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The utilization of durian peels (*Durio zibethinus*) for the manufacturing of charcoal briquettes as alternative fuel

Sitti Rahmawati, Afadil, Suherman, Tri Santoso, Paulus Hengky Abram, Rabasia

Mathematics and Sciences Division, Faculty of Teacher Training and Education, Tadulako University, Palu, 94118, Indonesia

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Corresponding Author:
Sitti Rahmawati
Chemistry Study Program, Mathematics and Sciences Division, Faculty of Teacher Training and Education, Tadulako University;
Phone: +6285241111314
Email: sittirahmawati.q3a@gmail.com

Abstract. *Durian peels is a biomass waste that can be used as an alternative fuel in charcoal briquettes. Durian peels contain combustible materials, namely high cellulose (50 - 60%) and lignin (5%), and low starch (5%). This study aims to determine the characteristics of charcoal briquettes from durian skin waste using adhesive from sago starch as an alternative fuel. The adhesive used is adhesive from sago flour, which is 3% of the weight of the charcoal used. In this study, 500 g of charcoal was used, so the adhesive used was 15 g. The results of testing the quality of briquettes products made from durian peels obtained calorific value (5,189.13 cal/g), moisture content value (3.60%), ash content value (3.56%), volatile matter value (21.13%), and the value of bounds carbon content (69.23%), density (0.48 g/cm^3), combustion rate (0.22 g/sec). Briquettes produced from durian skin waste using starch from sago as an adhesive can be used as an environmentally friendly alternative fuel.*

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INTRODUCTION

Recent energy crises demonstrate that the maximum level of energy consumption has been achieved. This incident serves as a warning to humanity that the era of cheap and abundant energy has finished and will soon be nothing more than a distant memory that future generations will not have the opportunity to experience. This is due to the consumption of resources, particularly fossil fuels, which have become limited without regard for what would occur when these energy sources run out. The problem of scarcity is what motivates individuals to make sacrifices and consider alternate energy sources cautiously. Human efforts to find alternative energy sources should be based on raw resources that are readily available, renewable, and produce goods that can be utilized by all people.

Organic waste biomass is one of the raw materials that can be used as an alternative fuel. The trash comprises of plant and animal components extracted from nature or derived from agriculture, fishing, or other human activities. Biomass has the capability of being converted into alternative energy sources with relatively high energy content, such as rambutan peel waste and durian skin waste (Rahmawati 2013; Faisal et al. 2018). Other plentiful and underutilized forms of solid organic waste (biomass) include durian skin waste. Durian is a tree-like wild fruit plant native to the forests of Malaysia, Sumatera, and Kalimantan. Since the seventh century AD, this durian fruit has been known in Southeast Asia. Currently, an increasing number of people are interested in planting durian. Given the high demand and price compared to other fruits, this fruit is indeed commercially viable (Ding et al. 2015).

The market penetration of durian is anticipated to be fairly high during the next two decades. The durian market potential in Indonesia may still absorb the expansion of up to 100,000 ha at a production rate of 10 tons per hectare or one billion kilograms each season, according to a rough assessment. This computation is based on the assumption that the Indonesian population's annual durian absorption capacity can exceed 5 kg (1.5 grains) per person (Wiryanta 2008). In addition to generating edible fruit, durian also generates trash in the form of durian seeds and durian skin. These wastes are both considered organic waste. You may imagine how much durian-related organic garbage will be produced if durian fruit output reaches 10 tons per hectare, or 3,956 tons especially for production in Central Sulawesi. Considering that thousands of tons of durians are produced annually, the amount of organic waste is undoubtedly considerable. According to the calculations stated above, the improper handling of durian fruit production will indirectly produce an environmental concern. So far, Indonesians have only used durian to make delicacies such as lunkhead, a blend of compote, jam, a mixture of cake components, and tempoyak using the fruit's flesh and seeds. Meanwhile, the skin will become less valuable garbage (Wiryanta 2008).

