Study of bio-briquette formulation from mixture palm oil empty fruit bunches and palm oil shells

M Amrullah¹, E Mardawati¹, R Kastaman¹ and S Suryaningsih²
¹ Department of Agroindustrial Technology, Faculty of Agroindustrial Technology, Universitas Padjadjaran, Jatinangor, Indonesia
² Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jatinangor, Indonesia

Email: musfiqamrullah16@gmail.com

Abstract. Bio-briquette is an alternative fuel derived from biomass. West Java has the potential of palm oil empty bunches (OPEFB) and palm oil shells biomass that can be used as bio-briquette raw material. The characteristics of each raw material affect the quality of the bio-briquettes produced. It is necessary to find a mixture of formulations between palm oil empty bunches (OPEFB) and palm oil shells that produce the highest quality bio-briquettes. This study aims to find a mixture of palm oil empty bunches and palm oil shell formulations that produce bio-briquettes with optimum quality based on calorific value. This study used an experimental method with descriptive analysis. Variation of mixed formulations consisted of 5 treatments with a concentration of 7% adhesive material, carbonization temperature OPEFB 350 °C and palm oil shell 500 °C, compression pressure 225 kg/cm², drying temperature 60 °C within 3 hours (2 replication). The observational parameters were the calorific value and proximate characteristics.

The results showed that carbon content increased in both raw materials after the carbonization process expected. The highest calorific value of 5,475 cal/g was produced by bio briquettes with a mixture ratio of oil palm empty bunches and oil palm shells of 25:75.

1. Introduction

West Java is the province with the most population in Indonesia, according to statistical data the population in West Java in 2015 amounted to 43.05 million people and is predicted in 2025 to reach 52.78 million. The increasing population in West Java has a direct impact on energy use. The final energy consumption of West Java province in 2015 reached 19.19 MTOE (Million tons oil equivalent). Fulfilling energy consumption of 94% still uses fossil energy, with a 35% oil, 23% coal, and 36% natural gas. While the use of new renewable energy (EBT) is only 6% of total energy consumption in West Java [1]. The West Java provincial government announced that by 2025 energy consumption needs could be met using renewable energy at least 17% of total energy consumption. To support these needs, one of the EBTs that can be developed is bio briquette. Biobriquette is a solid fuel that comes from biomass sources.

West Java has the potential of biomass for bio briquettes feedstock by utilizing the solid waste of the oil palm industry. In 2016, West Java had an oil palm plantation area of 14,305 ha which was able to produce 35,227 tons of CPO (Crude Palm Oil) [2]. In 1 ton processing of oil palm fresh fruit bunches, produced 23% CPO, 7% PKO, 23% oil palm empty fruit bunches and 9% oil palm shells [3], so that the total oil palm empty fruit bunches and oil palm shells produced by West Java reached 35 thousand
tons/year and 13 thousand tons/year. At present, the largest use of both solid waste is used as boiler fuel with a percentage of 63% palm oil shell [3] and 10% palm oil empty fruit bunches [4] as an energy source in palm oil processing plants. Thus, there is still an excess of oil palm empty fruit bunches and oil palm shell waste which can be utilized as bio briquettes feedstock. Oil palm empty fruit bunches containing carbon and palm shells are potential to be used as raw material for bio briquettes because they have a high carbon atom content. Oil palm empty bunches contain 46.62% [5] and oil palm shells 55.82% [6] carbon atoms. Based on the amount of availability of raw materials, oil palm empty fruit bunches have more availability compared to palm oil shells. However when viewed from the calorific value as one of the fuel quality requirements, the oil palm empty fruit bunch calorific value is lower than the oil palm shell calorific value, which is 4,264.54 cal/gram while the oil palm shell is 5,637.88 cal/gram [7]. This study aims to produce mixed bio briquettes of oil palm empty bunches with oil palm shells that have high heating value characteristics and have sufficient raw material available so that the sustainability aspects of the use of these products can be fulfilled.

