preparation and pelletizing process

The filter cake as raw materials were prepared with 5 different initial moisture contents of 40%, 45%, 50%, 55% and 60% and then fed into a pelletizer. The pelletizer has 4-mm holes flat die with maximum capacity of 120 kg/hr shown in Figure 2 and Figure 3. The filter cake was continuously fed through the die causing heat generated by friction in pelletizing process. Due to the different temperature and heat conditions during pelletizing process, lignin (average crude fiber analysis of bagasse is Cellulose 43.2%, Hemi cellulose 31.5%, Lignin 22.0%, Ash 3.3%) [11] inside the samples was transformed into binder helping the agglomeration of samples making the pellet to form [12]. The obtained pellets were dried for 3 days by sun drying to reduce the moisture content (below 10%) as required by the standard of pellet.

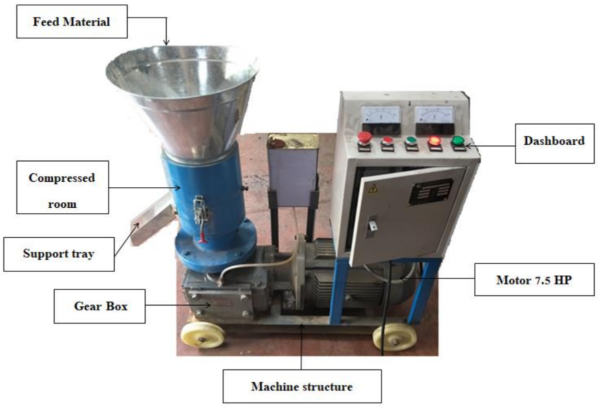

Figure 2. Pelletizer and its components.

Figure 3. Die.

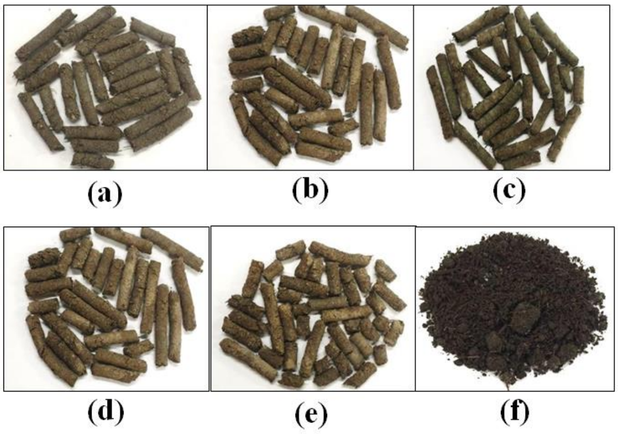

Figure 4. Pelletized filter cake pellets with various initial moisture contents at (a) 40%, (b) 45% (c) 50%, (d) 55%, (e) 60% and (f) filter cake before pelletization with 40%moisture content.

2.2. Physical properties of filter cake pellets

2.2.1. Dimension (Diameter and Length) Diameter and length of the pellets were randomly measured by a vernier caliper and mass was measured using a balance with a resolution of 0.1 g. Sample of 500 g of each pellet types (a-e) seen in Figure 4 were measured. The diameters and lengths were then averaged. The lengths of pellets were classified into 3 different ranges, i.e., 30-40 mm, 20-30 mm and below 20 mm. Then each pellet group was weighted to determine percentage of mass.

IOP Conf. Series: Earth and Environmental Science **257** (2019) 012021 doi:10.1088/1755-1315/257/1/012021

2.2.2. Bulk density Bulk density of 5 types of pellets was examined according to EN 15103 standard. The bulk density of each type of pellets was averaged from 3 samples.

2.2.3. Durability and Fines Durability testing was carried out according to EN 15210-1 standard. Each type of pellets were tested for 2 samples and averaged.

$$\%Durability = \frac{mass\ of\ pellets \vee crumbles\ after\ tumbling}{mass\ of\ pellets \vee crubles\ before\ tumbling} x100$$

The durability indicated the strength of the pellets that cannot be broken under a tested condition. While, Fines was tested according to EN 15149-1 standard. Fines is an index that indicates quantity of small pieces broken during the test. The pellets with higher fines indicated that the pellets were brittle, breakable and crumby. Similarly, 2 samples of each type of pellets were tested and averaged. The fines can be calculated by $\%Fines = \frac{W - W_1}{W} x100$

Where F = Fines content (%mass), W = original mass (g) and W_1 = remaining screened mass (g)

2.3. Proximate Analysis and Heating value

The proximate analysis of dried pellets after 3 days of sun drying was determined based on ASTM D3172. Moisture content (%M), Volatile Matter (%VM) and ash (%A) were determined and then Fixed carbon (FC) could be obtained by FC % = 100 - (M % + VM % + A %)

The heating value was determined according to ASTM D 240 standard using IKA C5000 Bomb calorimeter.