Durian peel waste has enormous promise as an alternative source of renewable energy raw material. The primary utilizable component is carbs. The concentration of carbohydrates in durian skin is relatively significant. Durian skin fiber is a byproduct of durian fruit; approximately 60 - 75% of durian fruit is composed of durian skin fiber. Lignin (15.45%), hemicellulose (13.09%), and cellulose (60.45%) make up durian peel (Aimi et al. 2014; Hambali and Rifai 2017; Langkai et al. 2015). These substances are flammable substances. This indicates that durian skin can be converted into alternative fuels, hence resolving environmental issues caused by durian skin waste in the form of pollution.

Numerous studies have been conducted on durian skin briquettes, including the features of durian skin and janeng starch adhesive briquettes. The calorific value of peel briquettes is 5,040 cal/g, the time necessary to ignite the briquettes is 10 minutes, and the duration of the flame on the briquettes without producing smoke at the commencement of burning is 55 minutes (Irhamni et al. 2019). The purpose of the research on the utilization of other durian skin waste is to produce durian skin briquettes via the carbonization process. The results indicated that the calorific value of durian skin was 4,569.54 kcal/kg, with a water content of 12.0% and an ash content of 15.0% (Shobib et al. 2018). In addition, the production and characterisation of a blend of durian skin and bintaro fruit as briquette fuel have been studied. The findings of the briquettes' characterisation yielded the optimal ratio of 50:30:20, with the lowest water content of 7.30%, the lowest ash content of 10.14%, the lowest volatile matter content of 89.75%, and the maximum heating value of 5,721 cal/gram (Fardani and Tjahjani 2018).

The reality is that Central Sulawesi durian skin waste has not been utilized. Therefore, researchers are seeking solutions for transforming durian skin waste into a marketable and economically viable fuel product that can compete with other products, such as transforming it into charcoal briquettes. In this work, sago starch adhesive was utilized to create durian shell charcoal briquettes, which had not been employed in prior investigations.

METHODS

Materials and Tools

Large paint cans, containers, charcoal briquette presses, small scales, charcoal briquette stoves and ordinary stoves, pans, wooden spoons, thermometers, compaction tools, 60 mesh sieves, bomb calorimeters, banana leaf, cups, furnace, and a digital scale were used in this study. Durian peel waste, kerosene, sago flour, and water are the ingredients.

Charcoal Production with Discarded Durian Skins

Put in durian peels, pour a little kerosene, and burn it, as shown in Figure 1. When the paint cans is about half filled, the fire decreases and goes out, meaning that the durian peels have become charcoal. Roll the paint cans, and pour water so that the smoldering durian peels do not turn to ashes so that charcoal is obtained.

Figure 1 Iron tin cans are used as a place to make charcoal

Making Charcoal Briquettes

In this study, participants weighed up to 500 grams. The adhesive combination, comprised of sago flour, was then measured to be 15 grams, or approximately 3% of the weight of charcoal powder. Prepared 517 ml of water to be combined with sago flour, heated it on the stove (warmer), and swirled it slowly to prevent clumping in order to make a gel. This sago glue is intended for use in conjunction with charcoal flour. The resultant gel is added to a bowl containing charcoal flour and stirred until thoroughly combined. The charcoal and sago gel combination is poured into the mold and compressed until solid. The resulting briquettes are sun-dried to remove moisture. Figure 2 depicts the method for producing durian shell charcoal briquettes and their characterisation.

