Jurnal
Teknologi

Full Paper

CHARACTERISTICS OF BINDERLESS PALM BIOMASS BRIQUETTES WITH VARIOUS PARTICLE SIZES

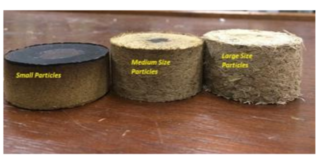
Hasan Mohd Faizal[a*], Z. A. Latiff[a], Muhammad Amin Mohd Iskandar[b]

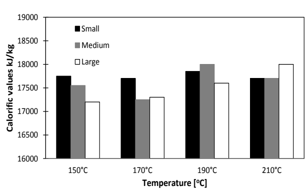
[a]Automotive Development Centre (ADC), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Article history
Received
20 July 2015
Received in revised form
23 September 2015
Accepted
22 October 2015

*Corresponding author
mfaizal@mail.fkm.utm.my

Graphical abstract





Abstract

The physical and combustion characteristics of binderless palm biomass briquettes were investigated experimentally for various particle sizes and heating temperatures (150-210℃). In this study, empty fruit bunch (EFB) fibres were used as a raw material. They were grounded and sieved into three different sizes; i) <300 μm(small size), ii) 0.5 mm to 1.0 mm (medium size) and iii) 1.0 mm to 3.9 mm (large size). As a result, all particle sizes are possible to be used for making binderless briquette since the reliable compressive strength can be obtained. All the values of compressive strength are sufficiently high to resist mechanical disintegration. In addition, all calorific values are found to be very close to the minimum requirement for making commercial briquette, based on standard DIN51731 (17500 kJ/kg). Meanwhile, the moisture and ash content of the briquettes produced are found to be very competitive with the values belonging to a widely used local briquette. Based on the experimental results, it can be said that the best quality of 100% EFB briquette can be achieved when small particle size is used and the briquetting process is performed at the highest heating temperature.

Keywords: Empty fruit bunch, EFB briquette, binder less briquette, heating temperature

© 2015 Penerbit UTM Press. All rights reserved

1.0 INTRODUCTION

The growing prices of fossil fuel and climate changes have driven the transformation from the energy highly dependence on fossil fuel to inexhaustible renewable energy such as solar, wind, mini hydro and biomass [1]. Renewable energy sources are abundant in Malaysia, and the significant ones are biomass and solar [2]. One of the important biomass resources in Malaysia is empty fruit bunch (EFB) that can be obtained during the extraction of palm oil from fresh fruit bunch (FFB). Active oil palm plantations cover close to five million hectares in the year 2011 [3]. As a result, abundant palm biomass wastes are produced during the processing of FFB, such as shell, mesocarp fibre and empty fruit bunch (EFB). Among these wastes, the production of EFB is the highest, approximately 15.6 to 21.6 million tonne EFB are produced per annum [4]. Due to this scenario, it is inevitable to harness these bioenergy sources, in order to prevent from becoming another waste product of the palm oil industry.

Densification of biomass is a compression of raw materials such as sawdust or palm biomass into solid biofuel with higher density [5]. It is one of the attractive ways to utilize EFB biomass residues, thus could reduce the dumping areas required for this waste. One of the main advantages of this technique is the increase in energy density per unit volume. Besides, the densification can make handling and transportation procedures becoming easier and cheaper. It can reduce the formation of dust and can improve combustion properties. Basically, densified biomass can be categorized into three types, namely as bale, briquette and pellet. Briquette is a small log with a diameter of between 30mm and 100mm and of any length [6]. Meanwhile, the logs with smaller diameter are called pellet, and much larger than that are called bale. The quality of densified products depends on two main aspects; strength and durability of the particle bonds [7].

Several researchers have investigated experimentally the characteristics of densified products that contain palm oil biomass residues. The first palm biomass briquette that contains mesocarp fibre and palm shell (weight ratio of 60 : 40) has been introduced by Husain *et al.* [8]. They have used starch as a binding agent. It was found that the average value of mechanical strength of the briquettes produced was about 2.56 MPa, and is considered as a good resistance against disintegration. In 2008, Nasrin *et al.*[9] have introduced the briquette that contains 100% pulverized EFB in order to utilize the massive amount of EFB produced every year . Two years later, the investigation on the performance of briquettes with a new mixture of EFB fibre and palm shells has been performed, in which the briquettes were found to fulfil the minimum requirement for export purpose, based on standard stated by DIN51731[10]. In the same year, Faizal *et al.*[11] have introduced the briquettes contain EFB fibre and mesocarp fibre (weight ratio 60 : 40) to fulfil the minimum requirement stated by DIN51731.

