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The influence of particle size variation on the quality of corn cob and teak leaf briquettes.

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Abstract— *Biomass can be utilized as a renewable energy source by processing it into briquettes. One type of biomass that can be developed into a new renewable energy source in the form of briquettes is corn cob and teak leaves. As a solid fuel, briquettes are required to meet quality standards acceptable to the market, including good quality in terms of moisture content, ash content, volatile matter content, and fixed carbon content. The quality of briquettes is greatly determined by several parameters, including the particle size of the materials composing the briquettes. The aim of this research is to investigate the influence of particle size on the quality of briquettes. The research methodology includes drying, carbonization, grinding, and screening processes of materials with particle size variations of 0.3 mm, 0.4 mm, 0.5 mm, and 0.8 mm. The powdered material obtained from screening is then molded and pressed into briquettes with a load pressure of 1 ton. The results of the tests indicate that particle size variation affects the quality of briquettes, including moisture content, ash content, volatile matter content, and fixed carbon content. In the moisture content test results of the briquettes, all test specimens did not meet the requirements for good quality briquettes according to the SNI 01-6235-2000. In the ash content test, only briquettes with a particle size of 0.3 mm did not meet the requirements for good quality briquettes. The volatile matter content test showed that briquettes with a particle size of 0.3 mm meet the required quality standards, while the fixed carbon content test showed that only briquettes with a particle size of 0.3 mm meet the requirements for good quality briquettes.*

Keywords— *biomass, corn cob and teak leaves briquettes, particle size, quality of briquettes*

I. INTRODUCTION

As the human population continues to increase, so does the demand for everyday necessities, one of which is fuel. Currently, society relies on fossil fuels as a primary source of fuel. Fossil fuels are non-renewable resources, and the more they are continuously used, the faster they will deplete. In fact, they are becoming increasingly scarce among communities. Society's dependence on fossil fuels can be mitigated by embracing new alternative energies, one of which is biomass fuel. Biomass consists of relatively young organic materials derived from plants, animals, agricultural products, and industrial cultivation waste (agriculture, forestry, livestock farming, fisheries) [1,2]. Biomass can be processed into briquettes, which are high-calorie fuel sources that can be utilized in daily life. One such biomass that can be converted into briquettes is corn cob [3].

In corn farming activities, corn cobs generate waste comprising 20.87% of the total waste, with 19.13% of this waste consisting of stems, leaves, and husks. Corn cobs contain a high percentage of crude fiber (33%), cellulose content of around 44.9%, and lignin content of approximately 33.3%. Corn cobs have an energy content ranging from 3,500 to 4,500 kcal/kg, and their combustion can reach temperatures as high as 205°C [4,5]. Corn cobs contain carbohydrates that can be utilized or processed into economically valuable products for human life. With technological utilization, corn cob waste, which has hitherto been discarded or burned, can be developed into a more economically valuable product, such as charcoal briquettes and raw materials for activated charcoal production [6]. In its application, the production of corn cob briquettes can also be mixed with other organic elements to enhance the quality and efficiency of briquette combustion. One of the added organic elements is teak leaves. Teak leaves have a relatively high lignin content, which is a crucial component in briquette formation. This plant belongs to the group of deciduous trees, shedding its leaves as a self-regulating mechanism during periods of water deficiency, especially in the dry season. Teak trees are classified as broad-leaved trees with generally round and straight trunks and high branching. Due to their characteristic leaf-shedding nature, teak leaves are a abundant source of biomass, especially in regions with teak forests cultivated specifically for forestry purposes [7,8].

The quality of briquettes is determined by several parameters, one of which is the particle size of the briquette constituents. Particle size has a significant impact on briquette quality because smaller particles tend to produce smaller voids, increasing the density of briquette particles and overall briquette quality while preventing damage. Particle size also affects briquette strength because smaller particles produce smaller voids, increasing the compressive strength of the briquette, and a good particle size distribution can enhance the likelihood of more effective arrangement. Smaller particles tend to produce denser and sturdier briquettes as they can interlock better, resulting in better-quality briquettes [9-11].

This research aims to investigate the effect of particle size of corn cob and teak leaf powder on the quality of briquettes, including moisture content, ash content, volatile matter content, and fixed carbon content.

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II. RESEARCH METHODOLOGY

2.1. Preparation of raw materials

In this process, the briquette materials, namely corn cobs and teak leaves, are first cleaned of impurities and then dried using manual drying methods. Corn cobs and teak leaves are placed in an open space and exposed to direct sunlight with good air circulation to expedite the drying process.

