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EFFECT OF PARTICLE SIZE AND TAPIOCA STARCH CONTENT ON PERFORMANCE OF THE RICE HUSK AND RED BEAN SKIN BRIQUETTES

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Abstract

This study investigated effects of particle size and the amount of tapioca starch adhesive on briquettes performance. Experiments were carried out by mixing microparticles of rice husk (2000-500; 250-125; and 100-74 μm), microparticles of kidney bean shells (2000-500; 250-125; and 100-74 μm), and binders (20, 30, 40, and 50%). In the experiments, the rice husk and red bean skin was cleaned, dried, and put in an electrical oven at 200°C for 2 hours. The waste from rice husks and red bean skin was then separated according to the particle size and processed into briquettes with the same pressure (18.59 N/cm^3). Several series of tests were carried out such as compressed density, relaxed density, relaxation ratio, percentage of moisture content, water boiling test, combustion rate, specific fuel consumption, and water resistance index. The results showed that briquettes have a good quality when using small particles (100-74 μm) with a binder concentration of 50%. The small particles have large surface area, and the high concentration of binders makes the bonds between the particles hold together strongly. For the briquettes with large particles (2000-500 μm), the good quality of briquette was obtained when using a binder concentration of 20%. The large particles and low binder concentration make the porosity of the briquette higher. Based on the results, combination of the rice husk and red bean skins have good characteristics, and the best was obtained when using particle sizes of 100-74 μm with adhesive concentrations of 50%. This study demonstrated the important of several parameters for enhancing briquette performance.

Keywords: Binders, Briquettes, Particle size, Red bean skin, Rice husk.

1. Introduction

Briquettes are the result of a loose conversion of biomass into solid biomass [1]. Briquettes are also flammable so they can be used as fuel [2]. Briquettes can be said to be carbon binding with the help of a binder [3]. Briquettes provide significant and tangible benefits in the economic field. Therefore, the quality and performance of briquettes are of great concern. The amount of binder is one of the significant effects on the thermal Behavior and combustion of briquettes [3].

There have been many results from research on briquettes, especially biomass briquettes [4] such as corn cobs, rice husks [5], banana waste [6], sawdust [7], and oil palm [8], and these studies have been used as a benchmark for briquettes [5-8]. However, understanding some parameters in the briquette has been limited.

In connection with these facts, this study aims to determine the characteristics of briquettes based on the effect of particle size and the effect of the ratio of the binder to the biomass briquettes from rice husks and red bean skin. A mixture of rice husks and red bean skin was used to utilize unused waste. Many factors affect the quality of briquettes, one of which is the amount of adhesive and the effect of particle size [4]. The study focused on how to improve the properties of solid fuels, and to obtain good quality briquettes with low moisture content, high strength, high density, slow flame propagation, and a large enough energy content [2]. With several series of tests on briquettes, namely: density, moisture content, durability, combustion rate, specific fuel consumption, and briquette waterproof index, we believe that this study can give information about how to produce high quality of briquettes.

2. Material and method

2.1. Material preparation

Rice husks and red bean skins are obtained from local market waste in Bandung, Indonesia. There are two variations in making this briquette, first for the variation in particle size obtained through drying, carbonation (200°C for 2 hours), finely and separated by particle size (2000-500; 250-125; and 100-74 μm), this is explained in Fig. 1. and the next variation is the binder ratio of tapioca flour, with binder ratios of 20, 30, 40, and 50%, with 10 mL of water. Rice husks and red bean skins with a ratio of 1:1 represent the properties of rice husks and red bean shells.

2.2. The process of making briquettes

In short, briquettes are made by mixing rice husks and red bean skin with tapioca starch as a binding agent. After mixing, it was printed using a mould with a height of 3.4 cm Dl and a height of 5.1 cm, with a pressure of 18.59 N/cm^2 for 30 seconds. The briquettes are then dried under the sun until the mass is constant. The experimental method in this study is shown in Fig. 1.

