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Production of Bio Charcoal Briquettes Made from Coal and Palm Fronds

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ABSTRACT

Biomass from oil palm fronds has not been effectively utilized in Central Lampung, there is a need for alternative processing of palm oil fronds into more useful materials. One method of processing palm fronds is to create bio charcoal briquettes, which are used as an alternative fuel. The purpose of this research was to see how palm fronds and particle size of palm oil fronds affected the properties of bio charcoal briquettes. The factorial completely randomized design (CRD) was used in the research with one factor, namely the particle size of the oil palm fronds passing through the sieve with one treatment, namely 20 mesh. To produce 25 experimental units, the study used five treatments with five replications. The obtained material was then tested for LSD. The results revealed that palm fronds had no impact on briquette density, moisture content, compressive strength, shatter resistance index, or rate of burning. The particle size of palm leaves going through the 20 mesh sieve affects density, compressive strength, shatter resistance index, and burning rate significantly. The findings revealed the following features of bio charcoal briquettes: The moisture content is 5.17-6.89%, the heating value is 4372.42 - 5074.50 cal/g a density of 0.568-0.674 g/cm3, a compressive strength of 3.85 - 4.58 kg/cm2, a shatter resistance index of 12.58-17.19%, a burning rate of 1.40-1.47 gram/minute, and a bottom temperature of 287°C. (for 60 minutes and a mass of 200 grams).

1. Introduction

Indonesia is an agricultural country that has considerable agricultural potential, one of which is oil palm. Based on data from the Central Bureau of Statistics (2015) the area of oil palm plantations has increased every year. In 2011 the total area of oil palm land was 9,102,296 ha and in 2015 it reached 11,300,370 ha, resulting in an increase of 24.15%. The volume of waste generated is very large, especially the waste of palm fronds that comes from clearing trees. Based on estimates, oil palm plants can produce 18-25 fronds/tree/year (Lubis, 1992) or around 10 dry tons/ha/year (Ginting & Elisabeth, 1997). According to a statement by Devendra (1990), a pruning cycle is every 14 days, each pruning is about 3 leaf sheaths with a weight of 1 frond reaching 10 kg. One ha of land is planted with around 148 trees so that every 14 days it will produce ±4,440 kg or 8,880 kg/month/ha. The dry matter content of the palm fronds is 35% so that the total dry matter of the palm fronds/month/ha is 3,108 kg.

Oil palm plantations produce residue or waste that has not been utilized optimally. One of the wastes obtained from oil palm plantations includes empty fruit bunches, shells, and palm fronds. Oil palm frond waste is often ignored while the population of oil palm fronds is very large. One of the most appropriate ways to utilize energy sources from biomass is by making biomass a raw material for making briquettes (Caroko et al., 2015).

Charcoal briquettes are carbon-containing solid fuels with a high calorific value and a lengthy burn time. Bio charcoal is charcoal produced by burning dry biomass without the use of oxygen. (pyrolysis). Briquettes are charcoal made by burning dry biomass with a small amount of oxygen. (carbonization). Biomass is organic material produced from both plant and animal living bodies. Leaves, grass, twigs, weeds, farming and livestock refuse, and peat are all examples of biomass (Johannes, 1991).

Bio-charcoal briquettes have several advantages compared to ordinary (conventional) charcoal, including the heat generated by bio-charcoal briquettes is relatively higher compared to ordinary wood and the calorific value can reach 5,000 calories, does not cause smoke or odor, does not need to be fanned or given air.

Oil palm fronds are a product of solid waste that many farmers use as animal feed or as compost because they contain high levels of fiber and carbohydrates. The simple process carried out shows that the better the raw materials used, the better the quality of the briquettes produced, especially in the rate of burning of the briquettes. Therefore, to obtain good quality coal briquettes, it is necessary to conduct research on the manufacture of briquettes with the main raw materials, namely a mixture of coal and palm oil which is expected to accelerate the rate of combustion. The research was conducted with the aim of utilizing palm oil fronds and coal waste as the basis for making bio-charcoal briquettes and analyzing the physical properties of bio-briquettes.

2. Materials and Methods

2.1 Research Sites

The research was carried out from July to September 2020 at the Agricultural Machine Tool Power Laboratory and the Water Resources and Land Engineering Laboratory, Department of Agricultural Engineering, Faculty of Agriculture, University of Lampung. The raw materials used in this study were palm fronds, tapioca adhesive, and coal. The study was conducted using a completely randomized factorial design (CRFD) with three treatments and five replications. The treatment given is presented in Table 1.

