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Biobriquette: A Mixture of Palm Kernel Shell and Coconut Shell, An Indonesian Study Case

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ABSTRACT

Nowadays, the world energy demand is very high while the fossil energy source decreases continuously. Biobriquette presents as environmentally friendly alternative energy from biomass. One of the potential resources of biomass for biobriquette is agricultural waste, such as palm kernel shells and coconut shells. The availability of these wastes is abundant but has not been utilized optimally. Thus, biobriquette production can solve two problems at once, namely energy and environmental problems. The objective of this study is to determine the optimum mass ratio of palm kernel shell and coconut shell which has the quality in terms of calorific value, and proximate characteristics (moisture content, ash content, volatile substances, and fixed carbon) qualified the SNI (Indonesia National Standard) specification (No. 01-6235-2000) for biobriquette. The mixing variations of the coconut shell and palm kernel were 100: 0, 75: 25, 50: 50, 25: 75, and 0: 100. The results of the quality analysis have shown that all samples have met all SNI criteria and the sample with 100% kernel composition was the best composition.

Key words : *Palm Kernel Shell, Coconut shell, Biobriquette, Alternative energy*

Introduction

Petroleum is a well-known source of energy widely used as the main fuel in Indonesia. This implies petroleum demand is always high but the supply is limited since it is one of the non-renewable fossil fuels. The depletion of this fuel will greatly affect social, economic, and environmental goals achievement for sustainable development (Sa'adah *et al.*, 2017).

In 2018, Petroleum reserves have decreased from 8,21 billion barrels reserved in the year 2008 to approximately 7,5 billion barrels (Indonesia Directorate General of Oil and Gas, 2018). It is necessary for Indonesia to immediately start pushing the people to use energy more efficiently in every aspect of life. As stated in Indonesia Government Regulation No. 5 in 2006, the government has decided to reduce 30% of the petroleum current usage by the year 2025.

Indonesia's energy needs focus on petroleum fuel with its currently decreasing reserves, on the other hand, renewable biomass energy exists with its quality that is no less compared to petroleum fuel. The use of alternative energy like biomass has not been fully optimized by its user, even though it has become crucial in various regions in the world, specifically in Indonesia which produces many of the world's largest agricultural commodities (Petir *et al.*, 2018).

The alternative source of energy that is recently being researched and developed is biomass fuel from agricultural waste. Biomass from agricultural waste will become a useless material if it doesn't receive further treatment. Otherwise, it can be utilized as a source of alternative energy, especially by converting it into biodiesel, biofuel, bioethanol, biogas, and biobriquette (Ministry of Agriculture and Forestry of Indonesia, 2008).

Alternative energy can be obtained from simple appropriate technology suitable for rural areas such as briquette, by utilizing agricultural waste such as rice husks, sawdust, coconut shell, and palm kernel shell. One of the methods for producing biobriquette is carbonization. In this method, the biomass material is heated at a relatively high temperature in the range of 150 - 750 °C with a limited amount of oxygen to produce charcoal for approximately 2 hours depending on the characteristics of the raw material (Brownsort, 2009).

The process of making biobriquette requires adhesive to hold carbonized biomass together. The commonly used adhesive material is cassava starch which is often used to make food and adhesives. The starch content in tapioca flour is quite high, which is 69,58%, therefore it is suitable to use as an adhesive material. (Muin *et al.*, 2017). Starch is composed of two types of carbohydrates, known as amylose and amylopectin, in different compositions. Amylose tends to be strong while amylopectin tends to be sticky. Other compositions in starch can be in the form of protein and fat. Normally, starch contains 15-30% amylose, 70-85% amylopectin, and 5-10% in-between materials. (Banks *et al., 1973)*.

