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EFFECT OF WATER ADDITION ON THE CHARACTERISTICS OF COCONUT SHELL CHARCOAL BRIQUETTES

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ABSTRACT:

Abstract— Indonesian coconut shell charcoal briquettes are one of the most popular briquettes in the international market. This opens up opportunities for researchers to conduct research to produce better briquette quality. Research on the effect of water addition on the characteristics of briquettes using a screw-type extruder machine is still rarely done. Therefore, research on the effect of water addition on the characteristics of coconut shell charcoal briquettes with variations in the addition of water as much as 20%, 25%, and 30% were carried out. The purpose of this research is to determine the value of ash content, moisture content, fly substance content, bound carbon, calorific value, density, compressive strength, brittleness, and combustion duration in each specimen. The results of the test will then be compared with the characteristics of commercial briquettes on the market and standardized with the standard parameters of several countries. In this study, there are 3 briquette specimens and 1 commercial briquette divided by the code of each specimen is br_1 for briquettes with 20% water addition, br_2 25%, br_3 30% and br_4 is a commercial briquette used for comparison. The results showed the effect of water addition on the characteristics of coconut shell charcoal briquettes. The best characteristics were obtained by specimens with the code br_2 which was able to produce the best mechanical properties by obtaining compressive strength test results of 70.78 kg/cm^2 as well as size stability and fragility values of 95.56% and 4.44% respectively. The test results in this study were also able to fulfill several standard parameters that exist in several countries such as Indonesia, Japan, and the UK.

Keywords: Index Terms—briquettes, coconut shell charcoal, Water addition

1. INTRODUCTION

Indonesian coconut shell charcoal briquettes are in high demand by foreign countries such as European and Middle Eastern countries. The high market interest in Indonesian briquettes is due to superior characteristics such as high calorific value, not causing smoke, and a longer burning time so it is suitable for Shisha (Hookah), barbeque (BBQ), and as an alternative to firewood [1]. This is also supported by export data from the Central Statistics Agency (BPS) which shows that in 2021 there were 154,524 tonnes of briquette exports [2]. However, the same source states that coconut shell production in 2021 produces around 338,640 Tonnes, which means that there will be 184,116 Tonnes of coconut shells that can be used as briquettes so that it has a selling value and can improve the economy with exports.

Currently, the manufacture of coconut shell charcoal briquettes on an industrial scale does not yet have a standardized composition of briquette making, especially the ratio of water addition. This is reinforced by the statement of Arbi et al (2018) which states that the addition of water in the briquetting process is generally still very diverse ranging from 10 to 150% of the charcoal ratio so the standardization that determines the addition of water in the briquetting process has not been determined [3-5]. The ratio of water addition in the briquetting process can affect the briquetting process. The less amount of water added in the briquetting process will cause the material to be difficult to mix and difficult to mold. On the other hand, if too much water is added, the resulting briquettes will be mushy and cannot be formed. The lack of standardization of water addition in the briquetting process opens up opportunities for researchers to conduct research on the effect of water addition on the characteristics of coconut shell charcoal briquettes with 3 variations of water addition as much as 20%, 25%, and 30%. The purpose of this research is to find the best water addition ratio for the briquetting process and to determine the proximate properties, ultimate properties, physical properties, and mechanical properties produced from the three specimens. The results of the briquette characteristics will be compared with the SNI 01-6235-2000 standard to determine which specimen is able to produce the best characteristics.

2. MATERIAL AND METHOD

Coconut shell charcoal is an impure carbon residue resulting from the carbonization process. The choice of this material is because coconut shell charcoal is able to produce a higher calorific value than other materials [6]. Coconut shell charcoal is mashed using a discmill machine with a filter size of 40 mesh. The coconut shell charcoal used in this study was obtained from sellers in the Tuntang area, Semarang Regency, Central Java.
The adhesive used in this study was tapioca starch. Tapioca starch is one of the organic adhesives obtained from yam processing and is one of the adhesives that have a relatively low price. The choice of tapioca starch as an adhesive in this study is because tapioca starch is an adhesive that has high absorption and is able to increase strength [7],[8]. The addition of tapioca starch in this study was 5% of the total weight of the raw materials [9].

