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# CHARACTERISTICS OF CHARCOAL BRIQUETTES FROM KEPOK BANANA PEEL WASTE (*Musa paradisiaca F.*) AS ALTERNATIVE FUEL

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## ABSTRACT

Banana peel is a biomass waste that has the potential to be used as charcoal briquettes. Banana peels contain lignocellulose, including 58.5% lignin, 41.8% cellulose and 38.1% hemicellulose, which are the main ingredients that must be present in the raw material for charcoal briquettes. This study aims to identify the characteristics of charcoal briquettes produced based on the Indonesian National Standard (SNI). The adhesive used is sago flour with a concentration of 5%, 10%, and 15% in 100 g of charcoal briquette raw material. The results obtained were the best adhesive concentration used, namely 5%. By testing, it obtained several characteristics that meet the SNI, including a density of 0.5957 g/cm$^3$, a compressive strength of 4.8920 kg/cm$^2$, and a calorific value of 10,815.9437 cal/g. At the same time, the characteristics that did not meet SNI were water content of 8.465%, ash content of 27.850%, volatile matter content of 46.967% and bound carbon content of 25.183%.

**Keywords:** Banana Peels, Charcoal Briquettes, Sago Flour.

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## INTRODUCTION

The main energy source used by humans is fossil fuels which were formed thousands of years ago and are non-renewable energy. The need for fossil energy increases along with the increasing human population and also the development of technology. In other words, if it is used continuously with an increasing amount, it is possible that there will be a scarcity of energy sources that can even be depleted.[1] An alternative to reducing the use of fossil fuels is urgently needed. One of them is making charcoal briquettes from biomass. Biomass has the potential to be processed into alternative energy sources with relatively large energy content, such as rambutan peel waste and durian skin waste.[2,3] Other solid organic waste (biomass) which is very abundant and underutilized, one of which is banana peel waste, especially the kepok banana (*Musa paradisiaca F.*). Kepok banana is a type of banana that is more delicious to eat after processing. In the processing in Palu City, many Kepok bananas are used as snacks such as fried bananas, chips and banana sticks. Banana peels can be used as compost, bioethanol raw material, animal feed, and charcoal briquettes. However, in Palu City, the banana peel produced from this processing is underutilized, so it only becomes waste.

The criteria that must be owned by a plant to become an energy fuel are cellulose and lignin content.[4] The main ingredient that must be contained in the charcoal briquette raw material is lignocellulose. Lignocellulose consists of cellulose, hemicellulose, and lignin. The lignocellulose content in banana peels belonging to biomass includes 38.1% hemicellulose, 58.5% lignin and 41.8% cellulose.[5] The adhesive material used is sago flour. The content of sago flour as an adhesive material includes 27% amylose and 73% amylopectin. Amylose is hard, while amylopectin is sticky, so it is good to use for bonding.[5] The advantage of charcoal briquettes is that the materials used are easy to obtain because of the abundant and little to develop biomass waste. By making charcoal briquettes, it is hoped that it will be able to reduce waste to become an environmentally friendly alternative fuel. The method of making briquettes is also relatively easy and economical and uses simple tools. Based on the above background, research using


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Kepok banana peel waste to be used as a charcoal briquette material using sago flour as an adhesive aim to identify the characteristics of charcoal briquettes from Kepok banana peels based on the Indonesian National Standard.

## EXPERIMENTAL

### Tools and Materials

The tools used in this study were large paint cans, digital balance, mortar and pestle, oven, desiccator, watch glass, 70 mesh sieve, briquette printer, measuring cup, beaker, spatula, container (basin), calorimeter bomb, calorimeter, spoon, gegep, stopwatch, and Universal Testing Machine (UTM). The materials used in this research were banana peel waste, sago flour and sufficient water.

