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Utilization of Cocoa Pod Husk and Wood Charcoal into Briquettes as an Environmentally Friendly Alternative Fuel

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Abstract

Many efforts have been made to convert cocoa pod husk waste into charcoal briquettes, but they have not yet met the established Indonesian National Standard (SNI). Therefore, steps are needed to produce charcoal briquettes that comply with these standards. One approach that can be taken is by blending cocoa pod husk with wood charcoal since wood charcoal has a sufficiently high calorific value that can enhance the quality of the charcoal briquettes. This research aims to find the optimal conditions for making briquettes from cocoa pod husk and identify the impact of briquette composition and carbonization time on values such as moisture content, ash content, calorific value, and burning rate of the produced briquettes. The research process includes carbonization, grinding, sieving, adding a binder, and drying, followed by testing the briquettes' characteristics. This research was conducted by comparing the mass composition of cocoa pod husk charcoal and wood charcoal at ratios of 100:0, 75:25, 50:50, and 25:75, with carbonization times of 1.5, 2, 2.5, and 3 hours. The best analysis results, in accordance with the Indonesian National Standard (SNI), were obtained at a carbonization time of 2 hours with a composition of 50:50 (cocoa pod husk:wood charcoal). The values include a moisture content of 5.944%, ash content of 7.83571%, calorific value of 4388.5 kcal kg^{-1}, and burning rate of 0.0034 g $second^{-1}$. The length of the carbonization process has a significant impact on the characteristics of the resulting briquettes, including moisture content, ash content, calorific value and burning rate. The longer the carbonization process, the lower the moisture content and ash content, and the higher the heating value and burning rate.

Keywords: Briquette, carbonization, charcoal, cocoa pod husk

INTRODUCTION

Recently, energy consumption, especially fuel oil and gas, has increased significantly as the price continues to soar while the supply is dwindling (Puspitawati *et al*., 2023). In 2021, fuel consumption in Indonesia amounted to 23 million kiloliters, while by the end of 2023, it will reach 33 million kiloliters. However, on the contrary, Indonesia also has abundant and renewable biomass energy sources. Unfortunately, its utilization has not yet reached the optimal point. Based on a report issued by Kementerian Riset dan Teknologi Republik Indonesia (Ministry of Research and Technology of the Republic of Indonesia) in 2023, there will be around 56.97 gigawatts (GW) of biomass energy in Indonesia (Kemen ESDM (2023). The data shows that the potential of biomass energy is vast, but it has not been fully optimized as an environmentally friendly alternative energy option (Patabang, 2011).

The type of biomass waste that has great potential and is very abundant is the residue generated from activities in the plantation sector, for example, waste from cocoa beans. Based on data from Ditjenbun (2022), Indonesia's cocoa bean production reached 667.3 tons. In 2024, Indonesia was named the world's sixth largest cocoa producer, behind fifth-ranked Brazil. As much as 90 percent of cocoa plantations in Indonesia are managed by small-scale farmers, with a land area of 0.5 to 1 hectare per household. About 75 percent of national cocoa production comes from the island of Sulawesi. According to data from Ditjenbun (2024), the top cocoa-producing provinces are Central Sulawesi, Southeast Sulawesi, South Sulawesi, West Sulawesi and Bengkulu (Tiofani & Wiiyanti, 2024).

The use of cocoa pod husk in the production of charcoal briquettes is a significant energy alternative, but further studies need to be conducted to collect data on the characteristics of the biomass energy. This biomass energy is a vital alternative for household energy needs that is environmentally friendly and renewable. Unlike fossil fuels, agricultural waste is not suitable to be burned directly as it faces constraints in the combustion process and handling. Therefore, its transformation into charcoal briquettes is a necessary step to address the problem of agricultural waste. This process not only allows for more efficient waste handling, but also increases the calorific value of the waste (Suprapti & Ramlah, 2013).