2. Material and methods

2.1. Materials

The material used in this study is oil palm empty fruit bunches and oil palm shells which are palm oil processing wastes obtained from the palm oil mill of PT. Condong Garut. As for the adhesive using tapioca flour. The characteristics of empty bunches of oil palm and oil palm shells based on some literature are described in table 1:

| Content            | Palm oil empty fruit bunches | Palm oil shells |
|--------------------|------------------------------|----------------|
|                    | a    | b   | C    | d    | e    | f    |
| Carbon (%)         | 46.62| 48.78| 49.07| 53.78| 49.74| 55.82|
| Water Content (%)  | 5.18 | 8.75 | 7.95 | 5.73 | 11.00| 11.90|
| Volatile matter (%)| 82.58| 79.67| 83.86| 73.74| 67.20| 66.80|
| Ash Content (%)    | 3.45 | 3.02 | 5.36 | 2.21 | 2.10 | 3.40 |
| Fixed Carbon (%)   | 8.97 | 8.68 | 10.78| 18.37| 19.70| 17.90|

* Mohammed et al (2011) [5].  
* Ma and Yousof (2005) [8].  
* Yang et al (2006) [9].  
* Sukiran (2008) [10].  
* Abnisa et al (2011) [11].  
* Lee et al (2006) [6].

2.2. Methods

This study uses an experimental method with descriptive data analysis. Research begins by carrying out the carbonation process on oil palm and oil palm shell empty fruit bunches. The carbonation process is carried out to remove materials that are not useful in the combustion process and increase the fixed carbon content. The carbonation process of oil palm empty fruit bunches is regulated at 350 °C for 2 hours, while the palm oil shell is carried out at 450 °C for 2.5 hours. Determination of temperature and carbonation time is influenced by differences in the lignocellulose composition of the two ingredients [12]. Carbonated charcoal from both materials was carried out uniformly using a 20 mesh sieve. The formulation of mixed oil palm empty fruit bunches and oil palm shells consists of 5 different concentration treatments. The total mixture of raw materials for oil palm empty fruit bunches and oil palm shells for each bio briquettes is 80 grams. During the process of making briquettes from the five variations of treatment, 7% of the adhesive material will be added which is equal to 5.6 grams, the compression pressure is 225 kg/cm², and the drying temperature is 60 °C for 3 hours. After
homogenization between the three materials, forming was carried out using a cylindrical mold with dimensions of high 11 cm and diameter 4.23 cm. Composition 5 of the treatment is shown in table 2.

| Treatment | Oil Palm Empty Fruit Bunches (%) | Oil Palm Shell (%) | Adhesive Concentration (%) | Compression Pressure (kg/cm²) | Drying Time and Temperature |
|-----------|---------------------------------|-------------------|---------------------------|-------------------------------|----------------------------|
| 1         | 0                               | 100               | 7                         | 225                           | T = 60 °C t = 3 hr         |
| 2         | 25                              | 75                | 7                         | 225                           | T = 60 °C t = 3 hr         |
| 3         | 50                              | 50                | 7                         | 225                           | T = 60 °C t = 3 hr         |
| 4         | 75                              | 25                | 7                         | 225                           | T = 60 °C t = 3 hr         |
| 5         | 100                             | 0                 | 7                         | 225                           | T = 60 °C t = 3 hr         |

Each treatment is repeated twice. Test parameters in the form of calorific value and proximate analysis (moisture content, Volatile Matter, Ash Content, Fixed Carbon). Measurement of calorific value is carried out using a bomb calorimeter using the C 2000 IKA adiabatic calorimeter instrument. The formula for upper heating value (HHV) and lower calorific value (LHV) are as follows:

\[
LHV = \frac{(m \times C_p \times \Delta T)}{m \text { briket}}
\]  

\[
HHV = (T_2 - T_1 - T_{kp}) \times CV \left ( \frac{K_j}{K_g} \right )
\]

3. Result and discussion

3.1. Carbonized charcoal yield

In the carbonation process, thermochemical decomposition occurs in both materials into products with smaller molecules in the form of solids, liquids, and gases. The carbonation process carried out in this study uses the condition of slow pyrolysis. This is done to maintain the expected result in the form of carbon charcoal. The yield of the pyrolysis results is presented in table 3.

| Material                  | Initial Mass (kg) | Final Mass (kg) | Yield (%) |
|---------------------------|-------------------|-----------------|-----------|
| Oil palm empty fruit bunched | 4.5               | 1.5             | 33        |
| Oil palm shell            | 8.5               | 3.9             | 46        |

Yield of oil palm empty bunches produced from the pyrolysis process is 33% and yield of palm oil shells is 46%. The amount of yield produced from the pyrolysis process depends on the characteristics of the material and the temperature of the pyrolysis. Material decomposition occurs at 220 °C, while the process of forming charcoal starts at 320 °C [13]. The peak temperature of pyrolysis in this study reached 350 °C. More lignin amounts in oil palm shells cause the rate of warming to be slower than that of oil palm empty fruit bunches, which causes the percentage of charcoal produced to be higher [14]. The texture of raw materials for oil palm empty fruit bunches and oil palm shells before and after the carbonization process can be shown in figure 1.
3.2. Proximate characteristics of carbonized charcoal