3. Experimental results and discussions

3.1. Physical properties of filter cake pellets

3.1.1. Diameter and Length It was found that the diameter of filter cake pellets was 4.0 mm according to the 4-mm holes die. The percentage of mass of pellets for 3 classified lengths depended on the initial moisture content as shown in Figure 5. With initial moisture content of 40%, 68.40% of mass felt into 30-40 mm meaning that perfect shape of pellets was most obtained, and they were not easily broken. On the other hand, by increasing initial moisture, perfect pellets were less formed. By comparing to the EN 14961-1 standard, length of filter cake pellets agreed well with the standard. But the diameter of 4 mm is less than wood pellet standard. However, if 6-mm holes die is used, the desired diameter will be obtained.

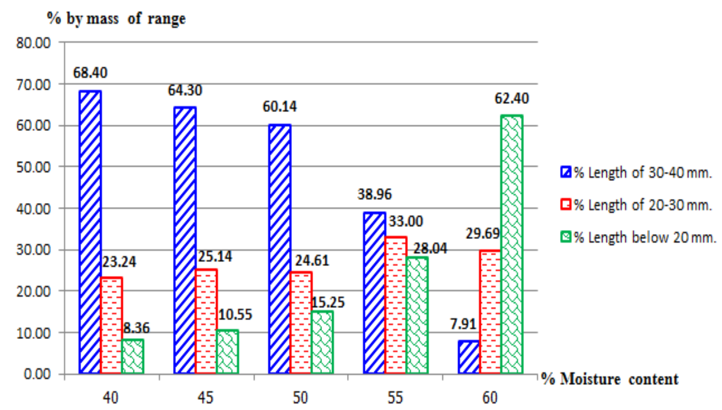

Figure 5. Percentage of mass for 3 classified lengths.

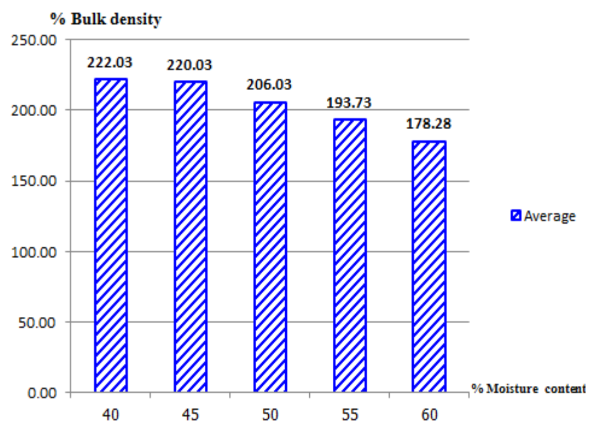

Figure 6. Bulk density.

3.1.2. Bulk density The bulk densities of pellets with 5 initial moisture contents were slightly different. The filter cake pellets with 40% initial moisture content had the highest bulk density of 222.03 kg/m^3 and the density decreased when initial moisture increased as shown in Figure 6. The bulk density value of biomass fuel based on EN 14961-1 standard should be greater than 600 kg/m^3 [13]. Thus, it is suggested that pelletizing process must be altered to increase the density. It is suggested that for current bulk density, filter cake pellets must be used on site instead of being transported.