2.3. Determination of the properties of briquettes

2.3.1. Density

The compressed density (*CD*) is the density at which the briquette is removed from the mould (3.4 cm DI x 5.1 cm high). Relaxed density (*RD*) is the density of the briquettes after drying them in the sun. Relaxation ratio (RR) is the ratio of CD and RD to briquettes. Then calculated by the equation:

$$CD \ = \frac{Wc}{Vc} \tag{1}$$

where w_c, is the weight or wet briquette (g), and v_c is the volume of the wet briquettes (cm^3).

$$RD \ = \frac{Wr}{Vr} \tag{2}$$

where w_r is the weight of dry briquette (g) and v_c is the volume of dry briquette (cm^3).

$$RR \ = \frac{CD}{RD} \tag{3}$$

where CD is the compressed density, and RD is the relaxed density.

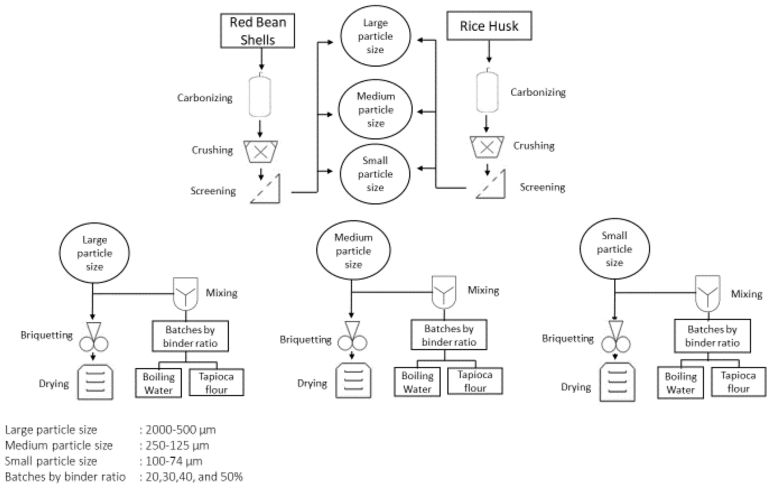

Fig. 1. Briquette making mechanism.

2.3.2. Percentage moisture content

The percentage of moisture content can be measured by comparing the mass of briquettes that have just come out of the mould with the mass of briquettes that have been dried in the sun. The percentage of moisture content can be determined using:

$$PMCw = \frac{D-E}{D} \times 100 \tag{4}$$

where D is the weight of wet briquette (g), dan E is the weight of dry briquette (g).

2.3.3. Durability index

The resistance index of briquettes is done by wrapping the briquettes in plastic and then dropping the briquettes from a height of 2 m. The durability index can be determined using:

$$DI = \frac{Wa}{Wo} \times 100 \tag{5}$$

where w_o is the briquette remaining (g), and w_a is the original weight (g).

2.3.4. Percentage of water resistance index

Percentage of water resistance is done by immersing the briquettes in water. Soaking is carried out for 30 seconds. The percentage of water absorption (PWA) is calculated using the following relationship:

$$PWA = \frac{Wa - Wo}{Wo} \times 100 \tag{6}$$

$$WRI = 100\% - PWA \tag{7}$$

where PWA is the percentage of water adsorbed (%), w_a is the weight wet briquette (g), and w_o is the original weight (g), and WRI is the water-resistance index.

2.3.5. Water boiling test

The water boiling test is carried out by comparing the temperature increase that occurs during the water heating process. In the heating process, 50 mL of water is used in a beaker on the briquette stove. The heating is carried out by briquettes with the help of 5 mL of methylated alcohol.

2.3.6. Burning rate

The rate of combustion in the briquette is carried out by adding 5 mL of methylated alcohol. The rate of combustion can be seen from the ratio of the mass difference between the briquettes before and after combustion with the length of the test time. The briquette burning rate is calculated using:

$$BR = \frac{Q1 - Q2}{T} \times 100 \tag{8}$$

where BR is the burning rate (g/s), Q1 is the initial briquette weight (g), Q2 is the final briquette weight after burning (g), and T is the total burning time (s).