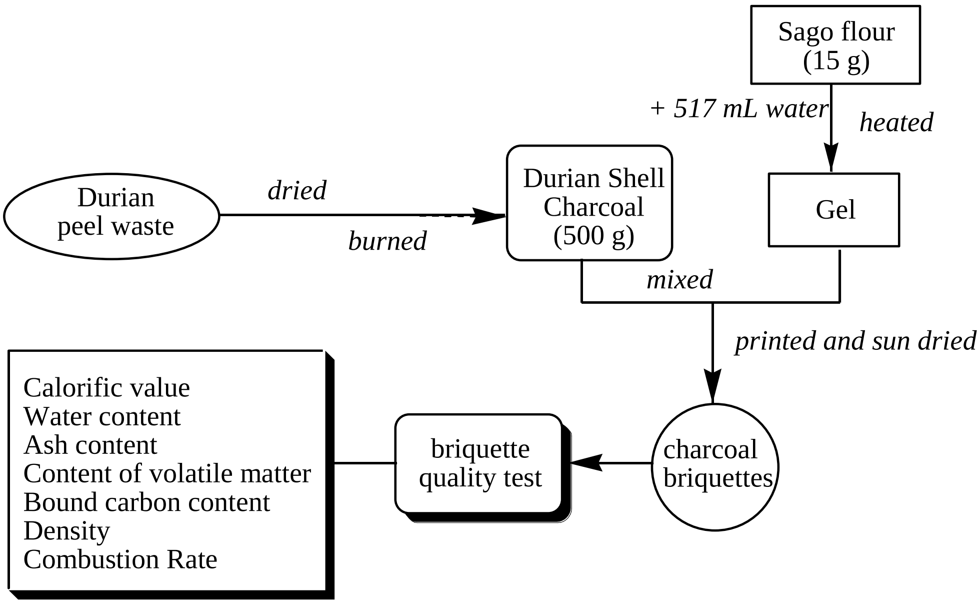

Figure 2 Scheme of making durian shell charcoal briquettes and their characterization

Testing of The Resulting Charcoal Briquettes

Chemical compositions like as ash content, volatile matter content, and bound carbon content are typically utilized to determine the quality of charcoal briquettes. Mechanical properties in addition to physical properties such as water content, specific gravity, and calorific value (Supriadi et al. 2022; Rahmawati et al. 2020; Rahmawati 2013)**.**

Determination of Calorific Value

The value of a fuel is the amount of heat energy that can be emitted per unit mass of the fuel when it completely burns (expressed in kilocalories per kilogram). The calorific value is determined by measuring the change in temperature at a constant volume to determine the amount of energy produced by burning one gram of charcoal. One calorie represents the amount of heat energy necessary to increase the temperature of one gram of water by one degree Celsius or Kelvin. Calculating the calorific value test using the equation:

$$\text{Calorific Value} = \frac{(\Delta \text{T} \times \text{Cv}) - \text{wire correction}}{\text{m}}$$

The sample is weighed up to 1gram and put in a cup for the calorific value test. The nickel wire should then be trimmed to 10 cm in length, attached to the positive and negative valves in the cup holder, and touched to the sample. Do not allow the nickel wire to escape from the sample when you slowly place it into the reactor and tighten the lid. Then, dispense oxygen gas into the reactor at a pressure of 20 - 30 atm. Water, approximately 2 L, is poured into the heating vessel tube. The positive and negative valves are connected to the current by the reactor, which is put into the heating vessel.

Correctly shut off the gadget. Make sure the stirrer is turned on and the specific thermometer bomb calorimeter is installed correctly so that the temperature in the heating vessel is steady and uniform (stirring for 5 minutes). Once the burner is turned on, watch the temperature rise as the combustion changes its starting point and continues to rise until it reaches a consistent temperature (record the temperature as the final temperature). In order to release oxygen, turn off the device, remove the reactor, special thermometer bomb calorimeter, and oxygen valve. Next, clean the reactor by opening it. To acquire the Energy Tara, calibrate the combustion tool using benzoate as a reference as in the preceding operating procedures (W).