Specimen Making

The process of making briquettes has several stages as shown in Figure 1. The process starts with the preparation of raw materials by cleaning the raw materials from dirt and unused parts. After the raw material is clean, it is continued with the charring or carbonization process. The results of the carbonization are then mashed using a disk mill with a filter size of 40 mesh. The coconut shell charcoal powder is then mixed with an adhesive of 5% of the total weight of the raw material and the addition of water with variations of 20%, 25%, and 30%.vThe results of mixing the material are then blended 3 times using a screw-type extruder machine. The results of the blending are then printed using a screw extruder machine and the results of the mold will be cut manually with the size requirements of 25 x 25 x 25 mm. The results of the molding process are then dried using an oven for 3 hours at 100°C. The last step of the specimen-making process is characterisation which aims to determine the effect of adding the percentage of water on the quality of the briquettes. In this study, the distribution of briquette samples can be seen in Table 1.

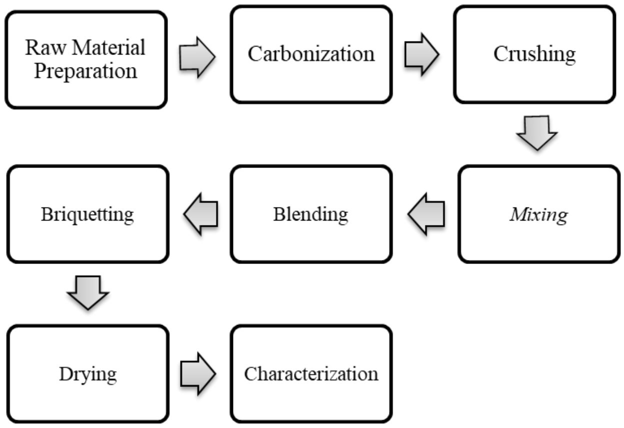

Figure 1 Briquetting process

Table 1: coconut shell charcoal briquette specimens

Specimen codes	Description
br_1	Coconut shell charcoal briquettes with 20% water addition
br_2	Coconut shell charcoal briquettes with 25% water addition
br_3	Coconut shell charcoal briquettes with 30% water addition
br_4	Coconut shell charcoal briquettes sold on the market

Specimen br_4 obtained from commercial briquettes will later be used as a comparison for the specimens contained in this study. Some of the standards used in this study are moisture content testing using ASTM D-3173- 03 standard, ash content using ASTM D-3174-04 standard, fly substance content using ASTM D-3175-02 standard, bound carbon content using ASTM D 3172-89 standard, calorific value using ASTM D240 standard, density using ASTM B-311-93 standard. Density using ASTM D-440-07 R02 standard. Compressive strength testing was carried out with a universal testing machine [10].

3. RESULTS AND DISCUSSION

A. Water Content

Water content testing is one of the proximate analysis tests conducted to determine the water content contained in briquettes. Charcoal briquettes have the property of absorbing water from their surroundings (hygroscopic) which is high, therefore the need for drying on briquettes so that the briquettes produced can last a long time and have good combustion performance [11]. Figure 2 shows the results of testing the moisture content (%) of each sample including br_1 7.26; br_2 6.8; br_3 6.73; and br_4 4.97. from the 3 samples it can be stated that all samples are able to meet the SNI 01-6235-2000 standard which states the maximum moisture content in briquettes is 8%. The results also show that the moisture content of the 3 samples is higher than that of commercial briquettes.

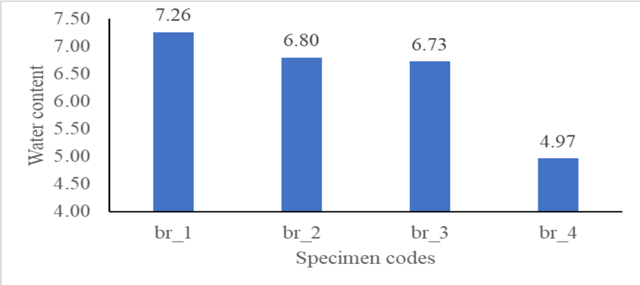

Figure 2 Comparison of moisture content in briquette specimens

In this study, the lowest water content was obtained by sample br_3 with a variation of 30% water addition in the briquetting process. This is thought to be due to the effect of adding water in the briquetting process facilitating the compression that occurs in briquettes. High pressure can cause briquettes to become denser, higher density, smoother, and more uniform so that particles of briquette mixture material can fill empty pores and reduce water molecules that can occupy these pores [12]. The addition of water in the briquetting process facilitates the compression of the briquettes so that there is an increase in the resulting density value. This is in accordance with the results of research conducted by Marchel dan Freeke (2019) which states that the water content contained in the briquette will be inversely proportional to the density or density produced by the briquette, the higher the density value produced, the lower the water content value, and vice versa [13].