2.3.7. Specific fuel consumption

Specific fuel consumption is the ratio of the mass difference between briquettes before and after combustion to the amount of water (50 mL) tested. The briquette specific fuel composition is calculated using:

$$SFC = \frac{Q_1 - Q_2}{QW} \tag{9}$$

where SFC is the specific fuel consumption (g/mL), Q_1 is the initial briquette weight (g), Q_2 is the final briquette weight after burning (g), and QW is the quantity of boiling water (mL).

3. Result and discussions

The process of making briquettes with the ratio of 1:1 was used to determine the characteristics of the briquettes from rice husks and red bean skin with the same ratio. The main ideas in this study were to produce briquettes that represent the two properties of the material. In the process of making briquettes, tapioca starch as binder was used. We found that the mixed mixture became very sticky and agglomerated at a maximum binder concentration of 50%, and there was a very homogeneous mixture at particle sizes of 100-74 μm. The test results of rice husk and red bean skin briquettes are shown in Figs. 1-10.

3.1. Compressed density

Figure 2 presents the compressed density results for particle sizes ranging from 2000-500 μm with yields ranging from 1.012 to 1.639 g/m^3. In briquettes with particle sizes of 250-125 μm, yields ranged from 1.114 to 1.835 g/m^3. Briquettes with particle sizes of 100-74 μm ranged from 1.377 to 1.714 g/m^3. We obtained that the highest compressed density for particle sizes of 250-125 μm with a 50% of binder was 1.835 g/m^3.

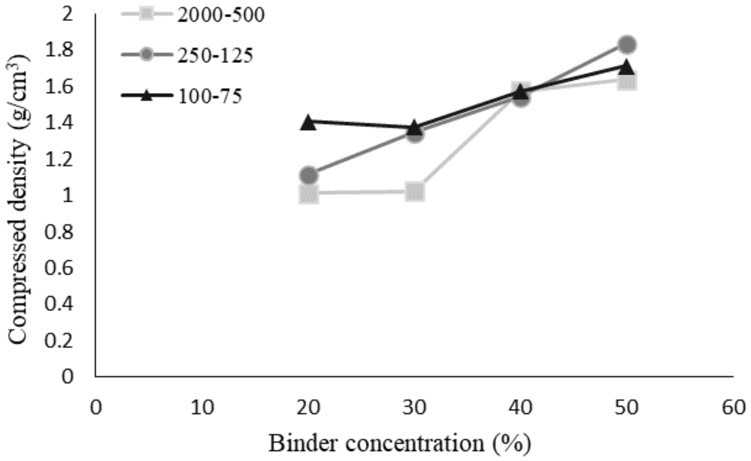

Fig. 2. Compressed density.

Figure 2 shows that the briquettes of rice husks and red bean skin had the best-compressed density when using medium particles with a binder size of 50%. When we used small particles, the resulting briquettes have high density [4]. If the particles are too small, it allows the binder and particles to be distributed homogeneous. When we compressed small particles, the dominances of binders are found, creating the compressed density value is not good since most of the compressed components is the binder. This is in line with Aransiola et al. [9] that the mean compressed density of briquettes varied from 952 to 1.437 kg/m^3 and it increased as the binder ratio increased.

3.2. Relaxed density

Figure 3 presents the relax density results for particle sizes of 2000-500 μm. The yields ranging from 0.471 to 0.885 g/m^3. Briquettes with particle sizes of 250-125 μm got results ranging from 0.730 to 0.955 g/m^3, and briquettes with particle sizes of 100-74 μm were from 0.898 to 0.955 g/m^3. The highest value was briquettes with particle sizes of 100-74 μm with a 50% of binder (0.995 g/cm^3). In Figure 2, the briquette experienced an increase in relax density as the binding concentration increased.