Biomass refers to a complex mixture of organic matter that generally consists of carbohydrates, fats, proteins, and small amounts of minerals such as sodium, phosphorus, calcium, and iron (Anggara, 2022). Carbohydrates, with about 75% dry weight, and lignin, with a maximum of 25%, are the main components in plant biomass. Although the composition may vary between crops, sustainability is a major advantage of using biomass as a fuel source. Estimates show that about 140 million tons of biomass matrices are used each year. Nonetheless, there are some limitations in utilizing biomass as fuel for motor vehicles (Ridhuan & Suranto, 2016).

Cocoa pod husk is a by-product of the cocoa crop (*Theobroma cacao*. L). Its nutritional composition is equivalent to grass, making it a potential source of biomass as an alternative feed to replace grass (Azizah *et al.*, 2022). In the cocoa pod structure, the rind makes up about 74%, the placenta about 2%, and the beans about 24%. The pod consists of ten grooves, five deep and five shallow, which criss-cross each other. The surface properties of the pod can vary, from smooth to rough, with various colors such as red green, pink, and dark red.

In terms of nutririon food content, cocoa pods can be used as feed because they contain crude protein of 11.71%, crude fiber of 20.79%, fat of 1.80%, and extractable material without nitrogen (EMWN) of 34.90%. According to Amirroenas (2003), cocoa pod husk contain a number of main components, including cellulose as much as 36.23%, hemicellulose about 1.14%, and lignin in the range of 20% to 27.95% (Poedjiwidodo, 1996).

Research on briquette making has also been carried out with cocoa husk and coal with a carbonization process. Briquettes were made from the carbonization process at 180 °C, then mixed with the composition of the mass of materials cocoa pod husk and coal 10:90, 15:85, 20:80, 25:75, and 30:70. From the results of the experiment it can be concluded that the more coal the higher the calorific value. In the composition of the mass of material 10:90, the highest calorific value is obtained, which is 6018 cal g^{-1} (Billah *et al.*, 2021).

Briquettes are made from the carbonization process with a time of 4 hours, then the carbon is refined to a size of 30, 50, and 70 mesh. The smaller the size of the carbon, the higher the heating value produced. The calorific value for 30 mesh size is 4163.11 cal g^{-1}, 50 mesh is 4281.61 cal g^{-1}, and 70 mesh is 4372.54 cal g^{-1} (Usman, 2017).

Research on briquettes has also been carried out with teak wood charcoal and coconut shell with a carbonization process. Briquettes are made from the carbonization process with a certain time, then carbon is mixed with a mass composition of 1:1 (finished wood charcoal: coconut shell), and added tapioca starch adhesive with a mass of 5%, 7%, and 10% of the total mass of ingredients. The best heating value was obtained with 5% adhesive concentration, which amounted to 5779.5 cal g^{-1} (Handoko *et al.*, 2019).

The Indonesian Coffee and Cocoa Research Institute states that cocoa pod husk is very abundant. One of the efforts in order to provide alternative energy as well as an alternative to the handling of cocoa pod husk is to utilize the waste as raw material for making briquettes (Pujiyanto, 2019). This research aims to utilize cocoa pod husk as raw material for briquettes, which is expected to help increase the economic value of cocoa pod husk. In this research, the mixing of cocoa pod husk charcoal and teak wood charcoal is carried out so that it is expected to increase the calorific value produced.

MATERIALS AND METHODS

Dried cocoa pod husk was obtained from the Indonesian Coffee and Cocoa Research Institute and wood charcoal was obtained from micro small medium enterprises (MSME) traders around Jember regency, Indonesia.