Determination of Water Content

This charcoal is made from durian peels, which have a low water content and a high calorific value. Charcoal with a low water content value has a high calorific value. The basic idea behind calculating the water content is to use heat energy to evaporate any free water that is present in the briquettes until there is a balance between their water content and the air around them. A porcelain dish with a known dry weight was filled with a sample of 1 gram (air dry weight). The sample-containing cup spent three hours being cooked in an oven at 105 °C.

$$\%\text{Moisture Content} = \frac{\text{Initial sample weight} - (\text{weight of the cup} + \text{final sample})}{\text{Initial sample weight}} \times 100\%$$

The oven's sterilization setting was set to 105 °C for the porcelain dish. To obtain the dry mass, the porcelain bowl was placed in a desiccator to cool. Blend the sample of briquettes. Utilize a digital balance to determine the sample briquette's mass. A cup containing a sample of briquettes is placed in an oven set to approximately 106.5°C. every 15 minutes, check. Remove from the oven, allow to cool for 5 minutes in the open air, then 8 minutes in a desiccator, and so on until constant. The moisture content of the sample of charcoal briquettes can be determined by weighing it until it reaches a steady weight.

Determination of Ash Content

High ash briquettes are particularly undesirable because they will crust over. The health of those nearby will also be impacted by this. The general rule is that the residual minerals from the combustion of organic matter at a temperature of roughly 600 °C are weighted to estimate the overall amount of ash in the substance. A 600 °C electric furnace is used to heat an empty porcelain cup until the weight of the cup remains constant. The sample is then placed into the porcelain cup. A sample in a cup was put back into the electric furnace at 600 °C for three hours. Afterward, it was dried in a desiccator and weighed.

$$\%\text{ash Content} = \frac{\text{Ash Weight}}{\text{Initial sample weight}} \times 100\%$$

A desiccator (dryer) was used to cool the cup after it had been introduced to the 600 °C furnace, and then it was weighed. To the cup, add 1 - 2 grams of the specimen. Close the cup once again, let it cool in a desiccator for an hour, then weigh it. Repeat the drying and weighing process until you reach a constant weight of 0.1 mg. Keep the cup closed while cooling and weighing to prevent moisture from the air from absorbing into the sample. Keep track of the combined weight of the dried specimen and the cup. Burn the closed cup's contents completely in the furnace after placing them there. Heat slowly at first to prevent fire and prevent the crucible from hard splashing, which will preserve the specimen. It is advised to burn fuel at a temperature of 580 - 600 °C. Open the lid of the desiccator and place the cup inside with its contents. Cool and precise weighing. Once the weight is consistent at 0.20 mg after cooling, repeat heating for 30 minutes.

Content of Volatile Matter

The principle for estimating the concentration of volatile compounds is to evaporate non-aqueous substances using heat energy. A porcelain dish containing water content samples is heated in an electric furnace at 950 °C for 15 minutes, cooled in a desiccator, and weighed. The level of temperature employed during the charcoal-making process will alter the concentration of volatile compounds. The greater the temperature, the lesser the amount of volatile compounds in the created charcoal.

$$\%\text{ volatile matter content} = \frac{\text{dry sample weight} - \text{dry sample weight of the moisture content}}{\text{initial weight sample at moisture content}} \times 100\%$$

The to-be-utilized empty cup is weighed on a computerized scale. Filled with samples generated from the water content computation. 15 minutes of heating at 800 - 900 °C in a furnace. The briquettes are cooled in a dehydrator (cooler). After cooling, the briquettes are weighed.

Bound Carbon Content

The bound carbon content influences the calorific value; the higher the bound carbon concentration, the greater the calorific value, as every oxidation reaction generates calories. Due to the varying chemical composition of different types of wood, the kind of wood has a significant impact on the carbon content of briquettes. The following equation is used to calculate the bound carbon content using the ASTM D-3172 standard:

$$\text{Bound Carbon content (\%)} = 100 - (\text{Ka} + \text{Vm} + \text{Ash})$$

Description:
Ka = Moisture content (%)
Vm = Volatile matter (%)
Ash = Ash Content (%)

If the water content, ash content, and volatile matter content of the briquettes are known, the bound carbon content can be calculated.

Density

The density of a material is the sum of its mass per unit volume. Briquette packaging, storage, and transportation will be influenced by density. The greater the density, the less space is required for the same weight of briquettes (Supriadi et al. 2022; Rahmawati 2013; Oladeji and Enweremadu 2012). The density is determined concurrently with the water content, ensuring that the test samples are identical. To determine the dimensions of the briquettes, they must first be measured and weighed.

$$\text{Density} = \frac{\text{Weight(g)}}{\text{Volume } (cm^3)}$$

Prepare all the equipment used, including the test object, weigh the briquettes, then measure the briquette volume (cylinder volume) by measuring the height and diameter of the briquettes.