Figure 3 has confirmed the briquettes mixture of rice husks and red bean skin, showing the best test for density relaxation is for briquettes with particle sizes of 100-74 μm with 50% of binder (0.995 g/cm^3). When comparing with the Akpenpuun et al. [10] that had relaxed density of about 0.3044-0.3874 g/m^3, the present briquettes are good. Briquettes with smaller particles tend to have a higher relax density than that with larger particles [4]. This explains that all spaces or cavities in the briquettes with small particles are filled by binders, making the volume size to become smaller. Indeed, this allows the relax density to be greater [10].

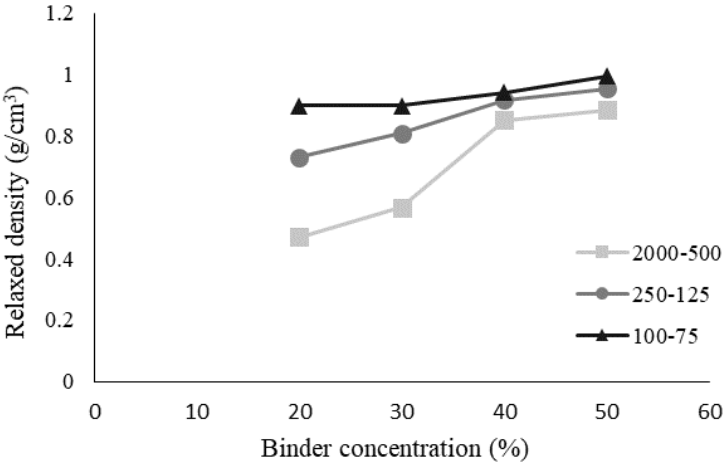

Fig. 3. Relaxed density.

3.3. Relaxation ratio

Figure 4 presents the results of briquette relaxation ratios for particle sizes of 2000-500 µm. The values ranged from 1.786 to 2.476. For briquettes with particle sizes of 250-125 µm, the results ranged from 1.523 to 1.920. For briquettes with particle sizes of 100-74 µm, the yields ranged from 1.566 to 1.723. The highest relaxation ratio value (2.476) was when using briquettes with particle sizes of 2000-500 µm and a binder of 50%. The value increased as the binder concentration increased. However, it is different from briquettes with particle sizes of 2000-500 µm, in which they experienced decreases in binder concentration of 30% and 40% but it increased at a binder concentration of 50%.

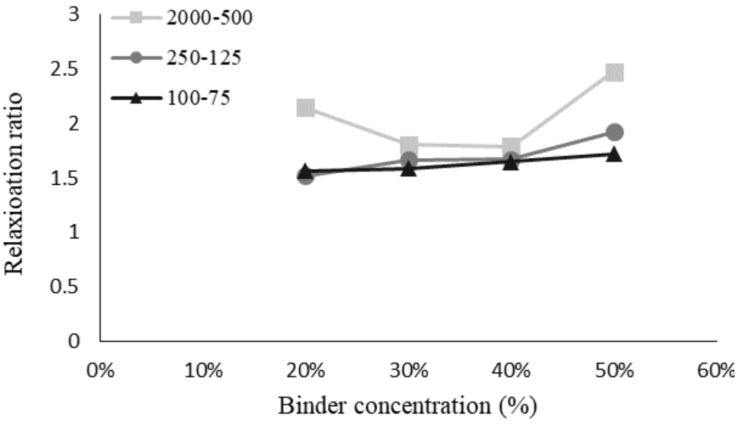

Fig. 4. Relaxation ratio.

The analysis showed that the binder concentration and size had a significant effect on the resulting relaxation ratio. According to the Aransiola et al. [9], it was stated that the result for the relaxation ratio was that the binder concentration of 30%, having the highest effects on obtainment of 1.40. When the binder concentration of 20% was used, it gained 1.38. Then, the binder concentration of 10% resulted 1.35. Based on the Aransiola et al. [9], the higher the binding concentration, the increases in the relaxation ratio can be obtained. If the binder concentration is not too high, a more stable briquette could be obtained. Higher values indicate a less stable material [11].

