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DEVELOPMENT OF PALM BIOMASS BRIQUETTES WITH POLYETHYLENE PLASTIC WASTE ADDITION

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Abstract

High global energy demand scenario has driven towards transformation from sole dependence on fossil fuels to utilization of inexhaustible renewable energy sources such as hydro, biomass, solar and wind. Renewable energy sources are abundant in Malaysia, especially palm biomass residues that are produced during the oil extraction process of fresh fruit bunch. Therefore, it is inevitable to harness these bioenergy sources, in order to prevent waste accumulation at adjacent to palm mills. Briquetting of palm biomass such as empty fruit bunch (EFB) with polyethylene (PE) plastics waste addition is expected not only could maximize the utilization of energy resources, but also could become as a potential solution for residue and municipal plastics waste disposal. In the present study, the physical and combustion properties of palm biomass briquettes that contain novel mixture of pulverized EFB and PE plastics waste were investigated experimentally. The briquettes were produced with different mixing ratio of EFB and PE plastics (weight ratios of 95:5, 90:10 and 85:15), under various heating temperatures (130-190°C) and at constant compaction pressure of 7 MPa. Based on the results, it can be said that heating temperature plays a significant role in affecting physical properties such as relaxed density and compressive strength. The values of relaxed density and compressive strength are within the range of 1100 to 1300 kg/m^3 and 0.8 to 1.2 MPa, respectively. Meanwhile, mixing ratio does affect relaxed density and gross calorific value. All values of gross calorific (17900 to 21000 kJ/kg) and moisture content (7% to 9%) are found to fulfill the requirement for commercialization as stated by DIN51731 (gross calorific value>17500 kJ/kg and moisture content<10%). Even though the values of ash content (3% to 4%) exceed the limitation as stated by the standard (<0.7%), it is still considered very competitive if compared to the commonly used local briquette that contains mesocarp fibre and shell (5.8%). Finally, it can be concluded that the best quality of briquette can be achieved when highest composition of PE plastics (weight percentage of 15%) is used and the briquetting process is performed at the highest temperature (190°C).

Keywords: Palm biomass, empty fruit bunch, EFB, briquette, polyethylene, PE plastics, power plant, vehicle system

1.0 INTRODUCTION

The increasing energy demand throughout the world has driven towards transformation from the sole dependence on fossil fuels to utilization of inexhaustible renewable energy sources such as hydro, biomass, solar and wind. Renewable energy sources are abundant in Malaysia, the significant ones are biomass and solar [1]. Oil palm plantations are being actively cultivated and harvested, that cover close to five million hectares for year 2011 [2]. As a result, massive amount of palm biomass residues are produced during the oil extraction process of fresh fruit bunch (FFB), such as shell, mesocarp fibre and empty fruit bunch (EFB). Due to this scenario, it is inevitable to harness these bioenergy sources, in order to prevent from just being dumped at adjacent to palm mills.

Briquetting is one of densification methods which is able to produce the compacted biomass with higher energy content per unit volume. This technique is one of the attractive ways to utilize palm residues in order to eliminate dumped areas adjacent to palm mills, by compacting it into a product with higher density.

In addition, this technique would give solution for difficult handling and expensive transportation procedures [3]. Besides application in power plant system, synthesized gases from the gasification of briquette also have potential to be used for vehicle system [4]. The first attempt to convert these palm residues into briquettes was successfully performed more than a decade ago, in which the briquettes contained mesocarp fibre and shell were produced with starch as a binding agent [5]. Then, six years later, binderless briquettes were successfully produced by using pulverized palm biomass [6]. The international standard was used to evaluate the performance of the binderless briquettes produced, that is DIN51731. In the following years, several other efforts in making briquette were continuously performed to utilize the massive amount of residues produced, that are mesocarp fibre [3] and EFB [7]. Based on these previous studies, it can be concluded that the heating values of briquettes produced are very close to the requirement stated by standard for commercial briquette production (DIN51731).