Combustion Rate

The principle used is to determine the weight of the burned briquettes per unit of time. This burning rate is related to the density of the briquettes. The burning rate is expressed by the following equation:

$$\mathrm{v} = \frac{\mathrm{Mt}}{\mathrm{t}}$$

where:
v = Rate of burning briquettes (g/sec)
Mt = Mass of briquettes burned (g)
t = Time spent burning (sec)

RESULTS AND DISCUSSION

The mixture of charcoal and sago gel is placed in the mold and pressed until solid. This procedure is designed to turn the dough into briquettes with good usability and results. The higher the applied pressure, the better and denser the density. A cylindrical briquette mold, such as a pipe, is used in briquette printing to make charcoal briquettes more dense and regular. After being molded into charcoal briquettes, the charcoal is sun-dried for five days. Figure 3 depicts the results of printing charcoal briquettes. After drying, the calorific value, moisture content, ash content, volatile matter content, bound carbon content, density, and combustion rate of the charcoal briquettes are all tested.

Figure 3 Results of printing charcoal briquettes

Calorific Value

The calorific value of an object is usually associated with its ability to conduct heat. Heat transfer is the amount of heat transferred over time to a British Thermal Units (BTU) that object with a thickness of one inch and a surface area of one foot square. One hour to raise the temperature of the object's surface by 10 °F. Briquettes with a high calorific value will be of high quality. In this study, the calorific value of the briquettes was determined in the laboratory using a bomb calorimeter. Prof. SW Parr invented this tool in 1,912, so it is also known as the "Parr Oxygen Bomb Calorimeter" (Figure 4).

Figure 4 Parr oxygen bomb calorimeter

The results of the calorific value analysis of briquettes in this study can be seen in Table 1, which shows the results of the calorific value analysis of durian skin briquettes, which is 5,189.13 cal/g. The analysis results show that the heating value of the durian peels briquette sample exceeds the standard of bio-coal, which is 5,189.13 cal/g (Ministry of Energy and Mineral Resources No. 047 of 2006). This study's calorific value is higher than that of durian peel briquettes with janeng starch adhesive, 5,040 cal/g, and lower than that of durian peel briquettes with tapioca flour adhesive, 4,569 cal/g, but higher than that of durian peel and bintaro peel briquettes, 5,721 cal/g (Irhamni et al. 2019; Shobib et al. 2018; Fardani and Tjahjani 2018). This is due to differences in briquette composition. According to this research, the charcoal produced is of high quality and has a high calorific value. Furthermore, increasing the compression rate of charcoal briquettes raises the specific gravity, and using different pressures affects the calorific value, which indicates the briquettes' quality level (Afra et al. 2021; Sunardi et al. 2019; Supriadi et al. 2022; Rahmawati et al. 2020).

Table 1 The Results of Calorific Value Analysis on Durian Peels Briquettes

Temperature		**T2 - T1**	**m (gr)**	**calorimeter heat capacity (w=Cal/°C)**	**Wire correction**		**Calorific value (cal/g)**
T2	**T1**				**2.3**	**6.6**	
30.5	28.85	1.65	0.54	1,707.46	15.18		5,189.13

Moisture Content

Charcoal with a high calorific value has a low water content value. This charcoal is made from durian peels, which contain little water. The higher the water content of the durian skin, the more heat will be required to remove the water into steam during the carbonization of the durian peels, resulting in a smaller amount of energy remaining in the charcoal. In this study, the moisture content of the briquettes was determined in a laboratory using an oven, desiccator, and digital scale. Table 2 shows the results of an analysis of the water content value in durian peel briquettes, which is 3.60%.