This research begins with cleaning the dirt on the cocoa pod husk and after cleaning, it is dried in under the sun until the texture of the cocoa pod husk hardens. Then the dried cocoa pod husk is put into the furnace for the carbonization process with a duration of 1.5, 2, 2.5, and 3 hours. After the carbonization process is complete, the cocoa pod husk charcoal is crushed by a hammer mill and sieved to 30 mesh. After that, cocoa pod husk charcoal is mixed with wood charcoal with 1) mass ratio of 100:0, 75:25, 50:50, and 25:75 at carbonization time of 1.5 hours. 2) Mass ratio of 100:0, 75:25, 50:50, and 25:75 at carbonization time of 2 hours. 3) Mass ratio of 100:0, 75:25, 50:50, and 25:75 at carbonization time of 2.5 hours. 4) Mass ratio of 100:0, 75:25, 50:50, and 25:75 at carbonization time of 3 hours. All treatments added tapioca starch adhesive as much as 12.5% of the total mass of the material. After mixing, the materials were molded with briquette molds and dried using an oven at 105 °C for 2 hours. After drying, the briquettes were placed in a desiccator to remove any remaining moisture. The finished briquettes were then analyzed for moisture content, ash content, calorific value, and burning rate.

Moisture Content Analysis

The procedure for measuring moisture content is that porcelain cups are oven at 105 °C for 1 hour. Cool in a desiccator for ½ hour, then weigh the empty porcelain cup. Put the sample into a porcelain cup (porcelain cup + sample weight). Put in the oven at 105°C for 2 hours, cool in a desiccator for ½ hour. Then weighed and heated into the oven at the same temperature and weighed again. The quality of moisture content can be calculated using an oven. Moisture content can be obtained using the equation:

Moisture content (%) =

(G0 - G1)/G0 x 100%

where,
G0 = sample weight before drying (g)
G1 = sample weight after drying (g)

Ash Content Analysis

The procedure for measuring ash content is to put the sample in a porcelain cup, weighed first. Then enter the furnace at 300 °C for 1.5 hours. After that, the temperature is increased to 600 °C for 2.5 hours. Then weighed after the furnace time was over. The quality of ash content can be calculated using a furnace. Ash content can be obtained using the equation:

Ash content (%) = (C/A) x 100%

where,
A = weight of material before ignition (g)
C = weight of ash/residue (g)

Calorific Value Analysis

The calorific value measurement procedure is weighing 1 g of sample that has been separated into an iron cup. Prepare a series of calorimeter bombs, connect with platinum wire and touch with the sample. Put 1 mL of water into the calorimeter bomb vessel, then insert the calorimeter bomb circuit into the vessel. Close the lid and fill with gas at 130 atm pressure. Filling the calorimeter bomb bucket with 2 L of water and inserting it into the calorimeter bomb jacket. Inserting the bomb vessel into the bucket and closing the lid. Started the engine and looked at the initial temperature. After 5 minutes, pressed the combustion button and left for 7 minutes. Look at the final temperature and turn off the engine. The quality of the calorific value can be measured using a bomb calorimeter (cal g^{-1}). The calorific value can be obtained by using the equation:

HHV = (T2-T1 - 0.05) x Cv

where,
T1 = Temperature before bombardment (°C)
T2 = Temperature after bombardment (°C)
1 Joule = 0.239 cal
HHV = Quality calorific value (cal g^{-1})
Specific heat of bomb calorimeter (Cv) = 73529.6 (joule g^{-1} °C)
Igniter wire temperature rise = 0.05 °C

Burning Rate Analysis

Burning rate analysis is a testing process by burning briquettes to determine the duration of a fuel flame, before the mass of the briquette is weighed first. The length of time of ignition is calculated using a stopwatch and the mass of the briquette is weighed with an analytical balance. The equation used to determine the combustion rate is:

$$\text{Burning rate} = \frac{\text{briquettes mass (g)}}{\text{burning time (sec)}}$$

RESULTS AND DISCUSSION

Moisture Content of Briquettes

The moisture content in briquettes has an influence on the heating value, where the lower the moisture content, the higher the heating value (Saleh *et al.*, 2017). Charcoal briquettes tend to have low moisture content. Therefore, the calculation of moisture content aims to evaluate the low level of moisture in the charcoal briquettes. Information on the moisture content for each treatment can be found in Figure 1.