Charcoal characteristics from carbonation results were obtained from the proximate analysis carried out at the ESDM Mineral and Coal Technology Laboratory. The parameters of the analysis consisted of the content of moisture content, Volatile Matter, Ash Content, and Fixed Carbon. The Fixed Carbon amount contained in the material is influenced by the other three parameters, the higher the fixed carbon, the lower the content of water, volatile matter, and ash content [12]. The criteria for materials as fuel are expected to have a high fixed carbon content. Data from the proximate analysis are shown in Table 4.

| Content            | Oil palm empty fruit buches | Palm oil shell |
|--------------------|----------------------------|---------------|
| Water content (%)  | 9.23                       | 4.94          |
| Volatile Matter (%)| 16.57                      | 32.84         |
| Ash Content (%)    | 23.34                      | 5.71          |
| Fixed Carbon (%)   | 50.86                      | 56.51         |

Based on proximate analysis results in Table 4, it is known that oil palm empty fruit bunches have a higher water content and ash content compared to oil palm shells. In the process of combustion of solid fuels, the substances used in the process are volatile matter and fixed carbon, while ash content is a substance that can not be burned so it is not used in the process of combustion of solid fuels. Materials that contain high volatile matter and fixed carbon are good ingredients for use as fuel. Based on the results of the analysis, it is known that oil palm shells have higher volatile matter and fixed carbon content compared to oil palm empty fruit bunches, namely 32.84% fixed carbon and ash content 56.51%.

3.3. Bio briquette

Bio briquette making is done by mixing oil palm empty bunches, oil palm shells, and tapioca adhesive materials. The total mixture of raw materials for oil palm empty fruit bunches and oil palm shells for each bio briquettes is 80 grams. The concentration of tapioca adhesive which is added is 7% of the total weight of the raw material which is equal to 5.6 grams. After homogenization between the three materials, forming was carried out using a cylindrical mold with dimensions of high 11 cm and diameter 4.23 cm. The pressure in the forming process given is 225 kg/cm². Bio briquette produced from each treatment is shown in Figure 2.
3.4. **Biobriquette calorific value analysis**

Analysis of calorific value was carried out using the C 2000 IKA adiabatic calorimeter instrument. In this study, the mass of samples tested from each bio briquette was set at 1.474 grams. The heating test was carried out twice for each treatment. The results of the analysis of calorific values are shown in Table 5.

**Table 5.** Calorific value of biobriquette from mixture OPEFB and oil palm shell.

| Treatment | Ratio | Average Calorific Value (cal/gram) |
|-----------|-------|-----------------------------------|
|           | Oil palm empty fruit bunches (%) | Oil palm shell (%) | Tapioca adhesive (%) |                               |
| 1         | 0     | 100                               | 7                   | 5,227                           |
| 2         | 25    | 75                                | 7                   | 5,475                           |
| 3         | 50    | 50                                | 7                   | 5,156                           |
| 4         | 75    | 25                                | 7                   | 4,630                           |
| 5         | 100   | 0                                 | 7                   | 5,263                           |

Table 5 shows the average calorific value of each ratio of material mixtures between oil palm empty fruit bunches and oil palm shells. Based on the test results carried out the highest calorific value was produced from the ratio of oil palm empty fruit bunches with oil palm shells 25:75. The calorific value generated from this ratio reaches 5,475 cal/gram. While the lowest calorific value was generated from the mixture ratio between oil palm empty fruit bunches and palm oil shells 75:25 with the resulting heating value of 4,630 cal/gram. The calorific value generated from the ratio of mixed oil palm empty fruit bunches with oil palm shells 25:75 has complied with Indonesian National Standard (SNI) No.1/6235/2000 which is only 5,000 cal/gram.

4. **Conclusion**

The carbonation process is proven to increase the level of fixed carbon in oil palm shell material and oil palm empty bunches. The volatile matter and fixed carbon content of oil palm shell charcoal are higher than that of oil palm empty fruit bunches. The highest calorific value of 5,475 cal/gram was produced by bio briquettes with a mixture ratio of oil palm empty bunches and oil palm shells of 25:75.
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