However, the fast growing demand requires the maximum utilization and recovery of energy [8, 9]. In this case, the addition of polyethylene plastics waste to the palm biomass briquette is one of the attractive options for coping with high global energy demand scenario. Recently, the briquettes contain sawdust/straw and polyethylene plastic waste have been produced [10]. They found that the calorific values of biomass briquettes are generally increase due to the plastics waste addition. In addition, when the ratio of biomass to polyethylene plastics was set to 70:30, the emission of carbon monoxide and nitrogen oxide from combustion of briquettes contain such mixture was found very competitive with 100% sawdust briquettes. The study also demonstrates that such briquette has potential to be commercialized due to improvement of combustion characteristics, especially in terms of heating value. Before that, Kers *et al*. (2010) have produced briquettes made of refuse derived fuel (RDF), which consists of mixture of municipal waste (38% wood chips from soft wood, 45% disintegrated carton waste, 11% disintegrated PET bottles and 6% textile waste) [11]. They recommended the addition of wood and paper wastes to the RDF in order to improve the mechanical strength of the briquettes produced. In the other study, they have also asserted that high pressing temperature and pressure should be applied when briquetting municipal waste [12]. The potential of polyethylene waste as a clean energy source to drive miniature steam engine for electric power generation has been proven by Anaraki through clean combustion process [13].

Based on the literature, it can be concluded that the fundamental investigation on briquette contains mixture of palm biomass and polyethylene plastics waste has not been performed yet, thereby leading us for new exploration about the briquette with the new mixture. Differ with previous approach performed by Zannikos *et al*. (2013) [10], the present study specifically focuses on the effect of composition ratio and briquetting temperature on both physical and combustion properties of the briquettes produced. The EFB was selected due to massive amount of its production in comparison to the other types of palm biomass such as palm kernel shell and mesocarp fibre [14]. In addition to infinite supply of the sources, the production of such briquette with such new mixture utilizes the potential energy from waste products. It is also expected that the introduction of this new briquette not only could maximize the utilization of the energy resources, but also could become as a potential solution for residue and municipal plastics waste disposal.

2.0 METHODOLOGY

2.1 Preparation of Raw Materials

In the present study, empty fruit bunch (EFB) fibre and polyethylene (PE) plastics were used as raw materials. EFB fibres were received from Felda Lok Heng, Kota Tinggi, Johor. Meanwhile, polyethylene (PE) plastics were obtained from a local supplier. The EFB fibres were ground and sieved into small particles size (<500μm) while the PE plastics were shredded and sieved into small tiny particles (1 mm to 3.35 mm). The sieving process was performed by using sieving machine (model: EFL 2 mk3). Before briquetting process, both EFB powder and shredded PE plastics were mixed to obtain homogeneity. The weight of the mixture for making each briquette was set around 40 grams.

2.2 Briquetting Process

The briquetting process was performed by using Instron Machine 600dx. The briquettes with diameter around 50mm were produced by using a die set made of stainless steel, as shown by Figure 1. A hole for thermocouple sensor was made inside the die wall in a way such that the horizontal distance between the sensor and the pulverized EFB (inner wall of die part) is around 3 mm. For heating purpose, the die part was covered with coil heater as shown by Figure 2 and was insulated to prevent heat loss. Both the thermocouple and coil heater were connected to a temperature controller to control the heating temperature.

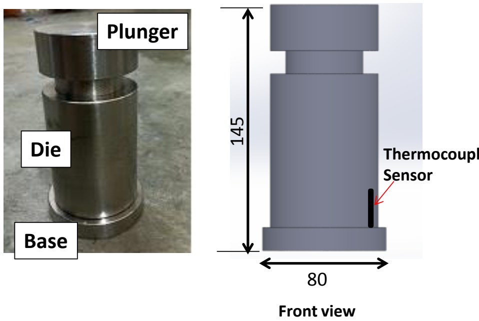

Figure 1 Die set and respective thermocouple location

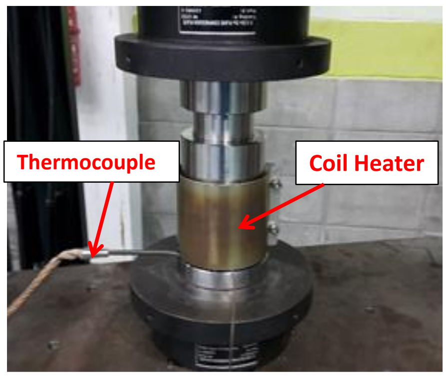

Figure 2 Briquetting process using Instron Machine 600dx

Briquetting processes were performed at constant compaction pressure of 7 MPa, for three mixing ratios of EFB and PE plastics (weight ratios of 95:5, 90:10 and 85:15). Meanwhile, heating temperature was varied between 130°C and 190°C with 20°C increment. In the present study, both mixing ratio and heating temperature were varied because it is necessary to fundamentally understand on how the behaviour of briquettes with different mixing ratio changes when the temperature is varied. In this case, which effect becomes dominant, whether effect of mixing ratio or effect of temperature, could be determined.