Figure 1 displays the moisture content values of each treatment variation in the briquetting process. Among the composition

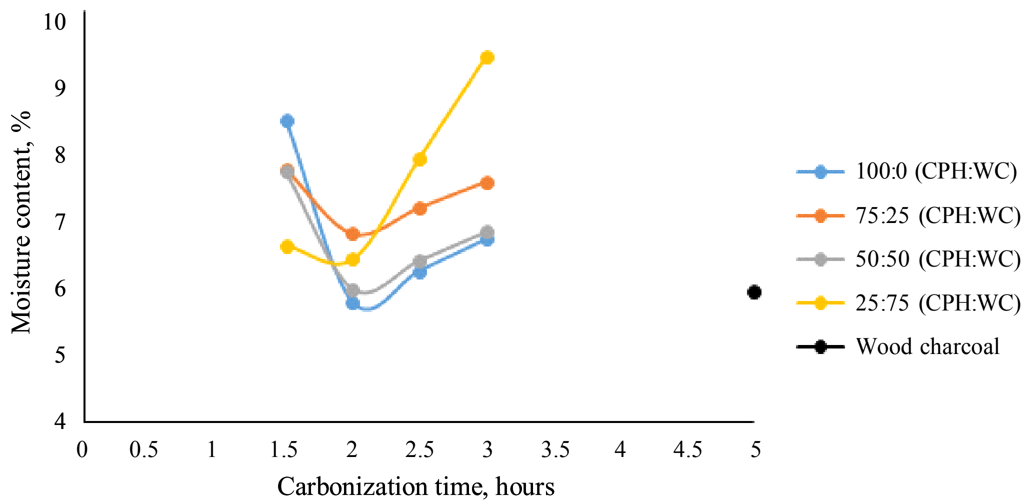

Figure 1. Relationship between carbonization time and moisture content of each mixture of cocoa pod husk charcoal (CPH) and teak wood charcoal (WH)

mixtures ranging from 100:0 of each mixture of cocoa pod husk charcoal (CPH) and teak wood charcoal (WH) to 25:75 (CPH:WC) at all carbonization times. A longer carbonization process should tend to produce lower moisture content, but in this case the opposite happened. Based on the data in Figure 1, the average value of water content tends to decrease at carbonization for 1.5 hours and 2 hours, but increases again at carbonization for 2.5 hours to 3 hours. This is due to the longer carbonization time, the more open the pores in the charcoal (Ganing *et al.*, 2021). Therefore, when the charcoal is transferred from the furnace to the container and weighing device, the hygroscopic charcoal will absorb more water vapor from the surrounding air.

The lowest moisture content was recorded in the 100:0 mixture (CPH:WC) with a carbonization duration of 2 hours, which was 5.75%. For comparison, the moisture content of briquettes made from cocoa pod husk and wood charcoal was compared with the standard wood charcoal briquettes. The results show that the average value of moisture content of all treatments is 7.07%, which has met the briquette standard set by SNI 01-6235-2000, which is a maximum of 8%.

This study shows that variations in briquette composition do not significantly affect the value of water content, because the difference in water content between briquettes is not so great. The average value of water content of all carbonization times in the composition 100:0 (CPH:WC) is 6.76%, in the composition 75:25 (CPH:WC) is 7.27%, in the composition 50:50 (CPH:WC) is 6.68%, and in the composition 25:75 (CPH:WC) is 7.54%. The difference in water content is not too significant.

Besides being affected by carbonization time, the moisture content of briquettes can also be affected by storage conditions, especially in humid conditions where charcoal can absorb moisture from its surroundings.

Ash Content of Briquettes

The residue obtained after the combustion process that does not contain carbon is called ash. The main component in ash is silica. The ash content in briquette production has a significant impact, as high ash content can reduce the quality of briquettes by forming crust (Arifah, 2017). Information regarding ash content values for each treatment can be found in Figure 2.