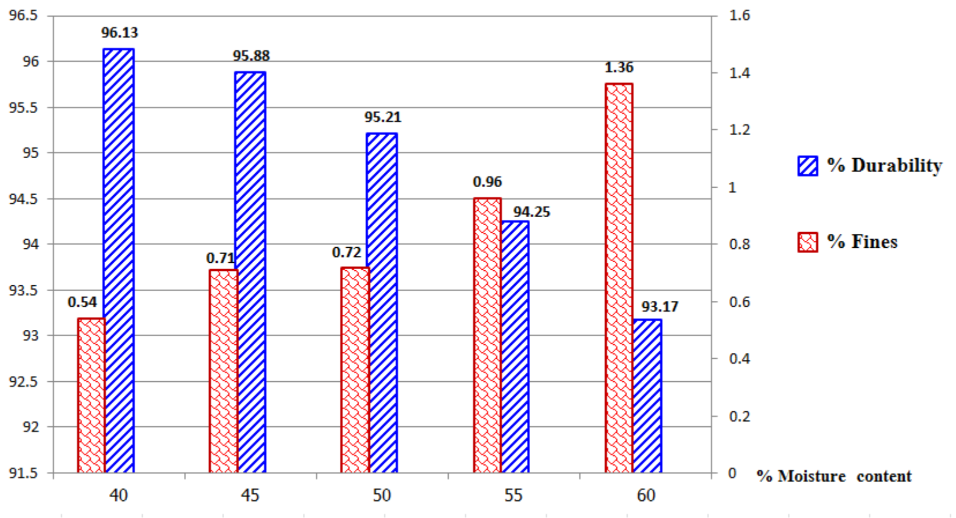

Figure 7. %Durability and %Fines of filter cake pellets.

3.1.3. Durability and fines analysis For 5 types of pellets seen in Figure 7, averaged durabilities were 96.13%, 95.88% 95.21%, 94.25% and 93.17% respectively. It was found that only at 40% initial moisture, the durability of filter cake pellets was acceptable according to the standard depicted in Table 1. From the fines analysis, the pellets made from 5 initial moisture contents indicated in the fragility of pellets. It was shown that with less initial moisture, the pellets could be less breakable. Similarly, with 40% initial moisture content, the fines value of pellets agreed well standard. The Durability and fines were found to have inversely relation.

Table 1. Physical properties of filter cake pellets and olive trees pellets.

Parameter	**Filter cake pellets**					**Pellets made from olive trees [7]**			**Biomass pellets Standard** EN 14961-1 [13]
	(a)	**(b)**	**(c)**	**(d)**	**(e)**	**OL**	**OP**	**OW**	
Diameter : mm	4.00	4.00	4.00	4.00	4.00	6 or 8	6 or 8	6 or 8	(6 ± 1mm)
Length : mm	30-40 (68.4%)	30-40 (64.3%)	30-40 (60.14%)	30-40 (38.96%)	< 20 (62.40%)	12.29	-	28.74	(3.15-40 mm)
Bulk density : kg/m^3	222.03	220.03	206.03	193.73	178.23	<1,000	<1,000	<1,000	≥ 600.00
Durability : %	96.13	95.88	95.21	94.25	93.17	0	42.3	91.7	DU ≥ 96.5
Fines : %	0.54	0.71	0.72	0.96	1.36	-	-	-	F≤ 1.0

(a): initial moisture content 40%, (b): initial moisture content 45%, (c): initial moisture content 50%, (d): initial moisture content 55%, (e): initial moisture content 60%, OL: Olive leaves, OP: Leaves and small branches, OW: Olive wood

From Table 1, it can be concluded that the physical properties of filter cake pellets were within the standard. On the other hand, the bulk density was too low compared with wood pellet standard. This suggested that the filter cake pellets are suitable for onsite use and have a disadvantage of logistic issue.

3.2. Proximate analysis and heating value

From proximate analysis shown in Table 2, filter cake pellets were compared with some biomass pellets and briquettes. It can be said that filter cake pellets having heating value of 11.71 MJ/kg can be used as fuel. Filter cake pellets was found to have higher heating value than bagasse since pellets contained much less moisture than bagasse. Although, the fixed carbon is quite low and ash content is too high, the pellets could be fired with bagasse as an additional fuel. Because of sun drying, the moisture of filter cake pellets was considerably low resulting in higher heating value compared with bagasse.

Table 2. Proximate analysis and higher heating value.

Parameters	Filter cake pellets	Bagasse [11]	Briquettes made from Different materials				Pellets made from olive trees [7]			Wood pellet Standard EN 14961-1 [13]
	FP		PP[6]	MP[14]	DP[14]	SW[15]	OL	OP	OW	
Moisture: M %	5.33	7.0-32.0	17.80	5.65	6.68	7.20	11.02	10.89	7.42	M≤ 10
Volatile matter: VM %	51.33	69.4-81.7	62.90	86.55	88.37	76.80	14.17	5.50	1.43	-
Ash: A %	35.67	3.3-7.21	3.30	5.03	4.57	5.30	63.74	79.80	90.15	A≤ 0.7
Fixed carbon: FC %	7.67	12.0-16.0	15.90	2.77	0.37	10.70	11.07	3.81	1.00	-
Heating value: (MJ/kg)	11.71	5.57-14.0	13.90	18.20	16.33	17.34	19.64	18.20	17.53	Q ≥16.5