Table 2 Results of analysis of moisture content in durian peels briquettes

Weight of empty plate	Weight of cup + initial sample	weight of initial sample	Weight of empty plate + final sample	weight of final sample
31.89	33.89	2.00	33.83	1.94
31.89	33.89	2.00	33.79	1.90
31.89	33.89	2.00	33.77	1.88
31.89	33.89	2.00	33.77	1.88
31.89	33.89	2.00	33.77	1.88

Based on Table 2, the water content value can be calculated by plugging existing data from the table into equation (2), so that the value of the water content of the briquettes is increased by 4.68%. Because the water content of this durian peels briquette is relatively low (around 3%), the combustion process is quick. Furthermore, Hasan et al. 2017 and Komilis et al. (2014) both believe that the higher the water content, the lower the calorific value. Because the water content is low, the quality of this durian peel briquette will produce a lot of heat. The value of water content obtained from the durian peels sample is lower than the value obtained from the analysis of water content in corn cobs, 6.39% (Rahmawati et al. 2020). The water content value of the durian skin briquettes produced meets the specified quality requirements, which is still less than the maximum permissible moisture content of 15% (Ministry of Energy and Mineral Resources No. 047 of 2006).

Ash Content

All briquettes contain inorganic substances, which can be calculated as the remaining weight after the briquettes have been completely burned. This remaining substance is referred to as ash. Briquette ash is made from clay, sand, and other mineral materials. Briquettes with a high ash content are unprofitable due to the formation of a crust. Furthermore, if briquettes are used as direct contact fuel, such as to burn food, fly ash will adhere to the outside of the food. As a result, the food will taste less delicious. This will also have an impact on the health of those around them (Grainger and Gibson 2012). The ash content analysis seeks to ascertain the ash content of the briquettes. This ash content must be considered in relation to combustion because it is a byproduct of combustion. Table 3 shows the results of the ash content analysis in durian peel briquettes, which is 3.56%.

Table 3 Results of Analysis of Ash Content in Durian Peels Briquettes

Weight of empty cup	Weight of cup + initial sample	weight of initial sample	Weight of cup + ash	Ash Weight = (Weight of cup + ash) – (Weight of empty cup)
79.39	81.39	2.00	79.46	0.07
			Ash Content	3.56

Based on the above table, the value of the ash content of the briquettes is obtained from durian peels by 3.56% by entering the value of the water content of the existing data in the table into the equation. The ash content test results show that the charcoal briquettes produced by research are of high quality. It has a low ash content of approximately 3.56%. As a result, the heat possessed is also greater, because the ash content in the briquettes is inversely proportional to the calorific value. The lower the heat produced by a briquette, the higher the ash content. In contrast, the higher the heat obtained, the lower the ash content produced by a briquette.

Content of Volatile Matter

The volatile substance content is determined by evaporating materials that do not contain water using heat energy. The level of volatile substances is affected by the temperature used in the charcoal-making process. The lower the level of volatile substances in the charcoal produced, the higher the temperature used. The goal of volatile substance analysis is to determine the levels of volatile substances in briquettes. Table 4 shows the results of the volatile substance analysis in durian peel briquettes, which is 21.13%.

Table 4 Results of analysis of evaporative levels in durian peels briquettes

Weight of the dry sample from moisture content	The initial weight of the sample from moisture content	Weight after heating to a temperature of 900°C	Content of volatile matter
1.88	2.00	1.46	21.13

According to Table 4, the percentage of volatile substances in these durian peel briquettes is 21.13%. The volatile matter content is higher than that of briquettes made in England, which is 16.41%, but it is comparable to that of briquettes made in Japan, which is about 15 - 30%. The effect of volatile matter on the carbon content of durian charcoal briquettes, namely, the higher the volatile matter value, the lower the fixed carbon value, which means the intensity of the fire is reduced, which also affects the calorific value. According to Gagula et al. (2020), the type of raw material influences the high and low levels of volatile substances. The combustion stability will be improved with a volatile percentage matter of more than 41.25% and 8% adhesive briquettes (Samsul 2004).