2.2. Carbonize the raw materials

In this process, carbonization is carried out with the aim of converting biomass materials, namely corn cobs and teak leaves, into charcoal. This process is conducted using a carbonization drum with a heating temperature ranging around 950°C for 2 hours.

2.3. Milling and filtering process.

The corn cob and teak leaf material that has undergone the carbonization process is further subjected to grinding and sieving using a grinding machine until smooth, followed by sieving using a milling machine with screen size variations of 0.3 mm, 0.4 mm, 0.5 mm, and 0.8 mm.

2.4. The process of mixing briquette materials.

The next process involves mixing corn cob and teak leaf powder with a binder, which is cornstarch flour. The mixing ratio consists of 10 % binder, 45 % corn cob, and 45 % teak leaf, with an additional 200 % water. To mix the raw materials with the binder, a mixing machine is used for approximately 5 to 10 minutes until the raw materials and binder are evenly mixed.

2.5. The molding of briquettes.

The evenly mixed briquette mixture with the predetermined ratio is then molded into cylindrical molds using a molding pressure of 3 tons.

2.6. The briquette drying process.

The briquettes resulting from the molding process are then dried in an electric oven at a drying temperature of 100°C for 5 hours. This drying process aims to reduce the moisture content in the briquettes, thereby expected to enhance the quality of the produced briquettes

2.7. Determination of briquette quality.

2.7.1. Testing the moisture content of briquettes

Moisture content is the substance obtained from the comparison of the weight of water in the briquette with the dry weight that has undergone the drying process. Moisture content greatly influences the combustion rate of briquettes because the higher the moisture content in the briquette, the lower the calorific value of the briquette.

$$\%\ moisture\ content = \frac{a-b}{a}\ x\ 100\% \ \text{.............................} \ (1)$$

spesification :
a = Initial specimen weight (gr)
b = Final specimem weight (gr)

2.7.2. Testing of ash content

Ash content is the substance obtained from the residue of briquette combustion. Ash content is influenced by several factors, namely the binder and the main raw materials of the briquette. The ash content of briquettes can be calculated using the equation:

$$\%\ ash\ content = \frac{weight\ of\ ash\ (gr)}{weight\ of\ specimen}\ x\ 100\% \ \text{.............} \ (2)$$

2.7.3. Testing volatile matter content

The volatile matter content is the amount of substances formed during the combustion of briquettes. Components within this volatile matter include pollutants, which are contaminants that can cause environmental pollution. The high volatile matter content is usually caused by suboptimal carbonization processes and unstable combustion during carbonization. The volatile matter content of biochar briquettes can vary depending on the type of raw materials used in their production, whether they are high or low.

2.7.4. Testing of fixed carbon content

The fixed carbon content can be obtained by subtracting the lost portion during heating in the testing of volatile matter and ash content.

% fixed carbon =100 % -(ash content + moisture content + vollatile matter content) ....(3)

III. RESULTS AND DISCUSSION

3.1. Testing the moisture content of briquettes

The results of the moisture content testing of corn cob and teak leaf briquettes are shown in the figure 1.

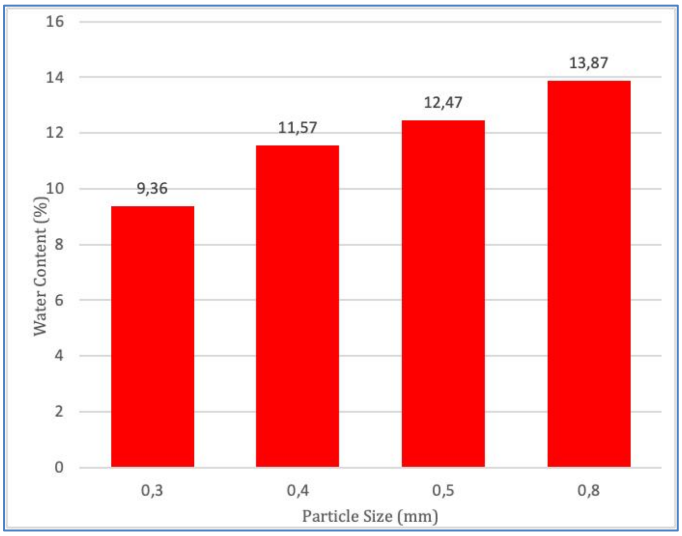

Figure 1. Graph of the moisture content testing results of corn cob and teak leaf briquettes

From Figure 1. it can be observed that the moisture content testing results using the moisture balance method yielded the following results for each mesh size variation: for mesh sizes of 0.3 mm, 0.4 mm, 0.5 mm, and 0.8 mm, the moisture content percentages were 9.36 %, 11.57 %, 12.47 %, and 13.87 % respectively. The graph indicates that smaller particle sizes result in lower moisture content. This is because the particle density also affects the moisture content test; the smaller the particle size, the lower the moisture content value obtained due to the higher density between particles, resulting in fewer spaces to absorb water as the gaps or pores for water vapor to

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enter become smaller. Conversely, the larger the particle size, the lower the density between the pores, resulting in larger gaps or pores for water vapor to easily absorb water [12]. These moisture content test results do not meet the briquette standards based on SNI 1-6235-2000, which stipulates a maximum moisture content of less than 8%.