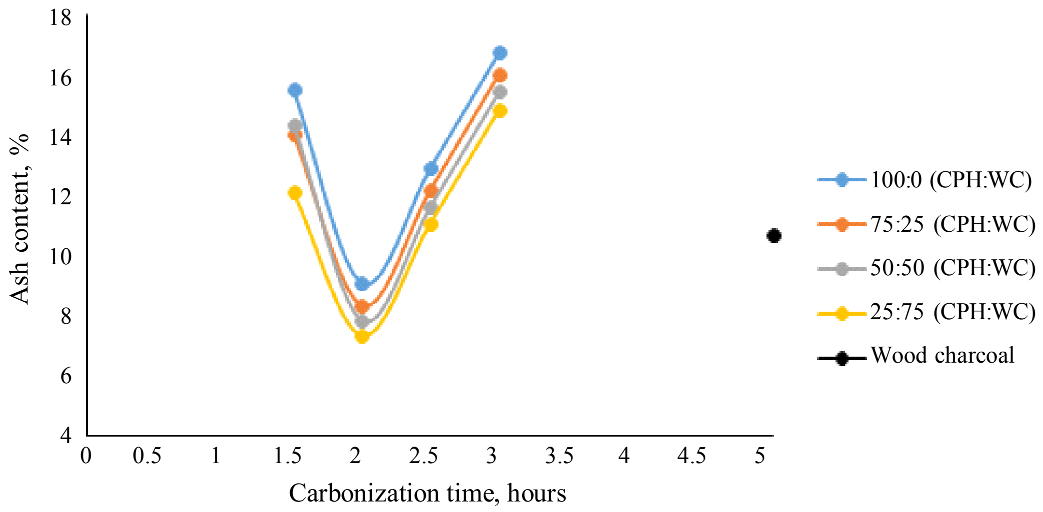

Figure 2. Relationship between carbonization time and ash content in each mixture of cocoa pod husk charcoal and teak wood charcoal

Figure 2 shows the ash content of each treatment variation in the briquetting process. From the composition mixture between 100:0 (CPH:WC) to 25:75 (CPH:WC) at all carbonization durations. According to Sinaga (2017), the ash content of briquettes tends to decrease as the charring time increases. However, the results of this experiment are not fully in line with this theory. Based on the data in Figure 2, the average ash content value tends to decrease at carbonization for 1.5 hours and 2 hours, but increases again at carbonization for 2.5 hours to 3 hours. This is due to the fact that the longer the carbonization process, the more the carbonized material will turn into ash. Thus, during the charcoal smoothing process, the ash will be mixed with the charcoal and during the sieving process, the ash becomes part of the smaller-sized material.

The lowest ash content was recorded for the 25:75 mixture (CPH:WC) with a carbonization duration of 2 hours, which was 7.33%. For comparison, the ash content of briquettes made from cocoa pod husk and wood charcoal was compared with the standard wood charcoal briquettes. As a result, the average ash content of all treatments was 12.47%, which still does not meet the briquette standard set by SNI 01-6235-2000, which sets the maximum value at 8%. However, some treatments did meet the standard.

This study also showed that variations in briquette composition had little effect on ash content. The highest average ash content was recorded at 100:0 (CPH:WC) for all carbonization durations, while the lowest average ash content was recorded at 25:75 (CPH:WC). This shows that as more charcoal from cocoa pod husk is used, the ash content tends to increase, and vice versa. This is due to the presence of impurity minerals in the cocoa pod husk that cannot be evaporated, such as SiO_2, Fe_2O_3, and alkali.

Calorific Value of Briquettes

The quality of the briquettes produced is highly dependent on the heating value, often referred to as Heating Value (HV), and is a key parameter in evaluating briquettes. The lower the moisture content and ash content in the briquettes, the higher the heating value. A breakdown of heating values can be found in Figure 3.