Table 1. Percentage of bio charcoal briquettes material

Treatment	Adhesive	Coal	Palm fronds
P1	10%	80%	10%
P2	10%	60%	30%
P3	10%	40%	50%
P4	10%	20%	70%
P5	10%	10%	80%

2.2 The process of making bio charcoal briquettes

A rabakong tool, which creates chopped fronds, is used to reduce the size of the palm fronds. Pounding coal with a pestle and mill reduces its size. The palm fronds are sun-dried until the moisture level is 8-12%. This is done to reduce the amount of water in the palm leaves. The palm frond particles were sieved through a Tyler Meinzer II sieve with a mesh size of 20. The coal was sieved through a 25 mesh Tyler Meinzer II sieve. By putting the briquette mixture into the printing chamber, the ready-made mixture of palm frond particles, coal, and tapioca adhesive is printed using a screw press briquette. The mold employed is a solid cylinder with a circumference of 5 cm and a height of 7 cm.

Figure 1. Screw press briquette

The process of drying the moisture content is a process to remove the moisture content in briquettes. This is because in the process of drying the briquettes there is a reduction in mass because the newly printed briquettes still contain a lot of water, so they need to be dried so that they do not interfere when testing the calorific value and burning rate. Testing the characteristics of bio charcoal briquettes refers to the National Standardization Agency (2000). Parameters of bio charcoal briquettes that meet the standards are moisture content, calorific value, density, burning rate, shatter resistance index, compressive strength and bottom temperature of the pan.

2.3 Briquettes moisture content

Testing the moisture content to determine the hygroscopic properties of briquettes (Triono, 2007). Measurement of moisture content was carried out on 25 samples of briquettes. Calculation of moisture content refers to ASTM (2000)

$$M\ (\%) = \frac{W_a - W_b}{W_a} x\ 100\% \quad (1)$$

M as moisture content (%), W_a as initial weight (g) and W_b as final weight (g)

2.4 Calorific value

The calorific value test is carried out to determine the amount of heat obtained from burning a certain amount of fuel (Sudiro, 2015). Calorific value measurement using a bomb calorimeter.

2.5 Density

Briquette density can be determined by measuring and determining the mass of briquettes for each unit volume of briquettes produced. Density is calculated by the following equation (Liu et al., 2013):

$$\text{Density } (\rho) = \frac{m}{V} \quad \text{...(3)}$$

$$\text{Volume (V)} = \frac{\pi}{4} d^2 l \quad \text{...(4)}$$

ρ as Density(g/cm^3), m as Mass (g), V as Briquette Volume (cm^3), l as Length (cm) and d as Diameter (cm) with π = 3.14.

2.6 Burn rate

Test the burning rate to determine the speed of the briquettes from smoldering to ashes. According to Sudiro (2015) the combustion characteristics of briquettes, which are used as a benchmark for making fuel that is efficient in its use. The equation used to determine the rate of combustion is (Onuegbu et al., 2010):

$$\text{Burn rate } (L_p) = \frac{M}{t} \quad \text{...(2)}$$

L_p as Burning rate (g/minute), M as Sample weight (gr) and t as Burning time (minutes).

2.7 Shatter Resistance Index

The shatter resistance index test is carried out by dropping the briquettes from a height of 2 meters onto a hard surface.

$$\text{SRI} = \left(1 - \left(\frac{m_a - m_b}{m_a}\right)\right) \times 100\% \quad \text{...(5)}$$

SRI as Shatter Resistance Index (%), m_a as initial weight (g) m_b as final weight (g)

2.8 Compressive strength

Testing the compressive strength by applying a load to the briquettes, until the briquettes crack and break.

$$\text{Compressive strength (P)} = \frac{F}{A} \quad \text{...(6)}$$

P as pressure strength (Kg/cm^2), F as maximum force (Kg) and A as surface area (cm^2).

2.9 Pan bottom temperature

Measuring the bottom temperature of the pot using a thermocouple on 6 samples of briquettes. The time interval for measuring the bottom temperature of the pot is 2 minutes until the briquettes are extinguished, the time measurement is carried out using a stopwatch.