For briquetting process, the mixture was compressed without heating for 30 minutes initially. Then, the mixture was continuously compressed at the desired heating temperature for another 30 minutes. After that, it was left at room temperature for cooling process. Finally, the briquette was taken out from the die set and was placed at ambient condition for around one week to obtain stability and rigidity.

2.3 Determination of Physical Properties

The physical properties of the briquettes produced were investigated in terms of relaxed density and compressive strength. The relaxed density was determined by using stereometric method as introduced by Rabier *et al*. (2006) [15]. The diameter and height of the briquettes were measured by using calliper while the mass was measured by using precise mechanical balance. Meanwhile, the test of compressive strength was conducted by using Instron machine 600dx. During this test, each briquette was placed between the plates of the machine horizontally. Then, force was continuously applied on the briquette until fracture was detected. The fracture of the briquettes produced was confirmed when there was sudden drop of the force applied.

2.4 Ultimate and Proximate Analysis

Ultimate analysis was performed by using CHNS analyzer (model: vario MICRO CUBE) to characterize the raw materials. Meanwhile, the proximate analysis was conducted to characterize both the raw materials and the briquettes produced, based on American Society for Testing and Materials (ASTM) standards as shown by Table 1.

Table 1 Standards Used for Proximate Analysis

Properties	Standard Used
Moisture Content	ASTM D3173
Volatile Matter	ASTM D3175
Ash Content	ASTM D3174

Results of ultimate analysis for the raw materials (pulverized EFB and shredded PE plastics) are shown in Table 2 below. The result of ultimate analysis for EFB is similar to that obtained in previous study performed by Husain *et al*. (2002) [5].

Table 2 Results of Ultimate Analysis for EFB and PE Plastics

	EFB	Polyethylene Plastics
Carbon (%)	44.20	75.56
Hydrogen (%)	5.82	11.98
Nitrogen (%)	0.64	0.10
Sulphur (%)	0.095	0.096

Table 3 Results of Proximate Analysis for EFB and PE Plastics

	EFB	Polyethylene Plastics
Fixed Carbon (%)	14.00	0.0
Moisture Content (%)	7.00	0.57
Volatile Matter (%)	75.50	92.37
Ash Content (%)	3.50	7.05

Based on Table 3, it can be said that the moisture contents of pulverized EFB and shredded PE plastics fulfil the requirement for commercial purpose as stated by DIN51731 (<10%). However, the ash contents of both EFB and PE plastics exceed the limitation stated by the standard (0.7%). Table 3 also demonstrates that PE plastics composed of high amount of volatile matter.

2.5 Determination of Gross Calorific Values

Gross calorific values of the raw materials and the briquettes produced were determined by using a bomb calorimeter (model LECO AC350) based on ASTM D240 standard. The result of the test for the raw materials is shown by Table 4 below.

Table 4 Gross Calorific Value of Raw Materials

Material	Average Calorific Value (kJ/kg)
EFB Fibre	16131
Polyethylene Plastics	40792

Based on Table 4, it can be said that the calorific value for EFB is lower than the minimum requirement as stated by DIN51731 (17500 kJ/kg). However, the calorific value belongs to PE plastics is much higher than the benchmark DIN51731. Therefore, it is worthwhile to utilize the PE plastics waste as energy source to improve the calorific value of the briquettes produced.

3.0 RESULTS AND DISCUSSION

In this section, results of physical and combustion properties of the raw materials (EFB and PE plastics) and the briquettes produced, are presented and discussed. The performance of the briquettes produced is compared with benchmark DIN51731 and commonly used local briquette that contain mesocarp fibre and shell [5].

3.1 Physical Properties of Briquettes

Figure 3 shows the image of briquettes with different mixing ratio of EFB and PE plastics. Generally, it can be said that the briquettes contain mixture of EFB and PE plastics were successfully produced with a smooth surface.

Figure 4 shows relaxed density of briquettes with different mixing ratio (EFB:PE) produced under various heating temperatures. At lower temperature range of 130℃ and 150℃, it can be clearly observed that the relaxed density increases with an increase in PE content. The notable changes however, could not be clearly observed for the cases with relatively higher heating temperatures (170℃ and 190℃). Meanwhile, for various heating temperatures, the density increases with an increase in temperature without regard to the mixing ratio. These results elucidate that more lignin that acts as a natural binder is produced at higher temperature, thus adhesive characteristic becomes stronger. As a result, the tendency for deformation becomes lower after briquetting. Therefore, the density of the briquettes increases when the heating temperature is increased. Based on the results, the lowest density belongs to the briquette with mixing ratio of 95:5 that was produced under temperature of 130℃ while the highest density belongs to briquette with mixing ratio of 85:15 that was produced under temperature of 190℃.