In 2013, Chin and Shiraz[12] have made comparison between two types of palm biomass briquettes that contained different binding agent, that are paper and starch. The palm biomass used were palm kernel shell and mesocarp fibre. They have concluded that the briquette with mixing ratio of 60 : 40 (palm kernel shell : mesocarp fibre) and paper as its binder show a feasible performance. Meanwhile, Arzola *et al.*[13] have found that the good quality pellets with mixture of palm kernel shell and mesocarp fibre can be achieved with 10% moisture content, 4% binder content and 40% mass of palm kernel shell.

As mentioned previously, massive amount of EFB is produced every year during the palm oil extraction. Thus, in the present study, the utilization of EFB is emphasized during briquette production. Taking a different approach from the previous research that used 100% EFB in pulverized form [9], the present research investigates fundamental characteristics of 100% EFB briquettes with various particle sizes. The quality of the briquettes produced was evaluated based on the fulfilment of standard requirement for commercial briquette (DIN51731) and the competitiveness with the performance of the widely used local briquette that contains mesocarp fibre and shell (weight ratio 60 : 40) [8]. The quality of the briquettes is considered good when such criteria are fulfilled.

2.0 METHODOLOGY

2.1 Proximate Analysis of Raw Materials

In the present study, EFB was used as the raw material. It was received from Kilang Sawit Felda Lok Heng, Kota Tinggi, Johor. Before briquetting, proximate analysis for the raw material was performed to determine the basic combustion properties. Proximate analysis was conducted based on American Society for Testing and Materials (ASTM) standards. Table 1 below shows the standards used for the proximate analysis of raw material and briquettes produced. Meanwhile, Table 2 shows the result of proximate analysis for the raw material which is EFB.

Table 1 Standard Used for Proximate Analysis

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

Table 2 Results of Proximate Analysis for EFB

Properties	Percentage(%)
Fixed Carbon	14.00
Moisture Content	7.00
Volatile Matter	75.50
Ash Content	3.50

Table 2 shows that, the moisture content for the raw material used in the present study satisfied the minimum requirement for the manufacture of commercial briquette as stated by DIN51731(<10%).

2.2 Gross Calorific Value of Raw Materials

Gross calorific value of raw materials is determined by using a bomb calorimeter, model LECO AC350. The average gross calorific value for EFB fibre was found to be 16131 kJ/kg. This value is lower than the minimum requirement as stated by DIN51731 (17500 kJ/kg). In the present study, the calorific value for briquettes after undergoing continuous heating was measured to investigate whether is there any improvement or not.

2.3 Preparation of Briquettes

Firstly, the raw material (EFB fibre) was grounded and sieved into three different sizes; i) <300 μm(small size), ii) 0.5 mm to 1.0 mm (medium size) and iii) 1.0 mm to 3.9 mm (large size).

For briquetting process, Instron 600 dx equipment was used. Figure 1 shows the die set and the respective location of thermocouple sensor. The die set was made of stainless steel. The horizontal distance between thermocouple sensor and inner wall of die part was set about 3mm. For heating purpose, the die part was covered with steel coil heater and insulator, as shown by Figure 2.

Briquetting processes were performed at various heating temperatures of 150° C, 170° C, 190° C and

210° C. Meanwhile, the compaction pressure was kept constant at 7 MPa. The amount of the raw material (EFB) used for making each briquette was around 45 g. Initially, the EFB was compressed without heating for around 30 minutes. Then, it was continuously heated with the desired temperature for 30 minutes. After that, it was left at room temperature for cooling. After the briquettes were taken out from the die set, they were placed in ambient condition for around a week to obtain stability and rigidity.

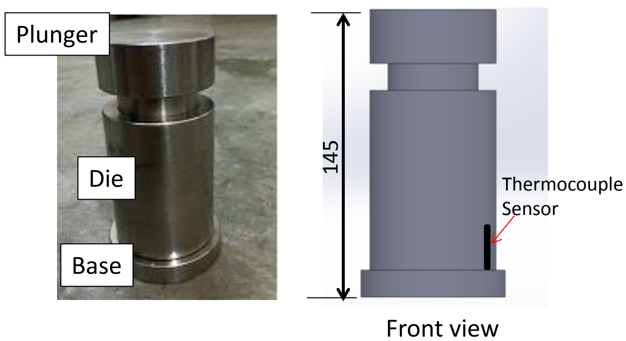


Figure 1 Die set for briquetting

Figure2 Die set covered with steel coil heater

2.4 Determination of Physical Characteristics of the Briquettes

Physical characteristics of the briquettes were investigated in terms of relaxed density and compressive strength. The density of the briquettes was determined using stereo metric method as proposed by Rabier *et al.* [14]. The volume of the briquette was measured using callipers and then the mass was measured using a precision mechanical balance.