Figure 3 shows the calorific value of various treatments in the briquetting process, ranging from a mixture composition of 100:0 (CPH:WC) to 25:75 (CPH:WC). Supposedly, the longer the carbonization process, the higher the heating value produced, but in this case the opposite happened. Based on Figure 3, the average heating value tends to increase at carbonization for 1.5 and 2 hours, but decreases at carbonization for 2.5 hours and 3 hours. This is due to the opening of charcoal pores during the longer carbonization time, so that the charcoal absorbs more moisture when transferred from the furnace to the container and scales (Ganing *et al.*, 2021). As a result, the water content trapped in the charcoal increases, which then has an impact on reducing the calorific value.

The highest calorific value was recorded at a mixture composition of 100:0 (CPH:WC) with a carbonization duration of 2 hours, reaching 4465.1 kcal kg^{-1}. Wood charcoal briquettes were used as a reference to compare the calorific value of briquettes made from cocoa pod husk and wood charcoal. However, all treatment results are still below the value of 5000 kcal kg^{-1}.

From Figure 3, it can be seen that variations in the composition of briquette raw materials produce different values. Changes in composition can increase the calorific value of briquettes. Therefore, the greater use of charcoal from cocoa pod husk in briquettes results in an increase in calorific value. Based on theory, high calorific value is usually associated with low moisture content. Muzakir (2017) stated that the higher the moisture content, the lower the calorific value of the resulting charcoal briquettes. Thus, the calorific value of charcoal briquettes from cocoa husk and wood charcoal for all mixture compositions has not met the minimum standard of 5000 kcal kg^{-1} set by SNI 01-6235-2000.

Briquette Burning Rate

The burning rate reflects the rate of weight loss of briquettes per second during the combustion process. The higher the burning rate, the faster the briquettes will burn. The combustion rate test data for each treatment can be seen in Figure 4.

Figure 4 shows the combustion rate test results from various treatments in the briquetting process. Starting from a mixture composition

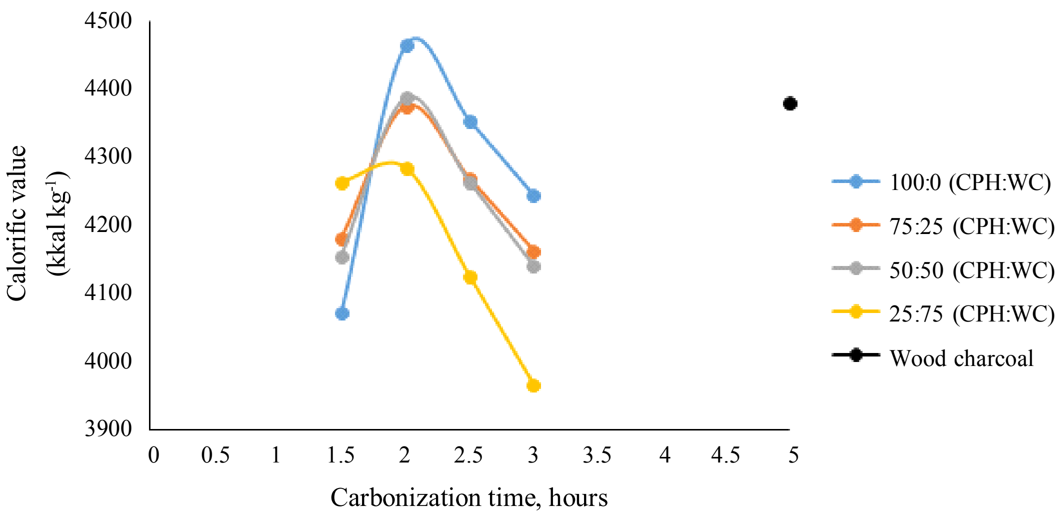

Figure 3. Relationship between carbonization time and calorific value of each mixture of cocoa pod husk charcoal and wood charcoal