3.4. Moisture content

Figure 5 shows the water content test of briquettes. The results showed that the particle sizes of 2000-500 μm allowed values from 0.453 to 0.533%. In the case of briquettes with particle sizes of 250-125 μm, it ranged from 0.326 to 0.470%. Then, briquettes with particle size 100-74 μm were from 0.356 to 0.400%. The lowest water content values (0.326%) were found in briquettes with particle sizes of 250-125 μm and a binder of 20%.

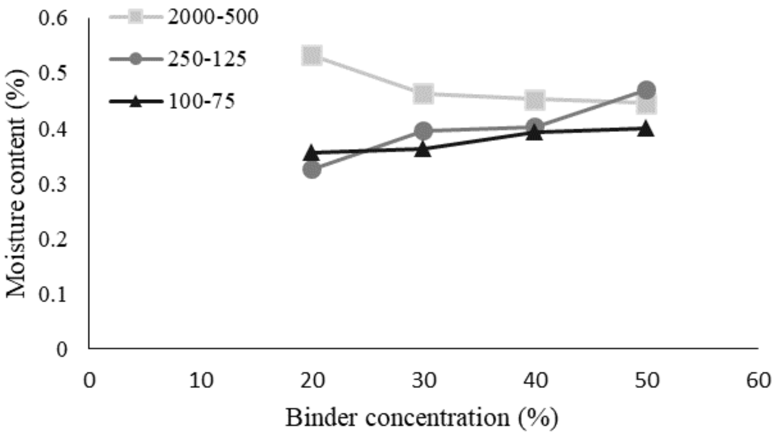

Fig. 5. Moisture content.

The results showed that the smaller the particle size gave impacts on the more water content in the briquettes. In addition, smaller particles have larger particle surface area, allowing more water to be bound. In briquettes with particle sizes of 250-125 μm and 100-74 μm, the water content increased with increasing binder concentration. The greater binder concentration in the briquette allowed the greater water content in the briquette. The level of binder concentration affects the moisture content of the briquettes [9]. The binder concentration of 30% has the highest water content of 6.58%, followed by 20% with a water content of 5.99%. The binder concentration of 10% has a moisture content of 5.29% [9]. So, it can be concluded that the water content in the briquettes increased with increasing the concentration of the binder.

3.5. Durability index

Figure 6 shows the resistance test of briquette. Briquettes with particle sizes of 2000-500 µm had the durability index of between 87.00 to 99.80%, whereas particle sizes of 250-125 µm was 97.60% to 99.70%. Particle sizes of 100-74 µm yielded 99.30-99.80%. The strongest resistance of briquettes was at particle sizes of 100-74 µm with a binder concentration of 30.00%.

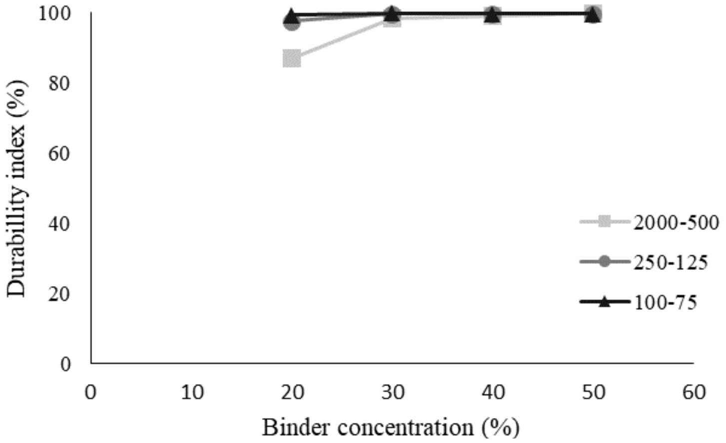

Fig. 6. Durability index.