Meanwhile, the compressive strength of the briquettes produced was determined using Instron 600 dx machine. Each briquette was placed on the metal plate horizontally. The load was continuously applied on the briquette until it cracked. The machine was then stopped and the data of the load was recorded.

2.5 Determination of Combustion Characteristics of the Briquettes

Combustion characteristics of briquettes were investigated in terms of gross calorific value, moisture content and ash content. As mentioned in Section 2.2, the gross calorific value of each briquette was determined using a bomb calorimeter (model LECO AC350) while the moisture content and ash content were obtained from proximate analysis.

3.0 RESULTS AND DISCUSSION

In this section, the physical and combustion characteristics of the briquettes produced were discussed. In addition, the performance of the briquettes was compared with the standard for making commercial briquette, as stated by DIN51731, and also is compared with the performance of the widely used local briquette.

3.1 Physical Characteristics of Briquettes

Based on the present study, the binderless briquettes are possible to be formed when continuous heating is applied within the temperature range of 150° C to 210° C. This means lignin that serves as a natural binder for the briquette has been produced due to heating process. Figure 3 below shows the briquettes made of different size EFB particles.

Figure 3 Briquettes with different particle size

Figure 4 shows the relaxed density of the briquettes with different particle sizes pressed at various heating temperatures. The figure shows that the density of briquettes with small size particles is highest, followed by that with medium and large size particles. This is because smaller size particles in the briquette will fill the volume better, thus the density becomes larger.

Based on Figure 4, it can be said that within this temperature range (150°C – 210°C), the density of the briquette is not really affected by the heating temperature as the density of the briquettes remain almost the same even though the temperature is changed.

Figure 5 shows the result of compressive strength of the briquettes produced. The figure shows that when the heating temperature is above 170°C, the compressive strength increased. This is because when the temperature is increased, the bonding between particles inside the briquette becomes stronger.

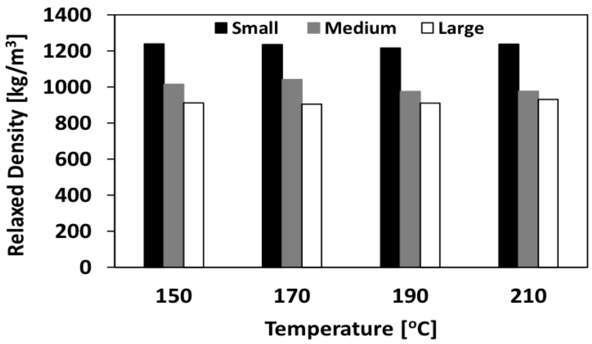


Figure 4 The variation of relaxed density of the briquette produced at different heating temperatures

Figure 5 also demonstrates that for the same heating temperature, the compressive strength increases when the smaller particles are used. This is due to the increase in inter-particle spaces were reduced. Overall, it can be said that all values of compressive strength are higher than the required minimum value for good resistance against mechanical disintegration that is 2.56 MPa [8]. Besides, the result of compressive strength is also similar with the result produced by a previous study [9].

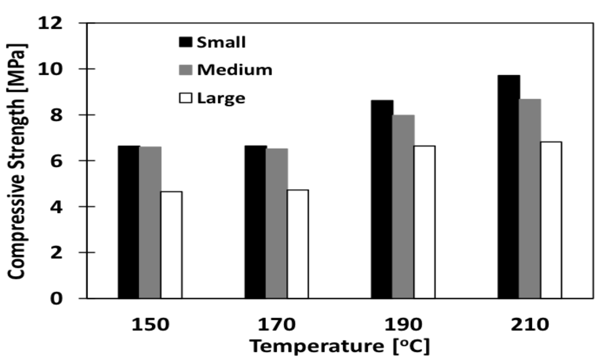


Figure 5 Variations of compressive strength of the briquette with heating temperatures

3.2 Combustion Characteristics of Briquettes

Figure 6 shows the calorific values of the briquettes produced. The figure shows that there is no specific trend in the resulting calorific value of the briquettes due to the heating temperatures, or to particle size. But for small and medium particle size, the calorific value is above the 17,500 kJ/kg required by DIN51731. For the large particle size, the calorific value went above the minimum value for heating temperature of 190° C and 210° C only.

