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Heating Value Enhancement of Fuel Pellets from Frond of Oil Palm

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Abstract—**Oil palm frond is agricultural waste from oil palm plantation area. Number of oil Palm trees in Thailand is about 70.4 million plants so total fronds can be calculated 1.7 million fronds per year. This research palm fronds were used as raw materials to produce pelletized fuel and waste glycerol as adhesive to reduce biodiesel production waste. The result from heating value analysis of frond is 17.25 MJ/kg. Therefore it is potential to make them to be useful by pelletizing. These pellets could be used for alternative energy in the industrial segment by mixing with glycerol to get higher heating value. The aim of this research was to find optimum ratio of ingredients (ratio of raw material, waste glycerol, and water) for producing fuel pellet from such materials.**

The results showed that all of the pelletized fuel characteristics met pellet fuel standard requirements except ash content. The heating value of fuel pellet from oil palm frond could achieved highest of 20.51 MJ/kg when the mixture ratio of raw material, water and waste glycerol was 50-0-50 and 50-5-45. At this mixture ratio, range of moisture content of fuel pellet was 2.12-4.35%, volatile matter was 77.37-83.11%, fixed carbon was 0.23-3.93%, ash content was 11.34-16.04% pelletizing percent was 87.50-93.07%. Ash content that could not meet the fuel pellet standard was lowest at 11.34%.

Keywords-fuel pellet; heating value; oil palm frond; waste glycerol

I. INTRODUCTION

Energy is important to manufacturing process, transportation and activities for people's life development. In Thailand the government has promoted the production and the use of biodiesel with purposes to reduce the country's importation fuel oil, enhance the energy security and promote the use of alternative energy made from domestic. According to Thai national policy to promote biodiesel as renewable energy, oil palm cultivated area has been increasing since palm oil is used as raw material for the industrial scale biodiesel plant. The government has aimed at increasing the total palm cultivation area in the country from 0.79 million acres to 3.95 million acres over the next 25 years. Thailand is currently the third world biggest palm oil producers. In 2006, oil palm plantation area in Thailand was 1.17 million acres and 2009 increased to 1.50 million acres [1].

With the high expansion of oil palm plantation area, the amount of residues generated also increase significantly. One acres of oil palm plantation can produce about 10-13 tones of biomass residues [2]. Department of Alternative Energy Development and efficiency was estimated that in 2009 Thailand will has 2.5 million tons of oil palm frond as biomass residue. Therefore, oil palm plantation area is currently one of the large sources of biomass in Thailand. The biomass from oil palm trees, such as frond can be the source of high value added products. Oil palm fronds can be used as ruminants feed directly or use as feedstock for producing oil palm frond base ruminants pellet as well as pulp for reinforcement component in newsprint production [3-5]. Although oil palm frond can be converted to various value added products, its potential as a source of renewable energy seems to be more promising. Oil palm frond utilization as a source of energy will bring other environmental benefit like reduction in CO_2 emissions [6]. Oil Palm frond is a possible raw material to be pelletized to be used in industrial furnace. There were a lot of researches reported that biowaste such as bean pod, cereal husk, cotton waste, wheat straw, sawdust, palm fiber, etc., can be pelletized to be utilized as good fuel [7-11].

There are a few research projects that produced the fuel pellet combined the waste glycerin from the biodiesel process with biomass. The energy content of fuel composing glycerin and biomass such as paper, sawdust and agricultural waste is in range 16.9-17.1 MJ/kg of glycerin [12-13]. For biodiesel manufacturing process using palm oil as feedstock, waste glycerol is generated 10% of crude palm oil. In 2008, it is estimated that 4.5 million liters of waste glycerol are produced from biodiesel industry in Thailand. This research aimed to use oil palm frond and waste glycerol to produce pelletized fuel to be alternative energy and to find suitable ratio of raw material, adhesive, and water for meeting highest heating value of such fuel pellet.

II. MATERIALS AND PROCEDURE

A. Raw Material

Oil palm frond used in this study was collected from Krabi province that has the most plantation area of oil palm in the Southern of Thailand. Oil palm frond is an agricultural waste which categorized as fibrous crop. The generation rate is about 0.27% per year. Currently oil palm

frond can be used as soil covering material for oil palm tree. The heating value of such frond is 17.25 MJ/kg.

Waste glycerol is a by-product of biodiesel production process which used palm oil as raw material. Waste glycerol were used as adhesive and can be used to enhance heating value of fuel pellet since a kilogram of glycerol gives high energy as 19.71 MJ/kg [14].