B. Ash Content

Ash content testing is one of the proximate analysis tests used to determine the ash content or inorganic residuals contained in briquettes. Ash content is the remaining minerals from combustion [10]. Figure 3 shows the results of the ash content (%) test for each sample, including br_1 1.82; br_2 1.93; br_3 2.32; and br_4 1.87. From these test results, it can be stated that the 3 samples are able to meet the SNI 01-6235-2000 standard which states that the maximum ash content in briquettes is 8%. The results also showed that only br_1 was able to produce lower ash content compared to commercial briquettes.

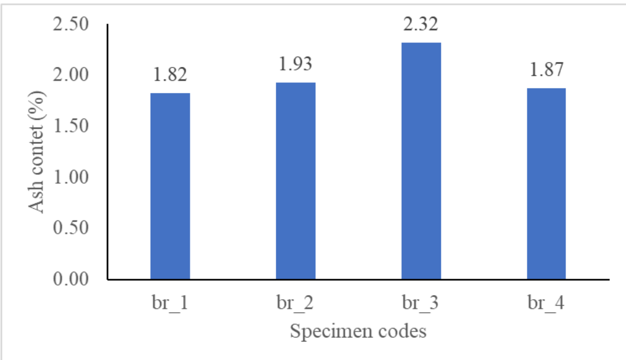

Figure 3 Comparison of ash content in briquette specimens

The highest ash content was obtained by the sample with the code br_3 with a percentage of 2.32%. There was an increase in ash content of 0.05% for every 1% addition of water from 20% to 30%. Meanwhile, the lowest ash content was obtained by specimen br_1 with a percentage of 1.87%. The increase in ash content as the percentage of water increases in the briquetting process is thought to be because the higher the percentage of water added in the briquetting process will make the mixing process easier and make the adhesive more evenly distributed. This makes it easier for inorganic components to be mixed into the briquettes, thus increasing the ash content. Ash content is an inorganic component consisting of mineral materials such as clay, silica, calcium, magnesium oxide, and others. The ash content such as silica can reduce the calorific value so that the higher ash content will worsen the quality of the briquettes [14].

Figure 3 shows an increase in ash content as the percentage of water added to the briquetting process increases. This is inversely proportional to Figure 2 where the water content decreases with the addition of water in the briquetting process. This phenomenon is in line with research conducted by Efendi et al. (2020) which states that the lower the moisture content produced by briquettes, the higher the ash content produced by briquettes [15].

C. Volatile Matter

Volatile matter testing is a proximate analysis test to determine the levels of substances that will affect the perfection of combustion, burn time, and smoke produced by briquettes [16]. In general, volatile matter can affect the ignition process, burn duration, and fixed carbon value in biomass [17]. Figure 4 shows the results of the volatile matter (%) comparison for each specimen including br_1 21.78; br_2 21.31; br_3 20.67 and br_4 17.26. These results show that all briquette specimens in this study have not met the SNI 01-6235-2000 standard which states that the minimum volatile matter content in briquettes is 15%. However, these results are still able to meet JIS (Japanese Industrial Standards) which states that the value of the volatile matter in briquettes should be between 15% and 30%.