2.10 Data analysis

The results of the briquettes characteristic test consist of moisture content, calorific value, burning rate, density, shatter resistance index, compressive strength, and bottom temperature of the pan. The process of data analysis was carried out using variance (ANOVA) and continued with the LSD (Smallest Significant Difference) test with a level of α = 0.05.

3. Results and Discussions

3.1 Bio charcoal briquettes product

The raw material was sieved using Tyler Meinzer II size 20 mesh on palm fronds. Each dough ratio used was as follows: 50% (360 grams) of palm frond particles, 40% (240 grams) of coal, and 10% (90 grams) of tapioca adhesive with a total of 100% (690 grams). Bio charcoal briquettes made without carbonization with a dry weight of 71 grams, 9.4 cm long and 4.80 cm in diameter.

Figure 2. Bio charcoal briquettes

3.2 Bio charcoal briquettes moisture content

Testing the moisture content of the bio charcoal briquettes aims to determine the degree of dryness, or the moisture content contained in the bio charcoal briquettes. A graph of the value of moisture content is presented in Figure 3.

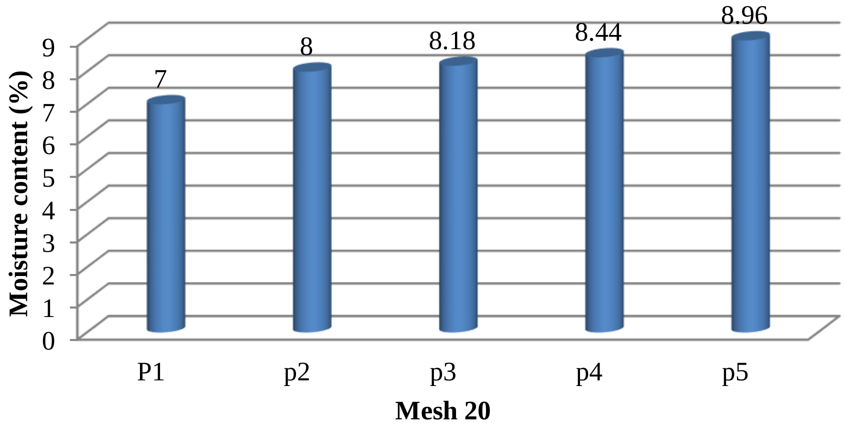

Figure 3. Moisture content of bio charcoal briquettes

Figure 3 depicts the findings of the P5 treatment with the highest average moisture content (20 mesh cassava stem particle size) and a moisture content of 8.89%. With a moisture content of 6.94%, the P1 procedure (cassava stem particle size 20 mesh) has the lowest moisture content. The moisture content findings indicate that the smaller the particle size of the palm fronds, the higher the moisture content, and the larger the particle size of the palm fronds, the lower the moisture content. Sudiro (2014) claims that larger particle sizes absorb less water than smaller particle sizes, which may be due to partial drying. Briquettes' moisture level tends to rise as particle size decreases. The variation in the size of the pores between the particles capable of storing water allows for this. The higher the moisture content of the briquettes, the lower the quality, which reduces the fuel value or makes it challenging to burn. The higher the water level, the better the briquettes. This is due to the fact that the heat supplied is first used to evaporate the water contained in the briquettes (Iriany et al., 2017).

3.3 Calorific value

The purpose of testing the calorific value of bio charcoal briquettes is to acquire information on the amount of heat energy that can be released by a fuel during a reaction or combustion process (Almu et al., 2015). Figure 4 depicts a graph of the typical calorific value of bio charcoal briquettes.

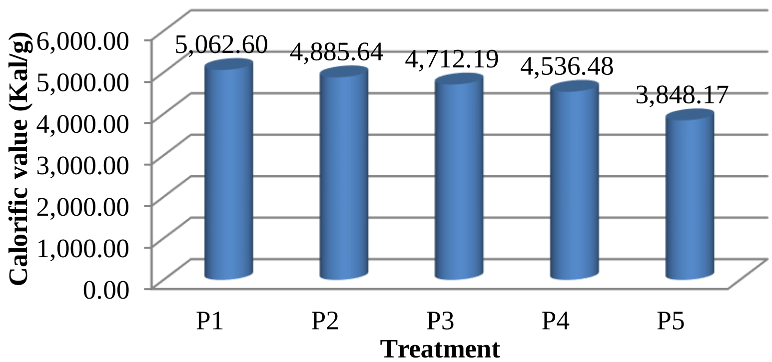

Figure 4. Calorific value of bio charcoal briquettes.