Figure 6 confirms that the best resistance test index (ranging from 99.30-99.80%) was for briquettes with small particles of 100-74 µm and a binder concentration of 30%. When viewing from the particle size, briquettes with small particle sizes have a high density. Thus, the density is high, resulting in a compact volume and high resistance. The concentration of the binder allowed the more moisture content and tapioca content. Particles were easily bound, making them be stronger than those using less binder concentration.

3.6. Water resistance index

In Fig. 7. the water-resistance results for particle sizes of 2000-500 µm ranged from 0.60 to 1.33%. For briquettes with particle sizes of 250-125 µm, it ranged from 0.23 to 0.89%. Briquettes with particle sizes of 100-74 µm were from 0.16 to 0.37%. The best water resistance index value is when using briquettes with particle sizes of 100-74 µm.

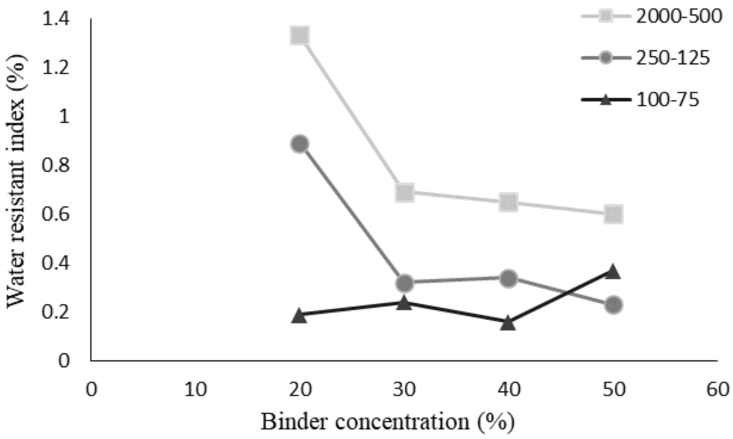

Fig. 7. Water resistance index.

The best water resistance index was obtained when using small particles. If the briquette is from small particles, it will have higher density [4]. Then, combining the binder, particles can bind tighter each other, making less water absorption. The higher binder concentration resulted the higher briquette density and less water absorption.

3.7. Burning rate

In Fig. 8. the burning rates of briquettes made from particle sizes of 2000 -500, 250-125, and 100-74 μm were 0.0072-0.017; 0.0033-0.0260; and 0.0045-0.0065 g/s, respectively. Table 1 and Fig. 8. confirmed that the highest burning rate (0.017 g/s) is owned by the briquette with particle sizes of 2000-500 μm and 20% of binder. The particle sizes based on the combustion test can be related to the porosity. The small particle size has low porosity so that there is less free space, and the air that comes in and out of the combustion process is blocked, this results in the combustion process being reduced [12].

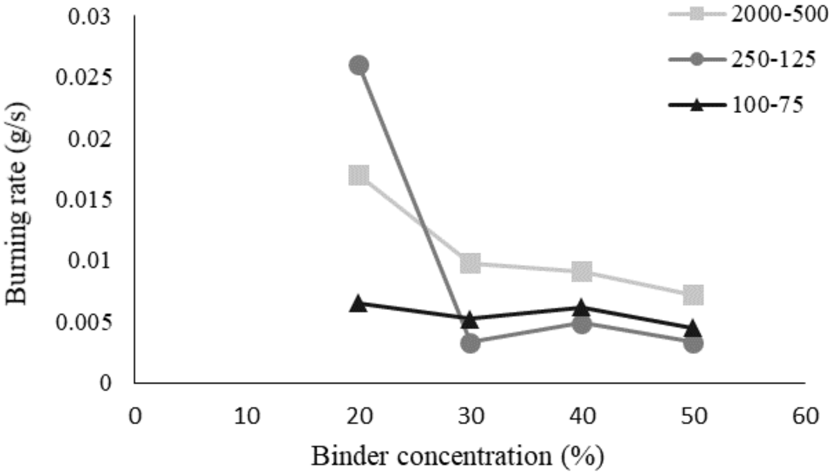

Fig. 8. Burning rate.