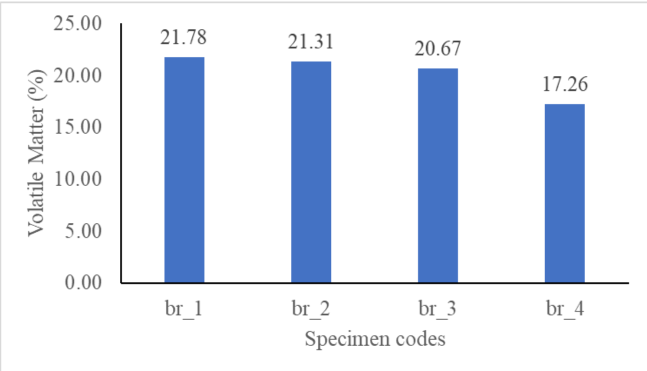

Figure 4 Comparison of volatile matter in briquette specimens

Figure 4 also shows a decrease in the value of volatile matter or flying matter from specimen br_1 with a value of 21.78% to specimen br_3 with a value of 20.67%. These results show that the volatile matter contained in the briquette specimens decreases by 0.114% for every 1% addition of water made. In this test we can conclude that the volatile matter content will decrease with the addition of water in the briquetting process. Volatile matter values show a constant decrease as water is added to the briquetting process. And if we refer to Figure 2, the value of water content also shows a constant decrease as the percentage of water added to the briquetting process increases. This is in line with research conducted by Rindayatno et al. (2021) and Sulistyaningkarti & Utami (2017) where the value of volatile matter will be directly proportional to the value of water content, the lower the water content owned by the briquette, the lower the value of volatile matter or flying substances owned by the briquette [16], [17].

D. Fixed Carbon

Figure 5 shows the comparison of fixed carbon with water addition. Results. Each sample obtained a fixed carbon value (%) of br_1 76.39; br_2 76.75; br_3 75.23 and br_4 80.88. These results show that the three samples of this study produce fixed carbon values that are lower than commercial briquettes. However, these results are still able to meet the JIS (Japanese Industrial Standards) standard which states that the bound carbon possessed by briquettes should range from 60-80%. The highest fixed carbon value belongs to the br_2 specimen with a value of 76.75%, and the lowest value in the br_3 specimen with a value of 75.23% as the percentage of water addition increases in the briquetting process.

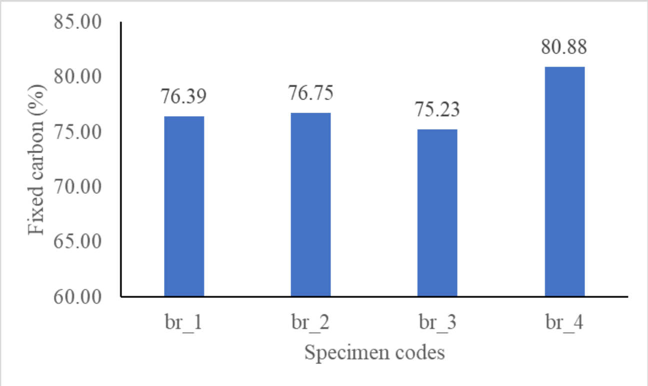

Figure 5 Comparison of bound carbon values in briquette specimens

Fixed Carbon or carbon content contained in briquettes is influenced by the raw materials used, the higher the value of bound carbon, the better the quality of charcoal used in the briquetting process. However, fixed carbon is also influenced by the volatile matter and ash content contained in the briquettes, the higher the volatile matter and ash content in the briquettes, the lower the bound carbon content, and vice versa [18-20]. This statement is consistent with Figure 4 which shows the results of the volatile matter test. In Figure 4, it can be seen that there is an increase in volatile matter content as the percentage of water added in the briquetting process increases.

E. Caloric Value

Calorific value testing is a test that aims to determine the maximum amount of heat energy produced by a fuel through a complete combustion reaction per unit mass or volume of the fuel [21]. Figure 6 shows the comparison between the calorific value and the variation of water addition. The test results of calorific value (calg/g) of each specimen are br_1 7040.00; br_2 7043.00; br_3 7006.00; and br_4 7017.00. These results show that only specimens br_1 and br_2 is able to produce better heating values than commercial briquettes. However, all specimens in this study are still able to meet the SNI 6235-2000 standard which states that the heating value produced by briquettes must exceed 5000 cal/g.