3.2. Testing the ash content of briquettes

Aside from moisture content, the ash content value also impacts the quality of the produced bio-briquettes. Ash is the residue from the combustion process of charcoal briquettes. The main mineral component present in ash is silica, which remains after the charcoal briquette combustion process is completed. The presence of ash can lead to a decrease in calorific value, thus bio-briquettes with high ash content tend to have lower quality [13,14]. The following Figure 2 illustrates the ash content test results of corn cob and teak leaf briquettes.

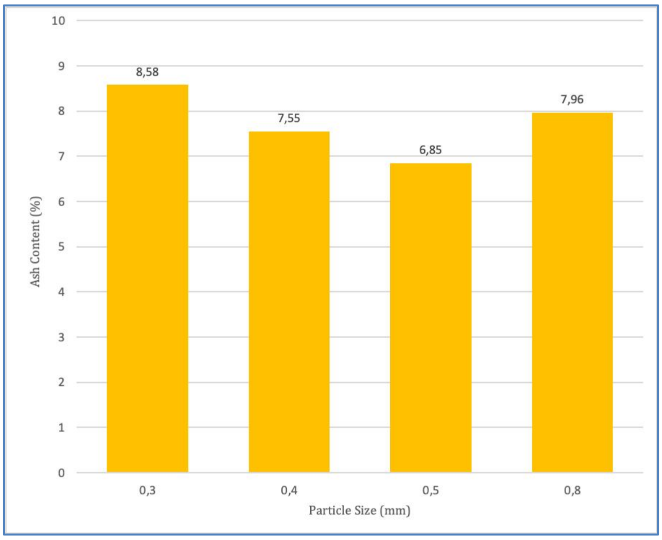

Figure 2. Graph of the ash content testing results of corn cob and teak leaf briquettes

From Figure 2 above, the ash content testing results using the ASTM D5142-02A method indicate the following for each mesh size variation: for particle size 0.3mm, the result is 8.58%, for particle size 0.4mm, the result is 7.55%, for particle size 0.5mm, it is 6.85%, and for particle size 0.8mm, it is 7.96%. Based on this data, it is evident that as the briquette particle size increases, the ash content in the briquette decreases. However, at a particle size of 0.8mm, there is a significant increase in ash content. This is because with smaller particle sizes, the ash content tends to be higher due to incomplete combustion during briquette burning, leaving behind residues of charcoal briquettes. Conversely, larger particle sizes result in lower ash content because of more complete combustion during briquette burning, leaving fewer residues of charcoal briquettes. Ash content can also be influenced by the carbonization process; if carbonization is complete, pure charcoal without any uncarbonized charcoal residue is obtained, resulting in lower ash content. In this study, the ash content results met the briquette requirements, especially for particle sizes 0.4 mm, 0.5 mm, and 0.8 mm, in accordance with the SNI 1-6235-2000 standard, with the SNI requirement value for ash content testing being < 8%.

3.3. Testing the vollatile matter of briquettes

Volatile substances also affect the quality of bio-briquettes; the smaller the particle size, the lower the concentration of volatile substances. The results of the volatile matter content testing of corn cob and teak leaf briquettes are shown in the following Figure:

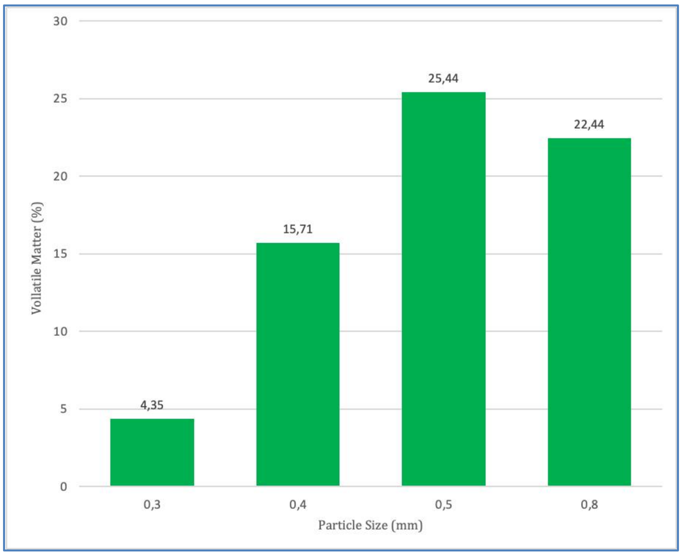

Figure 3. Graph of the vollatile matter content testing results of corn cob and teak leaf briquettes