### Making Charcoal

Charcoal used is charcoal from the banana peel of Kepok. Kepok banana peels are cleaned first and then dried in the sun for 4 days to dry. The place to make charcoal is to use a large tin with a hole in the lid about 15 cm. Banana peel that is dry is put a little into the tin to start the fire. After burning well, another banana peel is put to the full and closed. The banana peel is allowed to burn until it becomes charcoal, which is indicated by no more smoke coming out. The charcoal obtained is weighed, then mashed and sieved using a 70 mesh sieve. The charcoal that has been sieved is weighed as much as 100 g of the adhesive variation used.

### Making Charcoal Briquettes

The making of charcoal briquettes uses various adhesive concentrations, namely 5%, 10%, and 15% in 100 g of banana peel charcoal. Sago weighed by Table 1 is inserted into the basin, then added 25 mL of water and stirred until well mixed. Heat 50 mL of water in a measuring cup to a boil and enter the sago that has been mixed with water before. Stirred until it forms a gel then put in a bowl containing 100 g of charcoal flour and stir until well mixed. The mixture is put into a charcoal briquette mold and pressed until it is solid. Charcoal briquettes that have been printed are dried in the sun for ± 4 days.

Table-1: Comparison of the Mass of the Adhesive with the Volume of Water Used

| No. | Adhesives Concentration (%) | Adhesive Material Mass (g) | Water Volume (mL) |
|---|---|---|---|
| 1 | 5 | 3.75 | 75 |
| 2 | 10 | 7.50 | 75 |
| 3 | 15 | 11.25 | 75 |

### Testing of Charcoal Briquettes

Briquettes produced are tested to determine the quality in accordance with the Indonesian National Standard (SNI). The main parameters of the briquette product quality test studied in this study were density, compressive strength, moisture content, ash content, volatile substance content, bonded carbon content and heating value.

### Density of Charcoal Briquette

The principle of determining density or specific gravity is expressed in the results of the ratio between the weight and volume of charcoal briquettes using the formula ASTM D440-86, namely[6]:

$$\text{Density} = \frac{sample\ mass\ (g)}{sample\ volume\ (cm^3)} \tag{1}$$

### Compressive Strength of Charcoal Briquettes

A sample of briquettes under test is placed horizontally in the compression test fixture and is subjected to load until the charcoal briquettes cracks. The compressive strength is calculated based on the following formula: [2, 5]

$$\text{Kt (kg / cm}^2\text{)} = \frac{F\ (N)}{A\ (cm^2)} \tag{2}$$

Kt = Compressive strength (kg / $cm^2$)
F = Compressive force (N)

A = Sectional area ($cm^2$)
1 kg $/cm^2$ = 9.807 N $/cm^2$

**Moisture Content of Charcoal Briquettes**

Content in principle is to evaporate part of the free water contained in the briquette until a balance of water content is achieved with the surrounding air. The formula used to determine water content based on SNI 06-3730-1995 (Table-3) is as follows:

$$\text{Moisture Content (\%)} = \frac{W_1}{W_2} \times 100\% \qquad (3)$$

$W_1$ = Loss of sample weight (g)
$W_2$ = Sample weight (g)

The method of testing the moisture content is that the cup to be used is put in an oven at a temperature of 105°C until the weight of the plate is constant ± 30 minutes and cooled in a desiccator then weighed as the weight of an empty cup. The charcoal briquette sample was put in as much as 2 g into a cup then oven for 30 minutes at a temperature of 105°C. After that, it is cooled in a desiccator and then weighed. Repeat steps until sample weight are constant.

**Ash Content of Charcoal Briquette**

The Ash Content in charcoal briquettes consists of minerals that cannot be lost or evaporated during the washing process. Ash content is calculated based on SNI 06-3730-1995 (Table-3) as follows:

$$\text{Ash Content (\%)} = \frac{W_1}{W_2} \times 100\% \qquad (4)$$

$W_1$ = Ash weight (g)
$W_2$ = Sample weight (g)

The ash content test is the plates to be used in an oven with a temperature of 105°C for 30 minutes until the weight of the plates is constant. Then cooled in a desiccator and weighed. Put 1 g of the charcoal briquette sample into the cup. Furthermore, the plate containing the sample is put into a furnace with a temperature of 600°C for 3 hours. After that, it is cooled in a desiccator and the resulting ash is weighed.