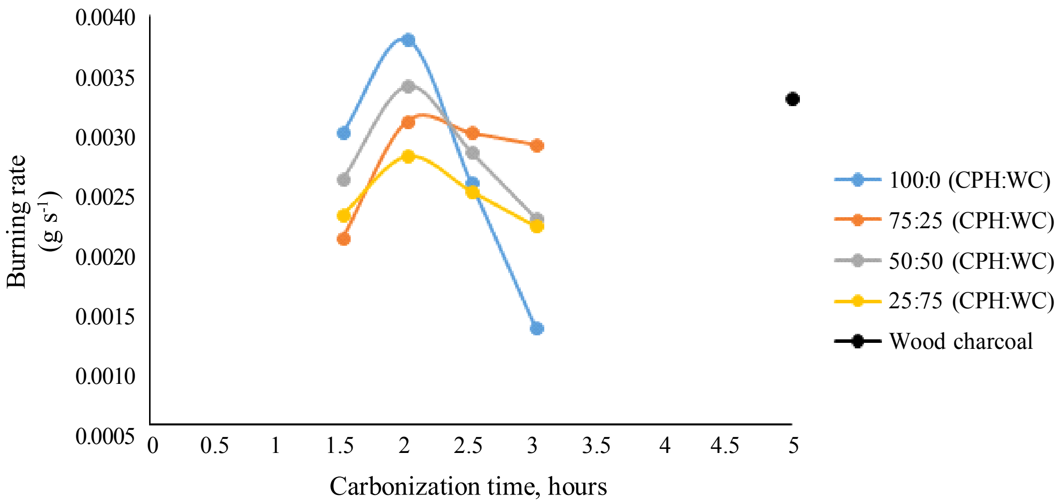

Figure 4. Relationship between carbonization time and combustion rate for each mixture of cocoa pod husk charcoal and wood charcoal

of 100:0 (CPH:WC) to 25:75 (CPH:WC), with various carbonization times. At carbonization for 1.5 hours and 2 hours, the burning rate tends to increase. However, after 2.5 hours to 3 hours of carbonization, the burning rate of the briquettes decreased. This is consistent with the results of moisture content and ash content in Figure 1 and Figure 2, where the burning rate of briquettes is faster when moisture and ash content are low. Conversely, when the moisture and ash content are high, the burning rate becomes slower.

The highest combustion rate was observed at 100:0 (CPH:WC) with a carbonization time of 2 hours, reaching 0.0038 grams second^{-1}. As a comparison, wood charcoal briquettes were used as a burning rate standard for briquettes made from cocoa pod husk and wood charcoal.

Variations in briquette composition in this experiment did not significantly affect the burning rate. The average burning rate of all carbonization times at 100:0 (CPH:WC) composition is 0.0027 g second^{-1}, at 75:25 (CPH:WC) composition is 0.0028 g second^{-1}, at 50:50 (CPH:WC) composition is 0.0028 g second^{-1}, and at 25:75 (CPH:WC) composition is 0.0025 g second^{-1}. According to Sumangat (2019), the burning rate of briquettes is influenced by the density of the briquettes. Briquettes that are too dense are difficult to burn, while those that are too loose can decompose during combustion. However, in this study, the briquette density factor was set as a fixed condition.

CONCLUSIONS

The best analysis results and in accordance with SNI are at a carbonization time of 2 hours with a composition of 50:50 (CPH:WC) with a moisture content of 5.944%, ash content of 7.83571%, calorific value of 4388.5 kcal kg^{-1}, and combustion rate of 0.0034 g second^{-1}.

The length of the carbonization process has a significant impact on the characteristics of the resulting briquettes, including moisture content, ash content, heating value, and burning rate. The longer the carbonization process, the lower the moisture content and ash content, and the higher the heating value and burning rate. However, at carbonization for 2.5 hours and 3 hours, there is an increase in moisture content and ash content, as well as a decrease in calorific value and burning rate. The mass composition of materials in briquetting tends to have less impact on moisture content and burning rate. However, it does have an effect on ash content and heating value. The more cocoa pod husk charcoal used, the more the ash content and calorific value will tend to increase.

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