Based on Figure 4, it is known that the lowest average calorific value of briquettes is 4,281.37cal/g in the P5 treatment of briquettes samples with (oil palm fronds at a cassava stem particle size of 20 mesh). The highest average calorific value was 5,014.80cal/g in the P1 treatment of the briquette sample (palm fronds with a particle size of 20 mesh). According to Triono (2007), the specific gravity of the raw elements used to make briquettes influences the calorific value. According to Damanhuri (2010), determining the calorific value of mixed ingredients with a bomb calorimeter is highly inaccurate. This occurs because very few samples are used for calorific value measurement, making it impossible to represent or establish the mixture's real composition.

3.4 Density

Testing the density of bio charcoal briquettes aims to prevent the fragility of the briquettes. The results of variance at the α = 0.05 level indicated that the particle size of the oil palm fronds had a significant effect on density. The results of the Anova test, the particle size of the palm fronds against density, are presented in Table 2.

Table 2. The results of the density ANOVA test of bio charcoal briquettes.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > f
Model	4	0.04606400	0.01151600	1.04	0.4103
Error	20	0.22100000	0.01105000		
Corrected Total	24	0.26706400			

The ANOVA test results in Table 2 indicate that the treatment of oil palm fronds has a significant impact on the density test on bio charcoal briquettes with pr>f 0.41 or less than = 0.05. Figure 4 depicts a density histogram of bio charcoal briquettes.

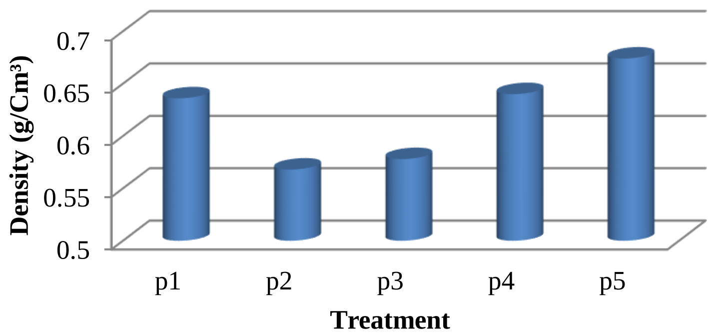

Figure 4. Density test value

In Figure 4 it is known that the highest average density results in the P_5 treatment of 0.674 g/cm³. The lowest density in the P_5 condition was 0.568 g/cm3. The density findings indicate that the particle size of the briquettes has a significant impact on their density value; the larger the particle size of the cassava stalks, the lower the density, and the smaller the particle size of the palm fronds, the higher the density. Larger particle diameters, according to Iriany et al. (2017), result in a lot of pore space between particles. Pore space between particles is reduced when particle sizes are tiny. When creating briquettes, particle size and homogeneity influence the density. Bio charcoal briquettes with uniform particle size will create higher density and compressive strength (Rio, 2015).

3.5 Compressive strength

Testing the compressive strength of the briquettes by applying a load to the bio charcoal briquettes until the briquettes crack or break. According to Iriany et al. (2017), compressive strength measures a briquette's resilience to external pressure that causes the briquette to crack. This demonstrates that the higher the compressive strength number, the longer the briquettes will last. The variance results revealed that the particle size of the palm fronds had a significant impact on the compressive strength of the bio-charcoal briquettes at the level of = 0.05. Table 3 shows the findings of the anova test for the size of cassava stem particles on the compressive strength of bio charcoal briquettes.

Table 3. ANOVA test results for the compressive strength of bio charcoal briquettes

Source	DF	Sum of Squares	Mean Square	F Value	Pr > f
Model	4	1.87812000	0.46953000	0.88	0.4915
Error	20	10.62828000	0.53141400		
Corrected Total	24	12.50640000			

In Table 3 the ANOVA test results show a pr>f of 0.49 or less than $\alpha = 0.05$, the treatment of oil palm fronds has a significant effect on the compressive strength test of bio charcoal briquettes. The compressive strength test graph of bio charcoal briquettes is provided in Figure 5.