From Figure 3, the results of volatile matter content testing using the ASTM D5142-02A method yielded the following results for each mesh size variation: for particle sizes of 0.3 mm, 0.4 mm, and 0.5 mm, the percentages are 4.35%, 15.71%, 25.44%, and 22.4%, respectively. Figure 3 shows that the highest volatile substance content is produced from the 0.5 mm particle size, while the lowest volatile content is found in particles sized 0.3 mm. Regarding particle size, this difference may be due to the density variation between 0.3 mm and 0.5 mm particles. The volatile matter content is influenced by the density of the briquette; briquettes with high density are less prone to evaporation because the space within the briquette is smaller, thus volatile substances are less likely to escape. Conversely, if the particle size increases, the space within the briquette becomes larger, allowing more volatile substances to evaporate [15]. In this study, the volatile matter content results for briquettes with a particle size of 0.3 mm met the requirements of SNI 1-6235-2000, where the SNI requirement for minimum volatile matter content is 15%. However, the particle sizes 0.4 mm, 0.5 mm, and 0.8 mm did not meet the specified standards.

3.4. Testing the fixed carbon of briquettes

The results of fixed carbon content testing aim to determine the amount of bound carbon present in charcoal

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briquettes. Carbon testing is obtained from three previous tests, namely moisture content testing, ash content testing, and volatile matter content testing [16]. Fixed carbon content has characteristics that are opposite to the volatile matter content value in briquettes. The results of fixed carbon content testing in corn cob and teak leaf briquettes are shown in the following Figure 4:

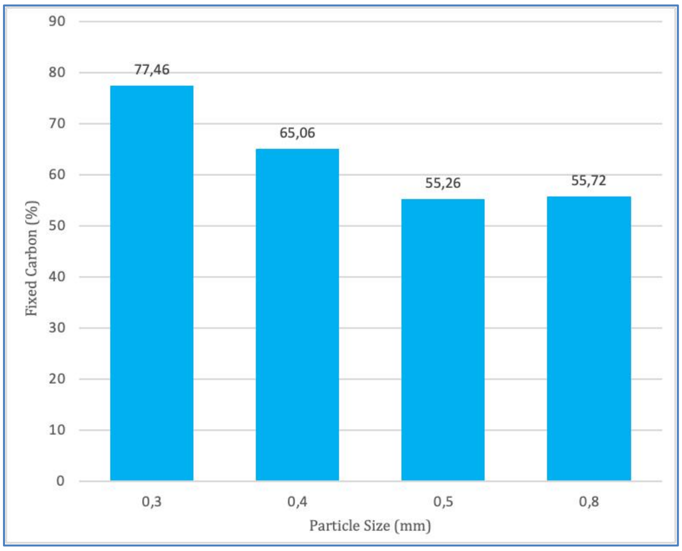

Figure 4. Graph of the vollatile matter content testing results of corn cob and teak leaf briquettes

Figure 4 shows the fixed carbon content values of corn cob and teak leaf briquettes with particle size variations. The highest fixed carbon value is obtained for briquette particles with a size of 0.3 mm, at 77.46%, while the lowest fixed carbon value is obtained for particle size 0.5 mm, at 55.26%. It can be concluded that the smaller the briquette particle size, the higher the carbon content obtained, and conversely, the larger the particle size, the lower the carbon content obtained. The graph indicates that as the particle size increases, the bound carbon content tends to decrease. Low fixed carbon levels are indicative of poor fuel (briquette) quality. Fixed carbon content conforms to the standard requirements for Japanese bio-briquettes, which is 60% - 80%, and the quality standard for British briquettes, which is over 75.3%. In this study, the fixed carbon content results did not meet the requirements set by SNI 01-6235-2000, which stipulates a value of more than 77% for briquettes with particle sizes of 0.4 mm, 0.5 mm, and 0.8 mm, while briquettes with a particle size of 0.3 mm met the required briquette quality.

IV. CONCLUSION

Based on the research results, it is shown that particle size has an influence on the moisture content, volatile matter content, ash content, and fixed carbon content of corn cob and teak leaf briquettes. The data indicates that the overall quality of corn cob and teak leaf briquettes does not meet the requirements of the SNI 01-6235-2000 standard and the Japanese bio-briquette standard.

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