(a) Ratio 95:5 (b) Ratio 90:10

(c)Ratio 85:15

Figure 3 Image of briquettes with different mixing ratio of EFB and PE plastics

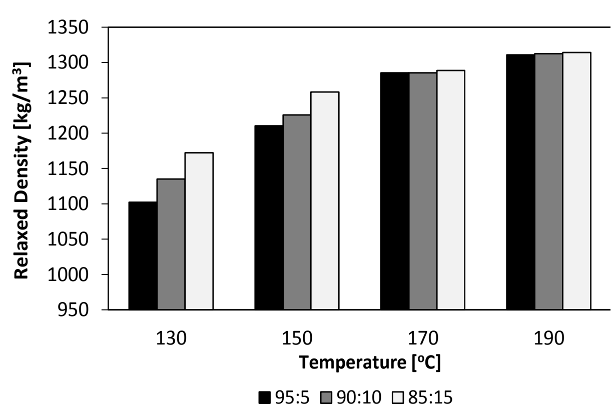

Figure 4 Relaxed density of briquettes with different mixing ratio (EFB:PE), for various heating temperatures

Figure 5 shows the compressive strength of briquettes with different mixing ratio, produced under various heating temperatures. The figure demonstrates that the values of compressive strength are within the range of 0.8 to 1.2 MPa. Based on the figure, it can be said that the compressive strength increases as temperature is increased. When the temperature is increased, more lignin is naturally produced, thus stronger adhesive characteristics is obtained.

In general, the compressive strength of the briquettes is considered reliable, that can withstand with sufficiently high force applied even though it is lower if compared to the strength belongs to commonly used local briquette [5] and briquette made of 100% EFB [16].

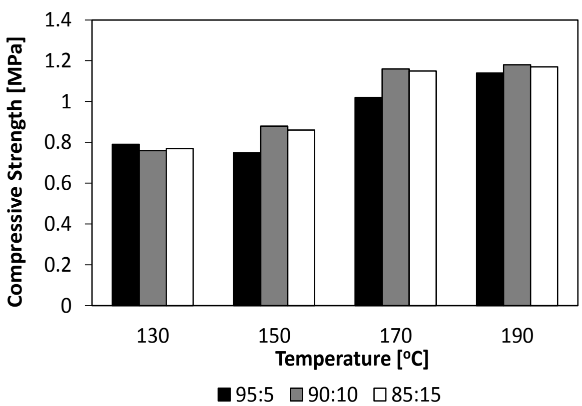

Figure 5 Compressive strength of briquettes with different mixing ratio (EFB:PE), for various heating temperatures

3.2 Combustion Properties of Briquettes

Figure 6 shows gross calorific values of briquettes with different composition of pulverized EFB and shredded PE plastics, produced under various heating temperatures. Here, a red dashed line which represents minimum requirement for commercialization as stated by standard DIN51731 is also created in the figure. DIN 51731 stated that the calorific values of the briquettes produced should be higher than 17500 kJ/kg. Based on Figure 6, it can be said that the range of calorific values for briquettes in the present study complies with the requirement stated by DIN 51731. Overall, the gross calorific values are within the range of 17900 kJ/kg to 21000 kJ/kg.

In terms of mixing ratio, the calorific values increase as the content of PE plastics is increased. Thus, it can be said that the PE plastics with a relatively high calorific value (refer to Table 4) causes the gross calorific values of the briquettes increase when PE content is increased.

For the same mixing ratio, the gross calorific values do not show any significant change as the temperature is increased. Thus, it can be said that within the temperature range of the present study, the gross calorific value is mostly affected by the briquette composition rather than heating temperature.