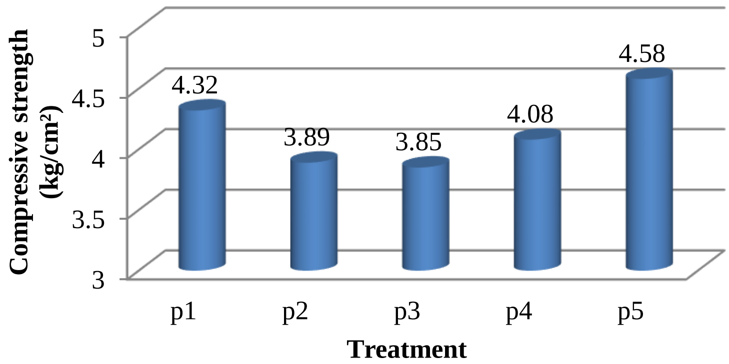

Figure 5. Compressive strength test values

Figure 5. shows that the p_3 treatment (20 mesh of oil palm fronds) had the lowest average value of 3.85 (kg/cm2) while the p_5 (20 mesh of oil palm fronds) had the highest average value of 4.85 (kg/cm2). The results of the compressive strength values show that treatment 3 is lower than treatment 5. In the compressive strength test the load given is 50,60,70,80 kg but there is no effect on the briquettes. When the briquettes are given a load of around 90 kg the briquettes crack. The value of compressive strength is highly affected by the type of material, particle size, density, type of adhesive, and pressure during printing, according to Setiowati and Triono (2014). This demonstrates that the higher a product's density value, the higher the ensuing compressive strength value.

3.6 Shatter resistance index

The results of variance at the level of α = 0.05 indicate that the particle size of cassava stems has a significant effect on the shatter resistance index of briquettes. The results of the Anova test, the particle size of palm fronds against the shatter resistance index of briquettes, are provided in Table 4.

Table 4. ANOVA test of shatter resistance index briquettes.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > f
Model	4	50.3205040	12.5801260	0.73	0.5809
Error	20	343.8493600	17.1924680		
Corrected Total	24	394.1698640			

Table 4. The results of the ANOVA test show a pr>f of 0.58, so the size of the palm fronds has no significant effect on the shatter resistance index test because the treatment value obtained is greater than α = 0.05 for bio charcoal briquettes. The graph of the bio charcoal briquettes test for shatter resistance index is provided in Figure 6.

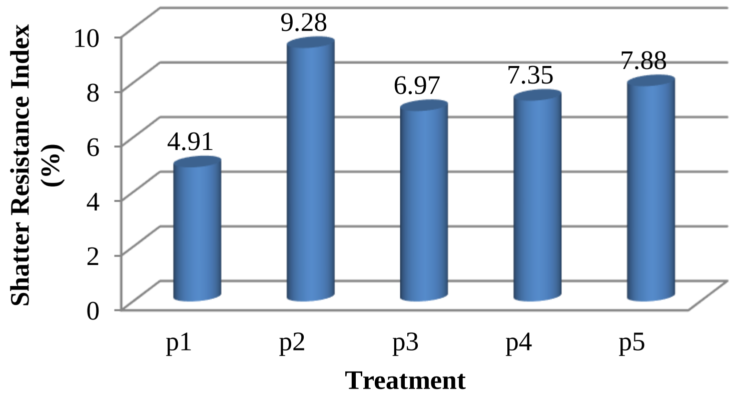

Figure 6. The shatter resistance index value of bio charcoal briquettes.

Figure 6 shows that the highest average shatter resistance index value is in the p_2 treatment (mesh palm oil particle size) of 9.28%. Meanwhile, the P_1 treatment (particle size of palm fronds was 20 mesh) with the lowest average value of 4.91%. The results of the shatter resistance index showed that treatment P1 had lower briquette resistance, while treatment P2 had higher briquette resistance. This shows that the higher the density value, the better the quality is the shatter resistance index.

3.7 Burn rate

Combustion rate testing is carried out to determine the effectiveness of a fuel. This is to find out the feasibility of the tested fuel so that it can be used later in its application (Almu et al., 2015). According to Borman (1997) in Syamsiro (2005) the rate of burning of bio charcoal briquettes depends on the concentration of raw materials, oxygen, gas temperature and particle size. The results of variance at the level of $\alpha = 0.05$ indicate that the particle size of the cassava stalks has a significant effect on the burning rate of the briquettes. The results of the Anova test, the particle size of palm fronds on the rate of burning of briquettes, are provided in Table 5.