Bound Carbon Content

In addition to the ash, volatile matter, and moisture content, the bound carbon content is the fraction of carbon in the charcoal. According to Sotannde et al. (2010), the higher the carbon content bound to charcoal, the lower the volatile matter content. Stringel (2020) stated that the final curing temperature should be greater than 500 ^{o}C to increase the content of bound carbon and volatile matter.

Based on this equation, it is possible to calculate that the bound carbon content of durian peel briquettes in this study is (69.23%). This bonded carbon content is equivalent to the 60 - 80% bonded carbon content of Japanese briquettes. The higher the pyrolysis temperature, the lower the ash and volatile matter content, and the higher the bound carbon content. The lower the pyrolysis temperature, on the other hand, the higher the ash content and volatile matter, and thus the lower the bound carbon content. Enders et al. (2012) discovered that the amount of bounds carbon has a positive correlation with the calorific value. This means that the higher the value of the bound carbon content, the higher the heating value of the briquettes. The bound carbon content in this study is high enough to have a high calorific value.

Density

The density of a material is the sum of its mass per unit volume. The density determination is performed concurrently with the water content determination to ensure that the test samples are identical. If the briquettes whose density will be determined must first be measured and weighed, then the density value of the briquettes can be calculated (Table 5). According to these findings, the density of the durian peel briquettes obtained in this study was 0.48 g/cm^3; 0.44 g/cm^3 and 0.41 g/cm^3. Where the mass or weight of the charcoal briquettes used as the test material is the one with the greatest weight of the three samples of compressed charcoal briquettes shown in Figure 5.

Table 5 Results of the Analysis Density Briquettes Durian Peels

Samples	**Mass (g)**	**Diameter**	**High**	**Volume**	**Density**
A	0.59 g	1.2	1.1	1.24	0.48 g/cm^3
B	0.54 g	1.2	1.1	1.24	0.44 g/cm^3
C	0.51 g	1.2	1.1	1.24	0.41 g/cm^3