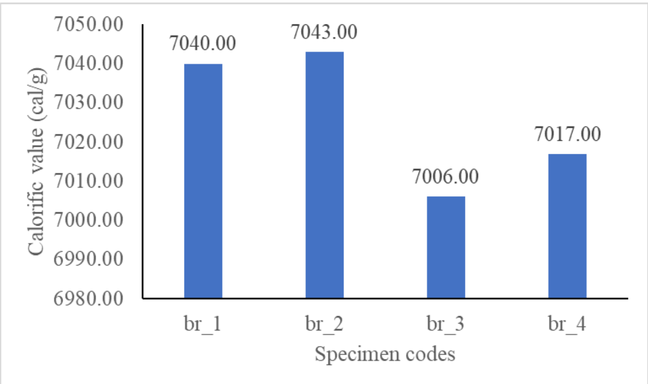

Figure 6 Comparison of calorific value of briquette specimens

The content of bound carbon in briquettes affects the calorific value of briquettes. The higher the carbon content of the briquettes, the higher the calorific value and thus the higher the combustion power. The addition of water in the briquetting process can indirectly affect the calorific value of the briquettes. This is because the higher the percentage of added water will result in ash content in the briquette which causes the bound carbon content in the briquette to decrease [21].

F. Density

Density is one of the important parameters that is an indicator of the quality of the briquettes produced. Density can be influenced by several factors including particle size, manufacturing method, and size of the briquettes made. The higher the density value of the material, the longer the combustion time that occurs, but the more difficult the material burns [22]. Figure 7 shows the comparison of water addition with the density of each specimen. The density test results (g/cm^3) of each specimen are br_1 0.99; br_2 1.00; br_3 1.02 g/cm^3 and br_4 0.90. These results show that all briquette specimens in this study are able to produce higher densities than commercial briquettes. Of the three specimens made in this study, br_2 and br_3 were able to meet the JIS standard which states that the density produced by briquettes should be between 1g/cm^3 to 2 g/cm^3.

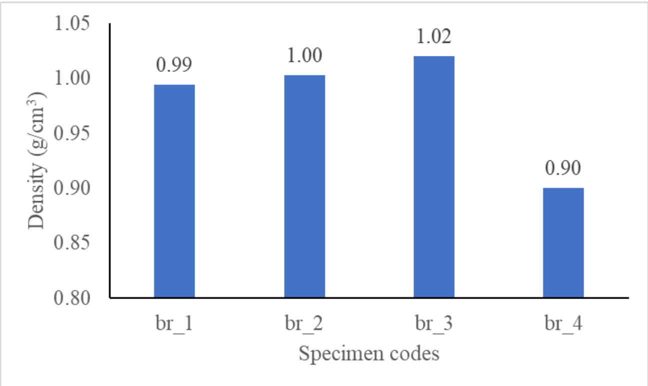

Figure 7 Comparison of density in briquette specimens

There is an increase in density value from specimen br_1 to br_3 and produces a difference of 0.03 g/cm^3 in each specimen. This shows that each addition of 1% water in the briquetting process will increase the density value by 0.03 g/cm^3. These results lead to the conclusion that the higher the amount of water used when making briquettes will increase the density value of the briquettes. The increase in density value along with the addition of water in the briquetting process causes particles to be more easily pressed to fill empty cavities, reduced porosity in this briquette which causes the increase in density value along with the addition of water in the briquetting process [23].

G. Drop Test

Drop test is a test to determine the value of briquette fragility and how much briquette particles are released due to impact after being dropped from a height [24]. Based on ASTM D-440-07 R02, the drop test is a test by dropping the specimen from a height of 1.83 m repeatedly until the number of times the specimen is dropped and deformation or crack occurs. Table 2 shows the results of the drop test and obtained size stability and friability data. Friability (%) obtained for each sample is br_1 14.93; br_2 4.44; br_3 43.30; and br_4 15.10. While the size stability (%) obtained for each specimen is br_1 85.07; br_2 95.56; br_3 56.70; and br_4 84.90. the best friability and size stability is obtained by specimen br_2 with each value yaiut 4.44% and 95.56. The drop test aims to determine the resistance of briquettes when hit by a hard object. So that it can minimize the occurrence of briquette damage during the process of packaging, distributing, and storing briquettes [25].