Table 5. The results of the ANOVA test of the burning rate of briquettes

Source	DF	Sum of Squares	Mean Square	F Value	Pr > f
Model	4	0.01624000	0.00406000	0.87	0.4992
Error	20	0.09336000	0.00466800		
Corrected Total	24	0.10960000			

In Table 5. The results of the ANOVA test show pr>f 0.49 or less than $\alpha = 0.05$, the treatment of oil palm fronds has a significant effect on the burning rate test on bio charcoal briquettes. The graph of the burning rate test for the density of bio charcoal briquettes is presented in Figure 7.

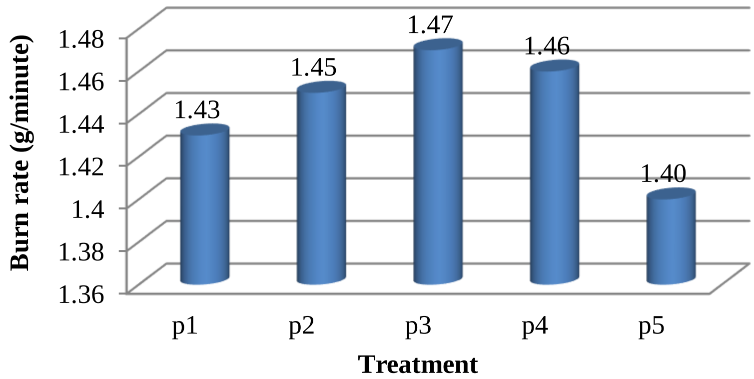

Figure 7. The burning rate of bio charcoal briquettes.

Figure 7 shows that the highest average value of combustion rate was in the p_3 treatment of palm frond particles of 1.47%, while the P_5 treatment (particle size of 20 mesh) had the lowest average value of 1.40%. The p5 treatment had lower briquette resistance, while the P3 treatment had higher briquette resistance. This shows that the higher the density value, the better the quality of the exposure rate. The high or low burning rate of briquettes is strongly influenced by the particle size used. The burning rate of briquettes can be related to the density value of each composition and the water content value. The higher the density of the briquettes, the lower the burning rate. This is due to the denser the particles in the briquettes, the longer the burning process will take, Anggara (2009) in Purnomo et al. (2014). The high or low burning rate of briquettes is strongly influenced by the particle size used. According to Iriany et al. (2017) the larger the particle size, the more porous space it has for oxygen to pass through, making it easier to burn, which will affect the rate of combustion. At a relatively small particle size so it is easy to compact and the pores between the particles are much less, the briquettes will be used up longer when burned.

3.8 Pan bottom temperature

Testing the temperature of the bottom plate of the pan using briquettes with the mass used for each treatment, amounting to 200 grams. Tamrin (2007) states that the higher the mass of the briquettes, the longer the coals die. The results of changes in the bottom temperature of the pot on cassava stem varieties are provided in Figure 8.