In Indonesia, it is estimated that 17,128,595 tonnes of coconut and 245,633,087 tonnes of palm oil are produced annually (FAO, 2019). There are vast tonnages of palm kernel shell and coconut shell wastes dumped on sites and around many of the palm oil and commodities made from coconut areas in the country (Haryanti *et al*, 2014; Maryono *et al.,* 2013). Palm kernel shell and coconut shell as one of the by-products accruing from oil palm and commodities made from coconut processing can be suitably converted to renewable energy to meet the high demand for petroleum. The mixture of palm kernel shell and coconut shell for biobriquette production has not been adequately investigated in Indonesia, therefore, this study look at the suitability of using these resources to produce biobriquette which has the quality in terms of calorific value, and proximate characteristics (moisture content, ash content, volatile substances, and fixed carbon value) qualified the SNI specification (No. 01-6235-2000) for biobriquette.

Materials and Methods

Tools and Materials

Materials used are palm kernel, coconut shell, cassava starch, and water. While the equipment required was carbonation drum, bomb calorimeter, analytical weighing, milling machine, evaporating dish, mesh, oven, desiccator, pressing mill, briquette cast, and silica gel.

Biobriquette Preparation

Pre-treatment

Before entering the carbonization process, drying and reducing the size of the palm kernel and coconut shell was conducted. Drying means reducing the water content contained in the palm kernels. Reducing the size means expanding the surface of the oil palm kernel for a shorter time of the carbonization process.

Carbonization

The carbonization stage should be done by putting the palm kernel and coconut shell into the carbonization drum. This carbonization process was conducted at a temperature of 450 °C for 2 hours. After the carbonization process is completed, the charcoal is removed and separated from the ashes, and then cooled.

The Making of Biobriquette

Charcoal that has been reduced in size is filtered using a 60 mesh sieve. The sifted charcoal is then mixed with tapioca adhesive. Experiments were done by using 5 variations in the composition of raw materials with adhesive as much as 6% and the ratio of palm kernel charcoal and coconut shell charcoal are 100: 0, 75: 25, 50: 50, 25: 75, and 0: 100. The next step is to press the briquette. The briquette dough is put into a mold with a diameter of 2.5 cm, a height of 5 cm, then it is pressed using a manual hydraulic machine with a pressure of 150 to 500 kg / cm^2. The molded briquettes will then be dried in the sun or the oven.

Raw Materials Observation Criteria

Observation of the raw material for oil palm kernels and coconut shells includes moisture content and particle size. The moisture content of the raw material greatly affects the calorific value or the resulting heat value of biobriquette. The high water content will cause a decrease in calorific value.

Biobriquette Testing Procedure

Calorific Value Test

The calorific value was analyzed with an oxygen automatic bomb calorimeter for water-contained biobriquette. The calorific value was calculated to determine the temperature rise and heat capacity in line with the standard procedure of the ASTM D5865 2013 standard as follows:

$$Calorific\ value = \left(\frac{(T2 - T1).c}{m}\right)\ \text{cal/g} \quad ..\ (1)$$

Where,

c = 2575,6 (Cal/°C) is the statute of each material burned to raise 1°C of water temperature and the calorimeter device

T_1 = initial temperature during the test (°C)

T_2 = final temperature during the test (°C)

Moisture Content Test

It is defined as the ratio of the moisture to the dry weight of the solid fuel. One gram of the biobriquette sample was weighed in a porcelain cup with a known weight, then it was put in an oven at a temperature of 105-110 °C for about 1 hour until the weight is constant. The moisture content was calculated from the mass lost after heating the biobriquette using ASTM D3173 2017 standards as follows:

$$K_A = \left(\frac{X_1 - X_2}{X1}\right).100\% \quad ..\ (2)$$

Where :

K_A = Moisture content (%)

X_1 = weight of the sample before drying (g)

X_2 = weight of the sample after drying (g)

Ash Content Test

Ash is a constituent obtained from solid heating fuel to a constant weight. One gram of the biobriquette sample was weighed then it was put in the furnace until the temperature reach 550 °C for about 4 hours. Then, the sample was cooled in a desiccator to normal temperature. The value is calculated under the ASTM D-3174 2012 standard formula by the follows equation:

$$K_{Ab} = \left(\frac{D}{B}\right).100\% \quad ..\ (3)$$

Where :