FP = Filter cake pellet, PP = Pineapple peel, MP = Mangosteen peel, DP = Durian peel, SW = Swamp
OL = Olive leaves, OP = Leaves and small branches, OW = Olive wood

4. Conclusion

Filter cake considered as waste in sugar industry was pelletized with 5 different initial moisture contents. Filter cake pellets obtained from those initial conditions were then analyzed for their physical properties. After sun drying of the pellets, proximate analysis and heating value were determined. The results showed that with 40% initial moisture content, the pellets gave better physical properties, i.e., rigid form, less fragile, high bulk density and low fines. These properties were compared to wood pellets standard and agreed well within the standard. The filter cake pellets also gave similar heating value compared with bagasse. However, high ash content of the pellets was a drawback. In addition, with low bulk density of the pellets, it was suggested that filter cake pellets should be used onsite and not suitable to transport as the logistic cost may be too high. Finally, it is recommended that filter cake pellets should be used as co-firing with bagasse for boilers in sugar industries.

5.References

[1] Office of the Cane and Sugar Board 2014 *http://www.ocsb.go.th/th/home/index.php*
[2] Makul N and Sua-iam G 2016 Characteristics and utilization of sugarcane filter cake waste in the production of lightweight foamed concrete. *Journal of cleaner production.* **126** p 118-133
[3] Sua-Iam G and Makul N 2017 Effect of incinerated sugarcane filter cake on the properties of self-compacting concrete. *Construction and Building Materials*. **130** p 32-40
[4] Jala A and Chakkrawan S January 2016 Bedding material mixed with different ratio of filter cake from sugar cane which effected on growth of 2 types of earthworm. *Thai Journal of Science and Technology*. p 43-55

[5] Prado R, Caione G and Campos C 2013 Filter Cake and Venessa as Fertilizers Contributing to Conservation Agriculture. *Applied and Environmental Soil Science.* **2013** 8 pages
[6] Tantisatayakul Th, Sayda K, Phusongsri S and Ngernreuangroj S 2015 Feasibility study of biomass briquettes production from pineapple peel. *Journal of Science and Technology.* **23 No.5** *(Special Issue)* p 754-773
[7] Garcia-Maraver A, Rodriguez M L, Serrano-Bernardo F, Diaz L F, Zamoranoa M 2015 Factors affecting the quality of pellets made from residual biomass of olive trees. *Fuel Processing Technology.* **129** p 1–7
[8] Haruna N Y and Afzalb M T 2016 Effect of Particle Size on Mechanical Properties of Pellets Made from Biomass Blends. *Procedia Engineering.* **148** p 93 – 99
[9] Jamradbedluk J and Lertsatitthanakorn Ch 2017 Influences of Mixing Ratios and Binder Types on Properties of Biomass Pellets. *Energy Procedia.* **138** p 1147–1152
[10] Sungkapan A and Eksangsri T 2018 Co-pelletized briquettes production from municipal wastewater sludge; Case study of pattaya municipal wastewater treatment plant. *The 9th Thailand national and international conference, 20 March 2018 Bangkok.* p 1523-1533
[11] Omoniyi, T.E., Olorunnisola A.O 2014 Experimental Characterization of Bagasse Biomass Material for Energy Production. *International Journal of Engineering and Technology* **4 No.10** p 582-589
[12] Torsagun S, Suparat J and Phanasdee N 2015 Design and construct the machine for compressing the biomass fuel pellets. *The 8th Thailand renewable energy for community conference* p 91-94
[13] Alakangas, Eija, (VTT) 2011 New European Pellet Standard - EN14961-1 coordinator of EUBIONET III. Finland. p 1-9
[14] Asavrukulchai A, Semsayan Sh, Prapakdee N, Piamsuwansiri N and Choochart N 2011 The durian and mangosteen rind are used in the form of solid fuel. *The 49th Kasetsart University Annual Conference Bangkok Thailand* p 162-168
[15] Tantisatayakul Th, Phongkasem S, Phuya P and Taipanguy P 2015 Community Renewable Energy from Compost *Science and Technology.* **23 (3)** p 418-429