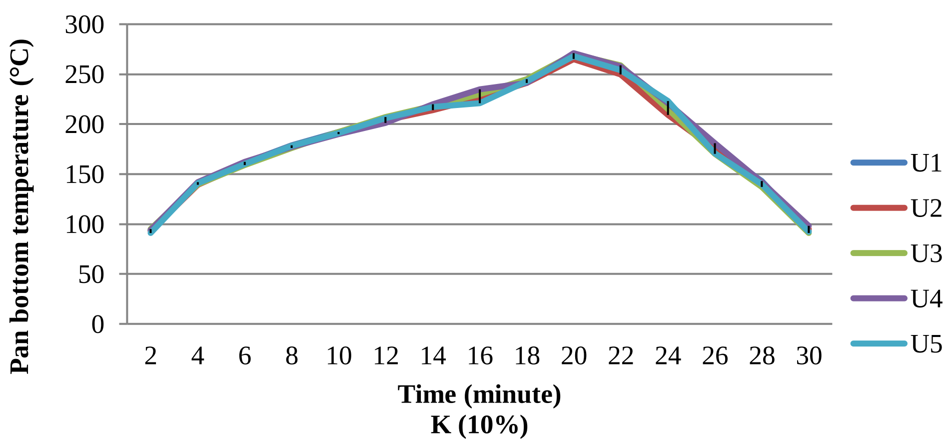

Figure 8. The bottom temperature of the pan in treatment I

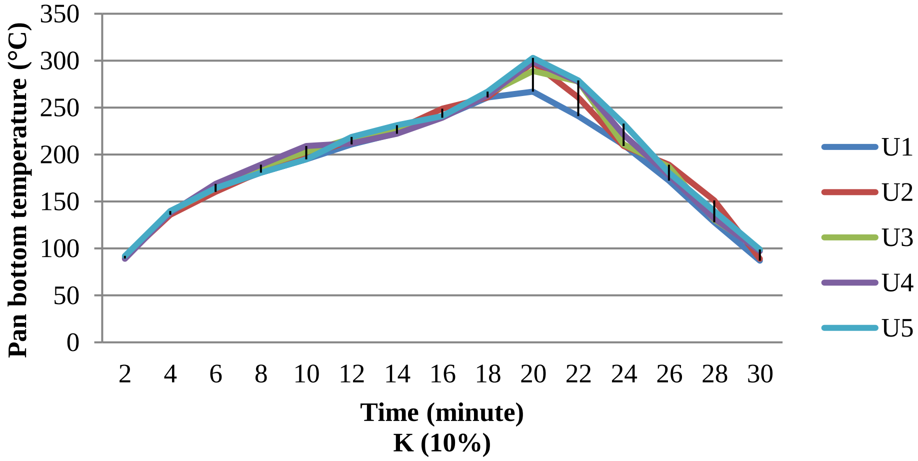

Figure 9. The bottom temperature of the pan in treatment II

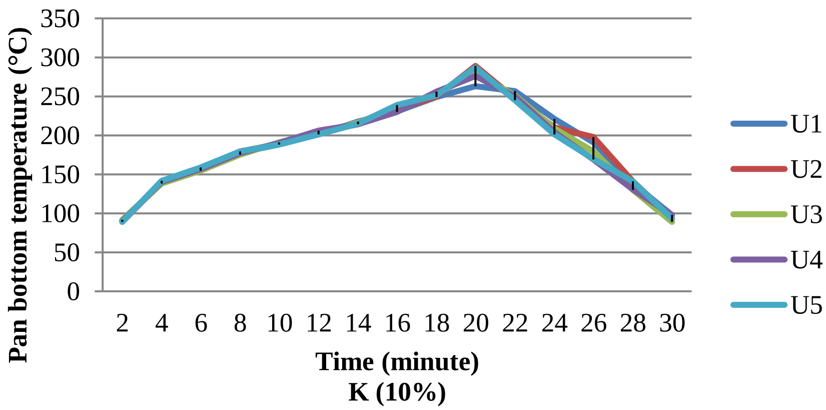

Figure 10. The bottom temperature of the pan in treatment III

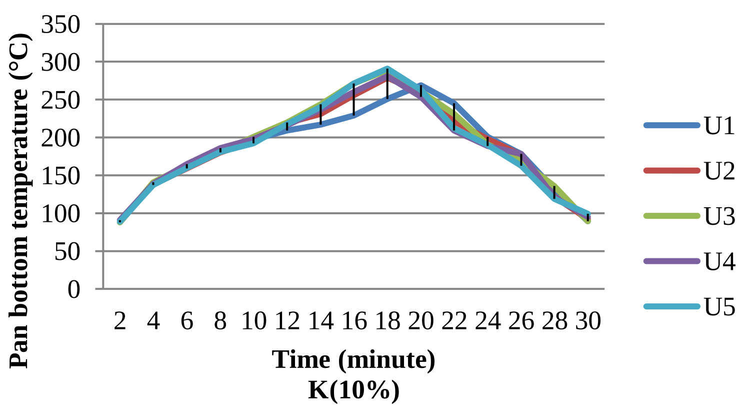

Figure 11. The bottom temperature of the pan in treatment IV

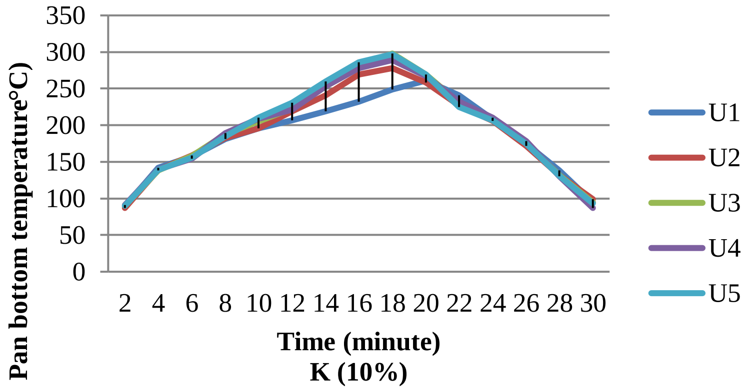

Figure 11. The bottom temperature of the pan in treatment V

Figure 8 shows that the bottom temperature of the cooking plate (pot) increases for 18-20 minutes after the initial ignition of the briquettes, the initial ignition of the briquettes is faster. This can be influenced by the particle size of the palm fronds, the calorific value, and the water content. Iriany et al (2017) stated that the larger the particle size there are many pores for oxygen to pass through, so that the briquettes will burn more easily, and will affect the rate of combustion. The mass used for testing the bottom temperature of the pot of 200 grams has a burning time of 60 minutes (from the briquettes smoldering to death), so the resulting combustion rate is 3.45 gr/minute. The fire on the bio charcoal briquettes started to appear within 10-12 minutes. The bottom temperature of the pot starts to increase by reaching its maximum temperature in 14-24 minutes. The maximum temperature that can be achieved indicates the presence of energy to heat the panic. Tamrin (2007) states that this high maximum temperature is due to the briquettes not only heating the bottom of the pan, but also heating the furnace chamber. Because the energy rate of coal during combustion increases with briquette mass, the highest bottom temperature of the pot can be higher with a large mass.

Research from Bahillo et al. (2006) in Jamilatun (2008) states that briquettes from a mixture of coal and biomass have several advantages, namely high levels of volatile matter compounds from biomass and high carbon content (fixed carbon) from coal. The high calorific value can increase the combustion temperature and reach the optimum temperature for a long time. The moisture content in the briquette burner can affect the amount of energy released during combustion. Briquettes with high water content, then some of the energy of the briquettes is used to evaporate the water in the briquettes. So that the energy that comes out into the environment is lower or the bottom temperature of the pot is measured lower. If the briquettes are very dry, little energy from the briquettes is used to evaporate