K_{Ab} = Ash Content (%)

D = weight of the ash (gram)

B = weight of the sample (gram)

Volatile Matter Content Test

The more volatile content in biobriquette, the easier it combusts. One gram of the biobriquette sample was weighed in a porcelain cup with a known weight, then it was put in the oven until the weight is constant. After that, the biobriquette was put in the furnace until the temperature reaches 900 °C for 7 minutes without direct contact with air. The amount of volatile is calculated using ASTM D3175 2018 standard with the following formula:

$$PVM = \left(\frac{B - C}{B}\right).100\% \quad ..\ (4)$$

Where :

PVM = Volatile Matter Content (%)

B = weight of the sample after oven (g)

C = weight of the sample after furnace (g)

Fixed carbon value

The higher value of fixed carbon in the briquette leads to enhancing the calorific value. This value test was calculated by subtracting the summation of the volatile decomposition and ash content from 100.

Fixed Carbon(%) = 100 – (water content + volatile matter content + ash content)

Combustion Test

There were two combustion tests conducted in this study. The first was to boil 100 ml of water using 4 pieces of biobriquette by turning it on simultaneously and counting the time from the first point of the fire to boiling water. The second combustion test was to calculate the burning time of the biobriquette by calculating the time spent to burn the biobriquette from the first point of the fire until the biobriquette run out.

Results

Carbonization Results

The carbonization process in this study was done separately, palm shell was processed with flat pan and Clin drum for coconut shell (Fig. 1). The difference in the hardness of the raw materials causes the carbonization process to be carried out using different containers to make the combustion time efficient. The carbonization process of palm kernel shell and coconut shell was carried out for 2 hours at 450 ^{o}C.

Fig. 1. Carbonization Process at the Bandung Ceramic Hall

This carbonization process removed several substances in raw materials, such as impurities, water, and other substances in raw materials that evaporate at the carbonization temperature. The yield produced in this carbonization process is a carbon (**Fig. 2**). The yield in the production process is important in the process of making biobriquettes, because the greater the yield produced, the higher the carbon value contained in the material. The yield resulting from this carbonization process is as follows

Fig. 2. Carbonization Process Result

Biobriquette's Characteristics Production Process

The first process in making biobriquettes is size reduction using an automatic chopper or milling. The chopper or grinder used does not have a definite mesh setting, so it is necessary to sift again to get the desired result. The sifting process is done manually using a 60 mesh sieve. This sifting process aims to obtain the same particle size.

Table 1. Yield Analysis Table

No	Material	Yield (%)	σ
1	Palm Kernel Shell	76%	0,042426
2	Palm Shell	70%	

Fig. 3. Sifted Charcoal

The next process is mixing the sifted charcoal with adhesive with a composition of 6% of the total composition. The ratio of starch adhesive with water used is 1: 10. The next process was biobriquette molding process. This biobriquette molding process used a manual printing press with a compressive power of 1500 psi or 105 kilograms. This compressive power was used because the density and texture of the biobriquette will be soft and crushed if the compressive power used is lower, on the other hand, if the compressive power is too high, the resulting biobriquette will be harder and harder to burn.

Fig. 4. Biobriquette Molding Process

The next step after biobriquette molding process is the drying process. The process was done by drying it under the sun for 10-12 hours. This drying process aims to reduce the water content contained in the biobriquette. The drying of the biobriquette was done until the texture of the biobriquette got dry, the characteristic of the dryness of the biobriquette is that when it is held it does not produce black marks on the hands.