Table 1. Burning rate

Particle size	Binding ratio	Mass before combustion (g)	Mass after combustion (g)	Time (s)
10-34	20%	9.02	3.27	336
	30%	8.97	5.94	308
	40%	8.21	5.94	248
	50%	8.72	7.02	236
60-120	20%	9.00	4.28	164
	30%	8.76	8.17	177
	40%	8.57	7.76	163
	50%	8.34	7.74	177
150-250	20%	9.70	8.55	176
	30%	7.70	6.22	284
	40%	9.13	8.25	141
	50%	9.16	8.31	197

3.8. Specific fuel consumption

Figure 9 shows the specific fuel consumption. For particle sizes ranges from 2000-500, 250-125, and 100-74 μm, the specific fuel consumptions are 0.0251-0.1150; 0.0944-0.0118; 0.0176-0.0340 g/mL, respectively. The highest fuel consumption test is for briquettes with particle sizes of 2000 - 500 μm with a binder of 20%, reaching the value of 0.115 g/mL. Similar to the combustion rate, the small particles have a low porosity so that there are less free spaces, and the air that comes in and out of the combustion process is blocked, this results in a reduced combustion process [12]. So that a large particle size consumes a large amount of fuel. On the contrary, the smaller the particle size, the lower the fuel consumption.

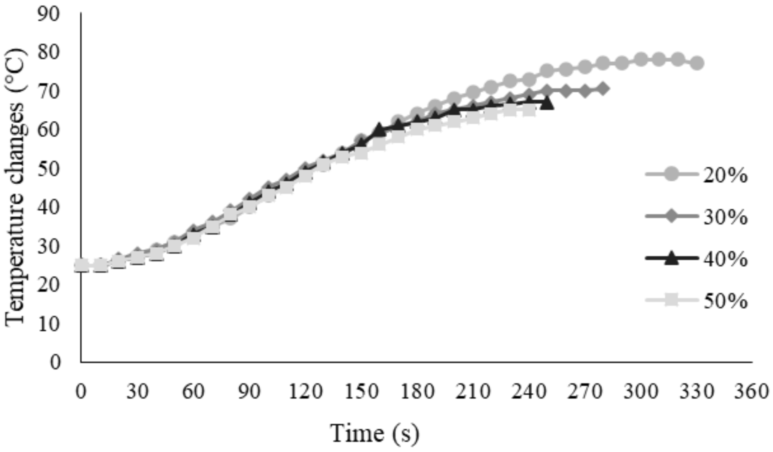

Fig. 9. Temperature changes in particle sizes briquettes 2000-500 μm.

The test results of the combustion rate and fuel consumption can be supported by Demirbas and Demirbas [12], that the briquette combustion rate varies from 0.92 ± 0.03 g/min to 2.66 ± 0.05 g/minute. This can be attributed by the fact the inter- and intra-particle porosity, allowing oxygen to easily in and out the pore system during the combustion process. Thus, the small particles allowed low porosity, and it tends to reduce ignition power [12] as well as to use lower fuel consumption. This is in line with the results about the existence of density and porosity [4]. The density and porosity can change the phenomena in the incomplete combustion.