B. Equipment

- High-speed grinder has high round per minute, frond was pulverized smaller than 2 mm as shown in Figure 1.
- Pellets machine used in this study has 3 phase, 3 kW, 1440 rpm, 15.5 A, 50 Hz of motor. Diameter of pellets is 6 mm and length of the pellets ranged 1-4 cm. Cylinder, 6 mm passed through this machine. Pellet machine was shown in Figure. 2 and pellets from oil palm frond as shown in Figure. 3.

C. Procedure

- Physical and chemical characteristics of oil palm frond were analyzed to find their heating value, moisture content, ash content, volatile content, fixed carbon content as shown in Table I.
- Pelletize mixture of oil palm frond, water, and waste glycerol by varying ratio of them by weight. Pellets will be analyzed combustion efficiency as mentioned above.

Figure 1. High-speed grinder

III. EXPERIMENT

A. Sample Preparation

Oil palm frond was dried in the sunlight for 2-3 days. Then pulverized the frond by high-speed grinder and selected size smaller than 2 mm through sieve number 10.

B. Experimental method

The research experiment divided into 2 parts.

First part, pelletized oil palm frond, varied ratio of mixture (percent by weight). Percent of biomass was varied from 50 to 70 percent by weight, water was varied from 0 to 10 percent and glycerol was also varied from 20 to 50 percent by weight as shown in Table 2.

Figure 2. Pelletizing machine

Figure 3. Pellets from oil palm frond

Table II. RATIOS OF OIL PALM FROND, WATER AND WASTE GLYCEROL FOR PELLETIZED FUEL

Mixture ratio(wt.)%	Frond	Water	Glycerol
50:0:50	50	0	50
50:5:45	50	5	45
50:10:40	50	10	40
60:0:40	60	0	40
60:5:35	60	5	35
60:10:30	60	10	30
70:0:30	70	0	30
70:5:25	70	5	25
70:10:20	70	10	20

All ratios of mixture were mixed in mixer and passed through pellet machine. Waste glycerol and water was heated to 75-80 degree celcius and 90-100 degree celcius respectively for better mixing and pelletizing.

Table I. PELLETIZED FUEL CHARACTERISTIC ANALYSIS

Parameter	Analysis Method
Heating value	Bomb calorimeter (ASTM D1989)
Specific density	Mass per volume of pellet [15]
Moisture content	Dried in oven at 105°C for 1 hour (ASTM D3173)
Volatile matter	Burn in furnace at 950°C for 9 minutes (ASTM D3175)
Ash content	Burn in furnace at 750°C for 1 hour (ASTM D3174)
Fixed carbon	100 minus moisture content, volatile matter and ash content (ASTM D3172)

After pelletizing, pellets were dried in sunlight or in oven in case of rainy.

2) Second part, dried pellets will be analyzed for moisture, volatile, fixed carbon, ash, heating value and density of pellets to find the optimum ratio of mixture.

IV. Result and Discussion

A. Raw material characteristics

- Physical and chemical characteristics of oil palm frond

Proximate analysis which is moisture content, volatile, fixed carbon and ash content of oil palm frond were 7.39%, 72.53%, 5.81% and 14.27% respectively. Oil palm frond contains significantly high ash content. Ultimate analysis of frond which is carbon, hydrogen, oxygen, nitrogen, sulfur was 38.38%, 5.53%, 53.73%, 2.27% and 0.09%, respectively. Heating value of oil palm frond was 17.25 MJ/kg showed that it had suitable characteristic to be used as fuel. The result of amount of oxygen was not decisive result because there may be other element not analyzed by this method. Proximate and ultimate analysis of oil palm frond were shown in Table III.

TABLE III. COMPOSITION OF OIL PALM FROND

Composition	Frond
Proximate analysis (wt%)	
Moisture content	7.39
Volatile matter	72.53
Fixed carbon	5.81
Ash	14.27
Ultimate analysis (wt%)	
Carbon (C)	38.38
Hydrogen (H)	5.53
Oxygen (O)	53.73
Nitrogen (N)	2.27
Sulfur (S)	0.09
Heating value (MJ/kg)	17.25

- Factor affecting pelletized fuel characteristics

This experiment aimed to study the optimum ratio of raw material (oil palm frond):water:waste glycerol and optimum condition ingredient for pelletized fuel. The test was considered from parameters which are pelletizing percent, pellet density, heating value, moisture content, volatile matter, fixed carbon and ash content.

- Effect of ratio of oil palm frond, water, and waste glycerol to pelletized fuel characteristics

Proximate parameters which are moisture content, volatile matter content, fixed carbon and ash content was presented in Figure 4. These values indicated that the higher waste glycerol ratio gave the lower ash content because the lower ratio of oil palm frond.