In addition to calorific value, moisture and ash content are the important characteristics in evaluating the quality of briquettes produced. Figure 7 shows the moisture content of the briquettes with different particle size and produced under various heating temperatures.

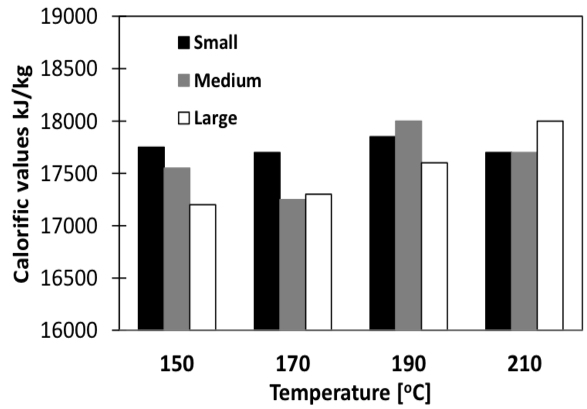


Figure 6 Calorific values of the briquettes produced

In this case, the proximate analysis was performed for briquettes produced under temperatures of 170° C, 190° C and 210° C. Figure 7 shows that the briquettes with small particle size is of good quality in terms of moisture content, which is below the standard DIN51731 for commercial briquette (<10 %). The briquettes made of medium and large size particles are found to have moisture contents that are slightly higher than the standard requirement that exceed the DIN standard by 1% for briquette made of medium sized particles cured at 170°C. When cured at higher temperatures, it complies with the standard moisture content requirement. For briquettes made from large size particles it requires curing at temperatures of 210°C to comply with this requirement. These values are still competitive compared to the moisture content of the widely used local briquette that is 12.5 % [8].

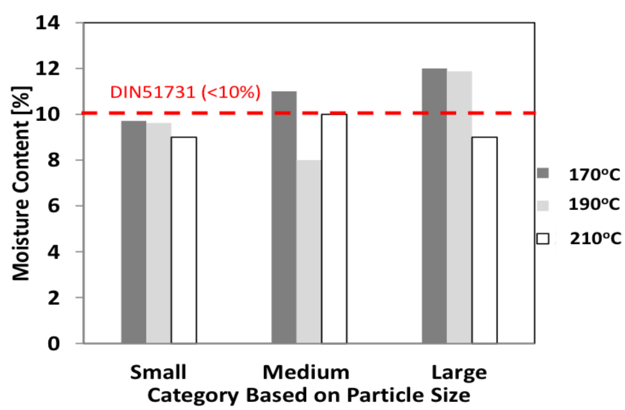


Figure 7 Moisture content of briquettes produced

Figure 8 shows the variation of ash content of briquettes with different particle size, produced under various heating temperatures. The figure shows that the values of ash content are within the range of 1 to 4 %, thus exceeded the limit as stated by DIN51731 (0.7 %). However, the values are still competitive if compared with the ash content of the widely used localbriquette (5.8 %) [8].

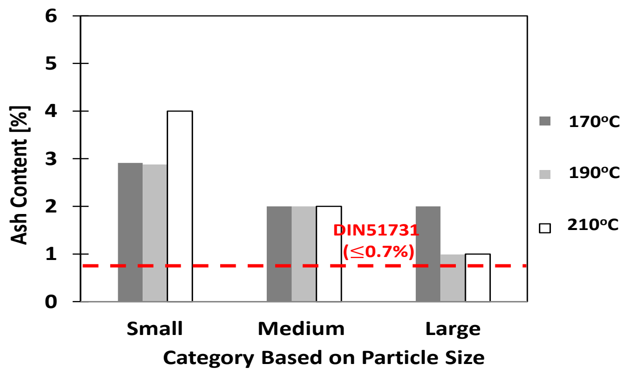


Figure 8 Ash content of briquettes produced

4.0 CONCLUSION

The binderless palm biomass briquettes were developed and tested for various EFB particles sizes. The relaxed density of the briquettes with smallest size particles gave higher mass density, thus lead to the higher energy density. Meanwhile, the highest compressive strength can be obtained when made from smaller particles and were densified at highest temperature (210° C).

Within the heating temperature range of the present study, it was found that the calorific values did not really depend on both particles size and even heating temperature. For the results of moisture and ash content, it can be said that the briquettes produced are competitive with the widely used local briquette even though some of the values exceeded the standard DIN51731 values.