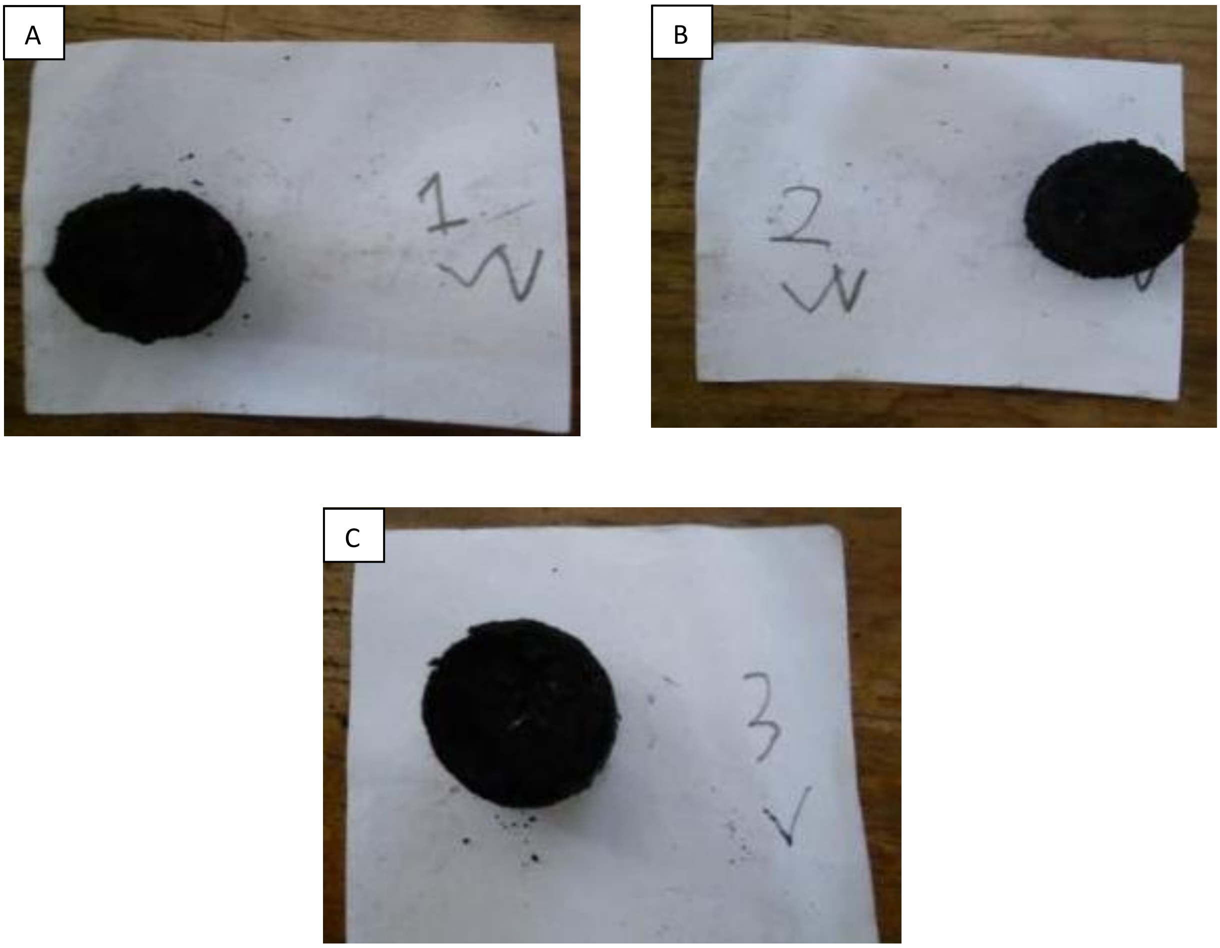

Figure 5 (A) Charcoal briquettes weighing 0.59 g, (B) Charcoal briquettes weighing 0.55 g, (C) Charcoal briquettes weighing 0.51 g

The amount of compression pressure applied affects density, which affects the efficiency of burning briquettes as fuel. The comparison of the weight and volume of briquettes demonstrates the principle of determining density or specific gravity. Briquette density influences packaging, storage, and transportation; the higher the density, the less volume or space required for the same weight of briquettes (Supriadi et al. 2022; Rahmawati 2013; Oladeji and Enweremadu 2012). This study's density is lower than the density of briquettes made in England, which is 0,84g/cm^3, but it meets the standard value for briquette density in Indonesia, which is 0.44 g/cm3. Briquette energy levels are affected by density. The higher the density, the more energy it contains. As a result, the energy contained in this study met the standards for Indonesian briquettes. A high density level also has advantages, such as briquettes becoming denser and stronger, as well as having a high level of stability and being more compact, which does not take up space. The moisture content, ash content, volatile matter content, bound carbon content, and calorific value of the resulting briquettes are all affected by the specific gravity of wood (Supriadi et al. 2022).

Combustion Rate

The weight of the burned briquettes per unit of time is calculated using this principle. This rate of combustion is proportional to the density of the briquettes. The following equation expresses the combustion rate (7). Based on the data presented above, the average combustion rate is approximately 0.22 g/s. The rate of combustion is proportional to the density value. The slower the rate of combustion, the higher the density of the briquettes. The faster the rate of combustion, the lower the density of the briquettes. This is due to the briquettes' high density, which has little contact with air (O_2), causing the combustion to be slow.

CONCLUSION

In Palu, there is a lot of durian peel waste, which has a lot of potential to be used as a ready-to-use fuel to produce heat energy as an alternative energy source to replace fuel oil, and its emissions still meet the emission quality standards in PERMEN ESDM No. 47 tahun 2006. Based on quality testing of durian skin briquettes, the resulting calorific value (5,189.13 cal/g), density (0.48 g/cm3), combustion rate (0.22 g/second), water content value (3.60%), ash content (3.56%), volatile matter content (21.13%), and bounds carbon content (69.23%). Briquettes made from durian skin waste with sago starch as an adhesive can be used as an environmentally friendly alternative fuel.

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