- Effect of waste glycerol on pelletizing percent

Pelletizing percent depended on waste glycerol. The decreasing glycerol resulted in increasing of pelletizing percent (Figure 5). Range of pelletizing percent was 87.50-94.71% which was negligibly increased.

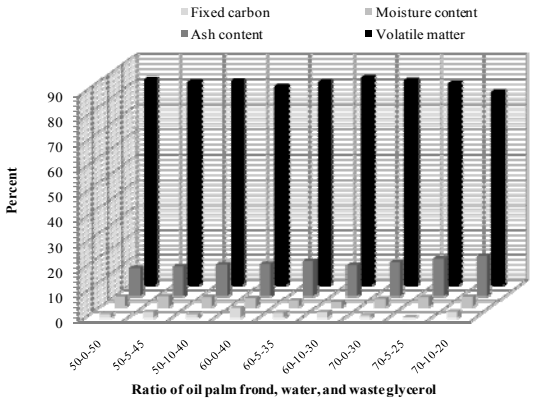

Figure 4. Proximate analysis of pelletized fuel

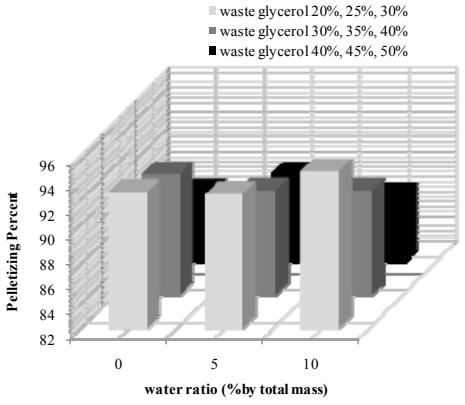

Figure 5. Pelletizing percent of pelletized fuel

- Effect of waste glycerol on heating value

The higher waste glycerol gave the higher heating value because heating value of waste glycerol is high as shown in Figure 6. Adding waste glycerol and oil palm frond made higher heating value from 17.25 MJ/kg to 20.51 MJ/kg by ratio of waste glycerol. From the result mentioned above, heating value of this pellet depended on waste glycerol.

- Effect of waste glycerol on pellet density

Figure 7 presented bulk density of pellet. It indicated that increasing waste glycerol affected decreasing bulk density because of the rise in waste glycerol affected moisture content in pelletized fuel. This is the same for the work by Gustafson and Kjelgaard [17] studied the compaction of hay for a wide range of moisture (28-44%(wb)). They found that the density of the product decreased as moisture content increased.

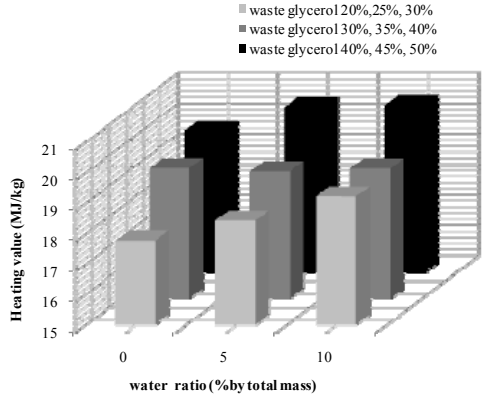

Figure 6. Heating value of pelletized fuel

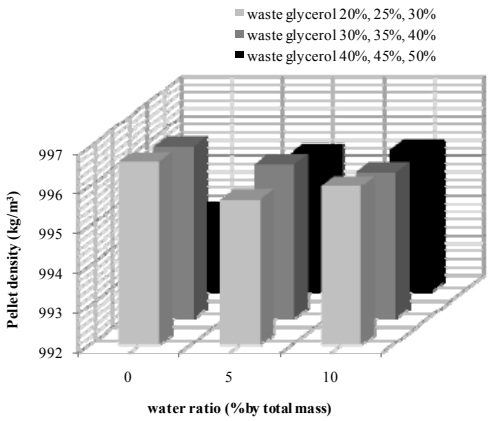

Figure 7. Pellet density of pelletized fuel

- Optimum ratio of pelletized fuel ingredient

From the results as mentioned above, typically, moisture content, volatile matter, ash content, fixed carbon, bulk density, heating value and pelletizing percent will be considered for quality of pelletized fuel in different way especially heating value is the most important parameter. Heating value has to high enough for supplying the need of industrial sector. Other parameters, example low ash increases combustibility, high bulk density fuel is convenient to be transported, and high pelletizing percent will make higher yield for pelletizing process. From this experiment, optimum ratio of oil palm frond:water:waste glycerol was 50:0:50 respectively. Because of almost all parameters have acceptable quality except ash content that higher than the pellet standard which was the lowest content of all ratios. Characterisics standard of pellet were shown in Table IV.