the water. Thus the energy released into the environment can increase the ambient temperature (bottom of the pot) more optimally (Tamrin, 2010). The results of testing the bottom temperature of the pan showed that to reach a temperature of 180°C in 10-12 minutes, at a temperature of 200°C in 20-22 minutes, and decreased in 22-24 minutes. According to Tamrin (2011) the results of temperature changes show that the temperature in the combustion chamber rises first, then drops again. This increase in temperature is due to the closing of the combustion chamber, the rate of heat leaving the space becomes small. This is because the room is closed, the wall functions as an insulator, before it is closed, the heat loss to the environment is quite large because there are no walls to block it. The maximum temperature of the bottom of the pot was produced for each treatment, the highest was in the $P2U_1$ treatment with a temperature of 303°C. According to Tamrin (2010) that the more mass of briquettes that are burned, the higher the resulting peak temperature. This is possible because the higher the mass of the briquettes that are burned, the more energy is released into the combustion chamber, while the heat loss through the closing wall remains constant. Jamilatun (2008) states that higher combustion temperatures can increase the rate of reaction and lead to shorter burning times.

In general, the bottom temperature of the cooking plate (pan) when burning briquettes can withstand a minimum temperature of more than 1800C for 32 minutes so that the briquettes can survive raw palm fronds with the addition of coal using tapioca adhesive.

4. Conclusions

According to the findings of the study, oil palm fronds combined with coal can be used to make briquettes with tapioca adhesive. The composition of palm frond and coal raw materials has a substantial impact on compressive strength, density, and shatter resistance index. (the smaller the particle size of palm fronds, the higher the compressive strength, density, shatter resistance index). The combustion rate rises as the particle size of the palm fronds increases. The following are the findings of the characteristics after testing the bio charcoal briquettes: The skillet has a moisture content of 7 - 8.96%, a heating value of 4.28137 - 5.014.80 cal/g, a density of 0.568-0.674 g/cm3, a compressive strength of 3.85 - 4.58 kg/cm2, a shatter resistance index of 12.58-17.19%, a burning rate of 1.40-1.47 gram/minute, and a bottom temperature of 287°C. (for 60 minutes and a mass of 200 grams).

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