Quality Analysis Based on SNI Standard

Calorific Value

The calorific value test was done by using the Adiabatic Calorimeter bomb - IKA 2000. According to the Indonesian National Standard 01-6235-2000, the calorific value of biobriquettes must have a minimum value of 5000 cal/g. The results shown from this biobriquette study indicate that the biobriquette with 100% palm kernel shell composition has the highest calorific value with a value of 6985 cal/g. Biobriquette with 100% coconut shell composition has the lowest calorific value with a value of 6869 cal/g. All variations of the biobriquette composition made have reached a calorific value above SNI 01-6235-2000. The calorific value obtained from all sample variants is higher than that one of Nigerian Coals which were reported to have calorific values of 4562 to 5398 cal/g (Chukwu *et al.,* 2016).

Moisture Content

Water content is the content contained in a material. Water is one of the important parameters that determine the quality of biobriquette. The low water content will make it easier for the briquettes to ignite and will not generate a lot of smoke in the burners.

Requirements for the quality of biobriquette moisture content are based on SNI 01-6235-2000, which requires a water content value with a maximum limit of 8%. While the procedure itself was according to the ASTM D-3173 2017. The results from the analysis of water content in this study have shown that all the composition variations acquired moisture content value below 8% which means that all of them have met the SNI 01-6235-2000 standard. The results of the water content test showed that the biobriquette with 100% coconut shell composition has the lowest water content of 2.26%, and the biobriquette with the highest water content is the 100% palm kernel shell variation composition biobriquette with 4.20%. Table 2 shows that more composition of palm kernel shell leads to higher moisture contents but in general all sample variations were below the SNI standard for biobriquette (8 wt%).

Ash Content

Requirements for the quality of biobriquette moisture content are based on SNI 01-6235-2000, which requires a water content value with a maximum limit of 8%. The ash content test was conducted as per ASTM D-3174 2012. Ash is the waste material from the burning processes. The results of the ash content test showed that the biobriquette with 100% coconut shell composition had the lowest ash content with 5.31%, biobriquette with the highest ash content is the 100% palm kernel shell variation composition biobriquette with a value of 5.98%.

Volatile Matter Content

The amount of volatile matter content was also conducted according to ASTM D-3175 2018. Requirements for the quality of biobriquette volatile matter content are based on SNI 01-6235-2000, which requires a volatile matter content value with a

Table 2. Analysis Result Data

	TK	TK75	TK50	TK25	CKS	SNI 01-6235-2000 threshold	Equivalent ASTM Procedure
Calorific Value (kal/gr)	6,898	6,920	6,941	6,959	6,985	Min 5500 kal/gr	ASTM D5865 2013
Ash Content	5.31±0,23%	5.50±0.43%	5.68±0.03%	5.76±0.36%	5.98±0.06%	Max 8%	ASTMD3174 2012
Moisture Content	2.26±0,28%	2.59±0.16%	2.91±0.23%	3.88±1.53%	4.20±3.30%	Max 8%	ASTM D-3173 2017
Fixed Carbon	88.06%	89.46%	89.07%	88.34%	88.42%	Min 77%	ASTM D5865 2013
Volatile Matter	4.37±0.90%	2.46±0.67%	2.34±1.01%	2.01±1.25%	1.39±0.48%	Max 15%	ASTM D3175 2018

maximum limit of 15%. The result from the analysis of volatile matter content in this study has shown that all the composition variations acquired volatile matter content values below 8% which means that all of them have met the SNI 01-6235-2000 standard. The results of the volatile matter content test have also shown that the biobriquette with 100% coconut shell composition has the highest volatile matter content of 4,37%, and the biobriquette with the lowest volatile matter content is the 100% palm kernel shell variation composition biobriquette with a value of 1.39%.

Fixed Carbon Value Test

The calculation and procedure were also based on ASTM D-5865 2013. The result from the analysis of carbon value in this study has shown that the biobriquette composed of 75% coconut shell and 25% palm kernel shell has the highest fixed carbon value which is 89,46% and biobriquette with the lowest fixed carbon value is the biobriquette with 100% coconut shell variation composition with a value of 88,06%.