Overall, it can be said that the best quality briquettes can be achieved when small particle size is used and the briquetting process is performed at the highest temperatures. This is because a briquette with highest mass density (thus highest energy density) and with highest compressive strength can be produced when such condition is applied which will produce briquettes with good combustion characteristics that fulfil the minimum requirement of DIN51731standard (for calorific value and moisture content) and will be competitive with the widely used local briquette (for ash content).

Acknowledgement

The authors acknowledge the Ministry of Education and Universiti Teknologi Malaysia for giving the cooperation and full support in this research. The authors wish to thank Research Management Centre (RMC) for the Potential Academic Staff Grant (Q.J130000.2724.01K44) from Ministry of Education and Universiti Teknologi Malaysia. The authors also acknowledge Kilang Sawit Felda Lok Heng, Kota Tinggi, Johor for giving its full cooperation in this research by supplying the raw materials (EFB fibres).

References

[1] Saad, M., Meghdad, B., Azadeh, S. and Zainal, S. 2014. Malaysia's Renewable Energy Policies and Programs with Green Aspects. *Renewable and Sustainable Energy Reviews*. 40: 497-504.

[2] Shafie, S.M., Mahlia, T.M., Masjuki, H.H. and Andriyana, A. 2011. Current Energy Usage and Sustainable Energy in Malaysia: A Review. *Renewable and Sustainable Energy Reviews*. 15(9): 4370-4377.

[3] Ronald, Z. 2013. Opportunities and Challenges in the Development of a Viable Malaysia Palm Oil Biomass Industry. *Journal of Oil Palm & The Environment*. 4: 41-46.

[4] Aljuboori, A.H.R. 2013. Oil Palm Biomass Residue in Malaysia: Availability and Sustainability. *International Journal of Biomass & Renewables*. 2(1): 13-18.

[5] Bhattacharya, S.C., Leon, M.A. and Rahman, M.M. 2002. A Study on Improved Biomass Briquetting. *Energy for Sustainable Development*. 6(2): 67-71.

[6] Cattaneo, D. 2003. Briquetting-A Forgotten Opportunity. *Wood Energy*. 2: 40-42.

[7] Tumuluru, J.S., T. Wright, C., Hess, J.R. and Kenney, K.L. 2011. A Review of Biomass Densification Systems to Develop Uniform Feedstock Commodities for Bioenergy Application. *Biofuels, Bioproducts & Biorefining*. 5: 683-707.

[8] Husain, Z., Zainal, Z. and Abdullah, Z. 2002. Briquetting of Palm Fibre and Shell from the Processing of Palm Nuts to Palm Oil. *Biomass and Bioenergy*. 22: 505-509.

[9] Nasrin, A.B., Ma, A.N., Choo, Y.M., Mohamad, S., Rohaya, M.H., Azali, A. and Zainal, Z. 2008. Oil Palm Biomass as Potential Substitution Raw Materials for Commercial Biomass Briquettes Production. *American Journal of Applied Sciences*. 5(3): 179-183.

[10] Nasrin, A.B., Ma, A.N., Choo, Y. M., Mohd. Basri, W., Joseph, L., Michael, S., Lim, W. S., Mohamad, S., Rohaya, M. H. and Astimar, A. A. 2010. Briquetting of Empty Fruit Bunch Fibre and Palm Shells using Piston Press Technology. *MPOB Information Series*. Malaysia: Malaysia Palm Oil Board.

[11] Faizal, H.M., Latiff, Z.A., Mazlan, A. W. and Darus A. N. 2010. Physical and Combustion Characteristics of Biomass Residues from Palm Oil Mills. *New Aspects of Fluid Mechanics, Heat Transfer and Environment Conference Proceedings*. 34-38.

[12] Chin, Y.S. and M. Shiraz, A. 2013. A Study of Biomass Fuel Briquettes from Oil Palm Mill Residues. *Asian Journal of Scientific Research*. 6(3): 537-545.

[13] Arzola, N., Gomez, A. and Rincon, S. 2014. Experimental Study of the Mechanical and Thermal Behavior of Pellets Produced from Oil Palm Biomass Blends. *Global NEST Journal*. 16(1): 179-187.

[14] Rabier, F., Temmerman, M., Bohm, T., Hartmann, H., Jensen, P.D., Rathbauer, J., Carrasco, J. and Fernandez, M. 2006. Particle Density Determination of Pellets and Briquettes. *Biomass and Bioenergy*. 30: 954-963.