3.9. Water boiling test

Figures 9, 10, and 11 show the results of the boiling water test for briquettes with particle sizes of 2000-500, 250-125, and 100-74 µm, which allowed the obtainment of high/low temperature of 78/66; 20/59; and 70/60 °C/°C, respectively. Large particles allowed the highest air temperature. When briquettes were supported by small binder concentration (2%), there is a large temperature change, in which this is in line with Arewa et al [2]. Meanwhile, briquettes with 4% of cassava starch binder gave the shortest time to reach its boiling point even though the temperature reached was higher. This shows that although the briquette reaches its maximum temperature in a shorter time, it indicates that the briquette surface maintains its maximum temperature longer [2]. The temperature change occurs rapidly, and the flame goes out quickly. The higher concentration of the binder resulted in the increases in the density. Indeed, this density can affect the air resistance of the briquette. Air resistance increases with the increases in density of the briquettes. In addition, the particle size gave impacts. If we use small particles, it provides larger surface area and vice versa, resulting in the production of higher density briquettes with good water resistance.

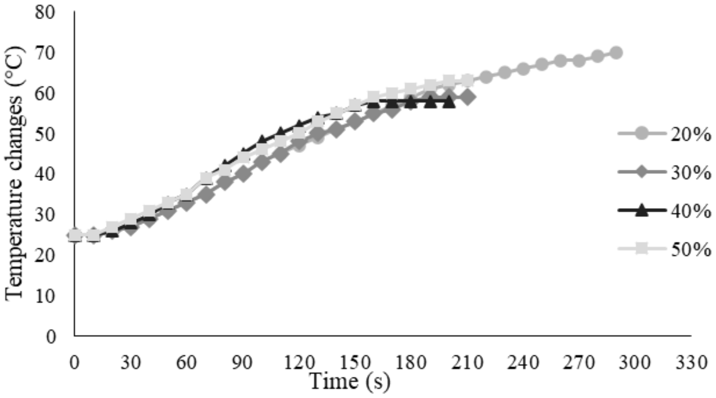

Fig. 10. Temperature changes in particle sizes briquettes 250-125 µm.

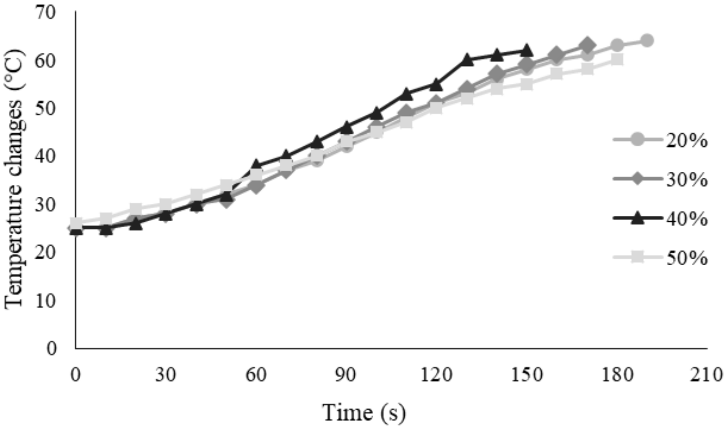

Fig. 11. Temperature changes in particle sizes briquettes 100-74 μm.

4. Conclusion

This study has carried out on briquettes by mixing microparticles of rice husk (2000-500; 250-125; and 100-74 μm), micro-particle kidney bean shells (2000-500; 250-125; and 100-74 μm), and binders (20, 30, 40, and 50%). Through a series of tests of compressed density, relaxed density, relaxation ratio, percentage of moisture content, water boiling test, combustion rate, specific fuel consumption, percentage of water resistance index, and percentage of resistance index. The results obtained on compressed density, relax density, relaxation ratio, percentage of moisture content, endurance index, and percentage index of water resistance stated that briquettes have good quality at small particle sizes (100-74 μm) with 50% binder. The small particle size has a large surface area, and the high concentration of binder makes the bonds between the particles strong. Meanwhile, the test results on the water boiling test, burning rate, and specific fuel usage found that the briquettes that had good quality were at large particle sizes (2000-500 μm) with a binder concentration of 20%. The large particle size and low binder make the briquette porosity higher. Based on the results obtained, it shows that the rice husk briquettes, and red bean skins have good characteristics, preferring particle sizes of 100-74 μm with adhesive concentrations of 50%.

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