Table 2: Effect of Water Addition on Drop Test Index

Specimen codes	Size stability (%)	Friability (%)
br_1	85.07	14.93
br_2	**95.56**	**4.44**

br_3	56.70	43.30
br_4	84.90	15.10

H. Compressive Strength

Compressive strength is one of the factors that will determine the quality and durability of the briquettes produced. A good compressive strength value can increase the density and duration of combustion that can be produced by briquettes [26]. This test is carried out with a universal testing machine which works by applying pressure to the briquette specimen continuously until the briquette is deformed. Figure 8 shows the comparison between compressive strength with variations in water addition for each specimen. The results of the compressive strength test (kg/cm^2) of each sample are br_1 53.74; br_2 70.78 br_3 14.68; and br_4 33.24. From the test results, it can be stated that only specimens with the code br_1 and br_2 are able to produce better strength values than commercial briquettes. According to Japanese briquette standardization, only specimens with code br_2 are able to meet the minimum limit of 60 kg/cm^2. The compressive strength test is carried out to determine the limit of the briquette's ability to accept the load, the high compressive strength is influenced by the density and specific gravity of an object [27].

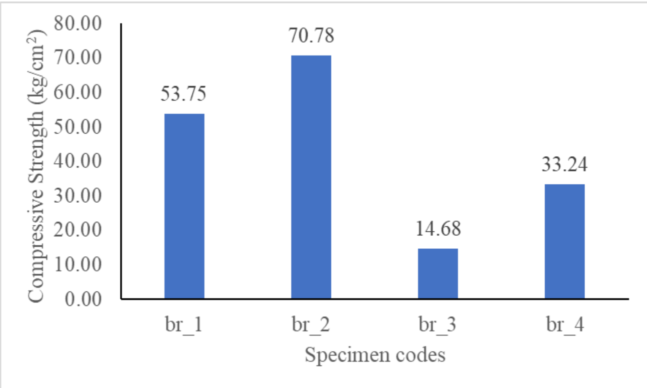

Figure 8 Comparison of briquette compressive strength results

I. Burn Duration

Burning duration testing is a test conducted to determine the time of the briquette flame when the briquette is fully lit until it becomes perfect ash. Burning duration can be influenced by several factors including moisture content, compressive strength, ash content, and calorific value. The lower the moisture content and ash content, the longer the duration of burning [28].

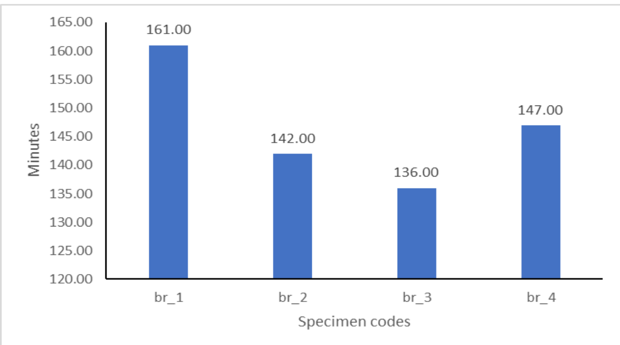

Figure 9 Comparison of briquette burn duration test results

Figure 9 shows the comparison between the duration of burning with variations in water addition. The test results of the combustion duration (minute) of each specimen are br_1 161.00; br_2

142.00; br_3 136.00 and br_4 147.00. From these results we can conclude that only the specimen with the code br_1 is able to obtain a higher combustion duration compared to commercial briquettes. The results of this study are less relevant to the research of Aziz et al., (2019) which states that the duration of combustion will decrease as the water content in the briquette increases [29]. In addition, other studies also state that the increase in fuel duration is due to the increase in volatile matter value and moisture content in briquettes [30], [31].

4. CONCLUSION

The manufacture of coconut shell charcoal briquettes with variations in the addition of water percentages of 20%, 25%, and 30% using a screw-type extruder machine was successfully carried out. With several tests such as moisture content, ash content, volatile matter content, bound carbon content, calorific value, density, brittleness, compressive strength, and combustion duration, we can know that the variation of water percentage addition in the briquetting process of coconut shell charcoal can affect the quality of briquettes. The results of this study were also compared with the characteristics of commercial briquettes and some parameters that have been established in several countries. The moisture content, ash content, and calorific value obtained in the research specimens were able to meet the Indonesian standards regulated in the SNI 01-6235-2000 criteria. As for the value of volatile matter content, bound carbon content, compressive strength, and brittleness are able to meet Japanese standards and British standards. From the results of the above research, the selected specimen with the code br_2 was able to produce briquettes with better mechanical properties when compared to other briquette specimens.

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