TABLE IV. CHARACTERISTICS STANDARD OF PELLET [16]

Characteristics of pellets	Standard	Frond pellet
Bulk density (kg/m^3)	>650	994-997
Heating value (MJ/kg)	>17	17.78-20.51
Moisture (%)	<10	2.12-4.35
Ash (%)	<0.5	11.3-16.0

V. CONCLUSION

The results from standard method analysis indicated that the use of oil palm frond and glycerol in pelletizing process is suitable for combustion as an energy source. Waste glycerol affected on heating value of pellet which range of pellet from oil palm frond was 17.78-20.51 MJ/kg. which met pellet standard as a result of glycerol concentration. The great amount of glycerol increased, the heating value increased as well. All parameters of all ratios met standard except ash content (11.34-16.04%) which was over pellet standard (0.5%). In conclusion the use of waste glycerol as adhesive for fuel pelletization, also increased the heating value of oil palm frond as well.

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REFERENCE

[1] Office of Agricultural Economics. Forecastting Result of Important Plant's Journal[online]. 2009. Available from : http://www.oae.go.th/mis/predict/Plmr48.html[April, 10 2009].

[2] J. Salathong, The sustainable use ofoil palm biomass in Malaysia with Thailand's comparative perspective. http://www.wiaps.waseda.ac.jp/initiative/2006/intern/group-02/PDF/Jessada%20Salathong.pdf; 2007[October, 10 2010].

[3] W.D.Wanrosli, Z. Zainuddin, K.N. Lawb, and R. Asro, Pulp from oil palm fronds by chemical processes, Ind Crops Prod 25 (2006), pp. 89–94.

[4] OA. Hassan, M. Ishida, Mohd I. Shukri, ZA. Tajuddin, Oil-palm fronds as a roughage feed source for ruminants in Malaysia[online]. FFTC for the Asian and Pacific Region. Available from : http://www.agnet.org/library/eb/420/[October, 10 2010].

[5] MARDI, Oil palm frond based ruminant pellet[online] (2008). Available from: http://www.mardi.my/main.php?Content=home&FolderID=157&CurLocation=131[October, 8 2010]

[6] S.H. Shuit, K.T. Tan, K.T. Lee, A.H. Kamaruddin, Oil Palm biomass as a sustainable energy source : A Malaysian case study. Energy 34 (2009) 1225-1235.

[7] O. O. Fasina, Physical properties of peanut hull pellets. Bioresource Technology99 (May 2007): 1259-1266.

[8] C. Ryu, K. Finney, Sharifi, V. N., and Swithenbank, J. 2008. Pelletised fuel production from coal tailings and spent mushroom compost-Part I Identification of pelletisation parameters. Fuel Processing Technology 89: 269-275.

[9] G. A. Holt, T.L. Blodgett, F.S. Nakayama, Physical and combustion characteristics of pellet fuel from cotton gin by-product by select processing treatments. Industrial Crops and Products 24 (2006): 204-213.

[10] S. Mani, L.G. Tabil, S. Sokhansanj, Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses. Biomass & Bioenergy 30 (2006): 648-654.

[11] D. Bergstrom, S. Israelsson, M. Ohman, S. A. Dahlqvist, , R. Gref, C. Boman and I. Wasterlund, Effect of raw material particle size distribution on the characteristics of Scots pine sawdust fuel pellet. Fuel Processing Technology89 (June 2008): 1324-1329.

[12] S. Brandy, K. Tam, G. Leung, C. Salam, Zero waste biodiesel:Using glycerin and biomass to create renewable energy. UCR Undergraduate Research Journal:2009; 5-11.

[13] Clark T. Burning Glycerin [online], Available from : http://journeytoforever.org/biodiesel_glycerin.html[January, 16 2009]. 2006.

[14] K. Chaiyaomporn and O. Chavalparit, Fuel pellets production from biodiesel waste. Environmental engineering, Chulalongkorn University, Thailand. EnvironmentAsia 3(1). 2010, pp.103-110.

[15] T. Bohm, H. Hartmann, Measuring particle density of wood pellets. Proceeding of the second world conference and technology exhibition on biomass for energy, industry and climate protection, Rome, Italy. 10-14 May 2004.

[16] European Biomass Industry Association. Comparison between briquettes and pellets[Online]. European Biomass Industry Association, 2005. Available from : http://www eubia.org/111.0.html[March, 28 2009].

[17] A.S. Gustafson, W.L. Kjelgaard, Hay pellet geometry and stability Agricultural Engineering 1963;44(8):442-5.