Combustion Test

The combustion test showed that the sample with 100% kernel took 8 minutes and 27 seconds, the fastest sample to boil the 100 ml of water. Biobriquette requiring the longest time to boil the same amount of water is the one with the composition of 100% coconut shell. The time required was 9 minutes and 8 seconds.

Discussion

The quality of biobriquette is affected by moisture content, ash content, volatile substances, fixed carbon, and calorific value. Based on the results shown (Fig. 2), the color of the biobriquette from the entire composition of the biobriquette variations showed a solid black color, which means that the previously biobriquette raw material has completely become charcoal after going through the carbonization process. The results obtained in terms of the texture the biobriquette with more palm kernel shell composition produced a stronger and less fragile texture, while the biobriquette with more coconut shell composition produced a more fragile and crumbled texture. While, the results of the average weight calculation of the biobriquette have shown that the biobriquette sample with a 100% palm shell composition has a heavier weight, while the biobriquette with a 100% coconut shell composition has lighter weight.

The calorific value greatly determines the quality of the charcoal briquettes. The higher the calorific value of charcoal briquettes, the better the quality of charcoal briquettes produced because the high calorific value leads more efficient combustion thereby reducing the amount of biobriquette used (Shekhar, 2011). This study result showed that biobriquette from mixed coconut shell and palm kernel shell has a better quality than coal providing a highly potential source of renewable energy.

The biobriquette should have low moisture content because the calorific value, thermal efficiency, and burning rate will be low in the high moisture level condition (Carnaje *et al.,* 2018; Onukak *et al.,* 2017). This work result in moisture content generally below the SNI standard, which means that the composition investigated was a good fit for a biobriquette. The moisture content of biobriquette is influenced by the raw ingredient characteristic (Brozek, 2016). The moisture content of the dried palm kernel shell is 7.96% (Fuadi *et al.,* 2012), while the dried coconut shell's one is 5.88% (Rizal *et al.,* 2020).

The main component present in ash is a non-combustible mineral known as silica, which is left behind after the combustion process has ended (Glushankova *et al*., 2018). The presence of ash decreases the heating value (Onukak *et al*., 2017) so that the quality biobriquette with high ash contents is low (Carnaje *et al*., 2018). Based on the results of the analysis of the ash content in this study, all the composition variations acquired ash content values below 8%, which means that all of them have met the SNI 01-6235-2000 standard.

Biobriquette with high levels of volatile matter will produce high combustion smoke (Ifa, 2020). Volatile matter is gases released when coal or briquette is heated without air contact at 950 °C under specific conditions and it consists of short and long-chain aliphatic carbon atoms and aromatic hydrocarbon and some sulfur. Volatile matter is a key interest in assessing the reactivity and ignitability of coal or briquette (Ozbayoglu, 2018). The high content of volatile matter in the charcoal briquette causes more smoke when it is burnt (Maryono *et al.,* 2013). From this study, it is appreciated that the more coconut shell composition in bio briquette, the more volatile matter content. This study result is congruent with the study reported by Pane *et al.* (2015), the type of raw material greatly influences the level of volatile matter of biobriquette.

Fixed carbon is the carbon found in the materials that remain after the volatile matter is removed. It differs from the coal ultimate carbon content in that some carbon is lost in the volatile hydrocarbons (Ozbayoglu, 2018). The fixed carbon-to volatile ratio (fuel ratio) indicates the ease of ignition and combustion, but the heat content of the volatile matter is a more reliable guide to ignition (Chukwu *et al.*, 2016). The result from fixed carbon value variant analysis has shown that composition does not have a significant impact on the resulting fixed carbon value.

Conclusion

Biobriquette from palm kernel shells and coconut shells has met the quality requirements of SNI 01-6235-2000. It is necessary to carry out further tests related to mechanical tests as well as more specific biobriquette combustion. Based on the ANOVA test, the result has shown that all biobriquette samples that had significant differences were only volatile substances. The composition of the raw material and the biobriquette adhesive can be varied to produce better quality.

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