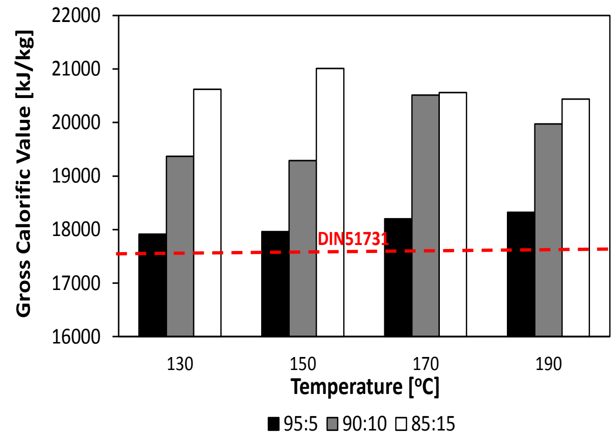

Figure 6 Gross calorific value of briquettes with different mixing ratio (EFB:PE), for various heating temperatures

For proximate analysis, the results of moisture content and ash content are presented and discussed. Figure 7 shows moisture content of the briquettes with different mixing ratio that produced under various heating temperatures. Here, a red dashed line created in the figure represents a limitation of moisture content for commercial purpose as stated by standard DIN51731 (<10%). Based on the figure, it can be said that all values of moisture content (7% to 9%) fulfil the requirement as stated by the standard (<10%). Within the temperature range of the present study, the dependence of moisture content on heating temperature also could not be clearly observed.

Figure 8 shows the ash content of the briquettes with different mixing ratio, produced under various heating temperatures. The red dashed line in the figure represents a limitation of ash content for commercial briquette production as stated by standard DIN51731 (<0.7%). Similar to the results of moisture content, the ash content of the briquettes produced does not depend on both mixing ratio and heating temperature. Even though the requirement as stated by DIN51731 is not fulfilled, the values of ash content (3% to 4%) obtained in the present study are considered very competitive if compared to the ash content belongs to commonly used local briquette (5.8%) [5].

Based on the results of the present study, it can be said that the best quality of briquette can be achieved when highest composition of PE plastics is used and the briquetting process is performed at highest temperature. This is because sufficiently high relaxed density and compressive strength can be obtained when such condition is applied, as well as good combustion properties.

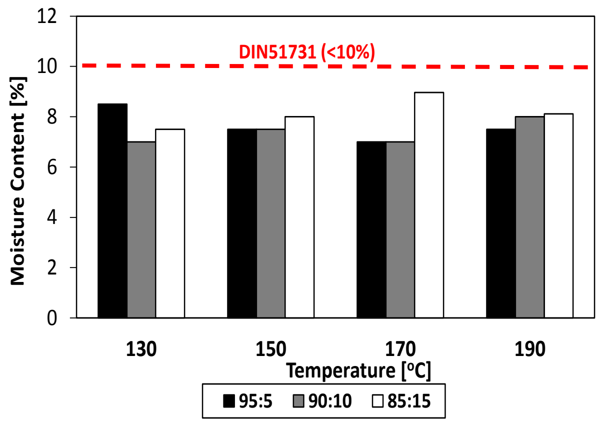

Figure 7 Moisture content of briquettes with different mixing ratio (EFB:PE), for various heating temperatures

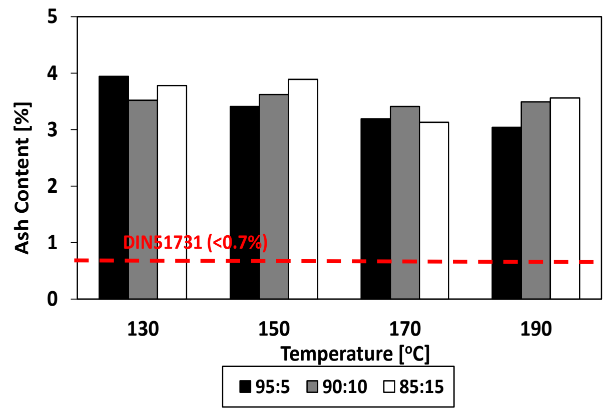

Figure 8 Ash content of briquettes with different mixing ratio (EFB:PE), for various heating temperatures

4.0 CONCLUSION

The briquettes with different mixing ratio of pulverized EFB and PE plastics were successfully developed, under various heating temperatures.

Generally, it can be said that within the temperature range used in the present study, heating temperature plays a significant role in affecting physical properties such as relaxed density and compressive strength. Meanwhile, mixing ratio of EFB and PE plastics does affect relaxed density and gross calorific value.

It was found that all values of gross calorific value and moisture content fulfill the requirement as stated by DIN51731, regardless of mixing ratio and heating temperature. Meanwhile, the ash content is considered very competitive if compared to that belongs to commonly used local briquette that contain mesocarp fibre and shell.

Overall, it can be said that the best quality of briquette can be achieved when highest composition of PE plastics is used and the briquetting process is performed at the highest temperature.

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