**Volatile Content of Charcoal Briquettes**

Levels of volatile substances are obtained by evaporating all volatile substances in charcoal briquette powder other than water. The content of volatile substances is expressed in% based on SNI 01-6235-2000 (Table-3) as follows:

$$\text{Volatile Content (\%)} = \frac{W_1 - W_2}{W_1} \times 100\% \qquad (5)$$

$W_1$ = Original sample weight (g)
$W_2$ = Weight after heating (g)

The method of testing for volatile substances, namely the plate to be used, is oven first at 105°C for 30 minutes until the weight of the plate is constant. Then it is cooled in a desiccator and weighed. Then 1 g of charcoal briquette sample was put into a cup and heated in a furnace at 950°C for 3 hours until the weight was constant. After that it is cooled in a desiccator and weighed.

**Bonded Carbon Content of Charcoal Briquettes**

Carbon is the fraction of carbon (C) in the briquette, apart from the fraction of water, volatile substances and ash. Bound carbon content is stated in SNI 06-3730-1995 (Table-3) as follows:
Bound carbon content (%) =(100%)-(ash content+volatile substance content)% (6)

**Calorific value of Charcoal Briquettes**

Calorific value test Charcoal briquettes are carried out using a bomb calorimeter. The equation used to determine the heating value is as follows:[2, 5]

$$\text{Calorific Value (cal/g)} = \frac{(C \times t) - (Pks \times pk^*) - (V_{Na_2CO_3} \times V^*{}_{Na_2CO_3})}{A} \qquad (7)$$

| | |
|---|---|
| C | = Heat capacity of benzoic acid (cal/g) |
| T | = Combustion temperature (°C) |
| Pks | = Length of residual wire (cm) |
| Pk * | = Correction of wire length (2.3 cal/cm) |
| $V_{Na_2CO_3}$ | = Volume titration (mL) |
| $V^*_{Na_2CO_3}$ | = Correction of the titration volume (1 cal/mL) |
| A | = Sample mass (g) |

The calorimeter tube is cleaned first. Then the empty capsule is weighed and the sample is inserted and then weighed again. After that, the capsule was tied using a 10 cm long nichrome wire and connected to the two electrodes of the calorimeter bomb. The prepared sample was put into the calorimeter bomb and closed tightly. Then $O_2$ gas is injected into the calorimeter bomb until the pressure is 30 atm then put into a bucket filled with 2 liters of water. The hamber calorimeter bomb is closed and connected to the electrode and stirrer cable to the operating system. The operating system is switched on by pressing the on button, then the temperature is set to zero and pressing the fire button marked sample burning begins, then the temperature is recorded every 15 seconds. The calorimeter bomb is removed from the chamber, then the gas is removed (until it is completely used up) and opened the lid. The remaining wire that is burned is measured and the combustion results are rinsed with distilled water and collected in the erlenmeyer, then 3 drops of pp indicator are added and titrated with $Na_2CO_3$ 0.1 N. Recorded the volume of the titration[5].

## RESULTS AND DISCUSSION

The characteristics analysis obtained from the Kepok banana peel charcoal briquettes made using sago starch adhesives of various concentrations met several Indonesian National Standards (SNI). The results obtained are presented in Table-2.

Charcoal briquettes are made using several concentrations, including 5%, 10% and 15%. The masses of adhesive used were 3.75 g, 7.50 g, and 11.25 g per 100 g. mixture of banana peel charcoal flour with 75 mL water volume. The concentration variation was carried out to find the right adhesive concentration for charcoal briquettes, where the adhesive concentration also determines the quality of the charcoal briquettes. A good mixture of raw materials and adhesives is one that is evenly mixed, water does not seep out when printing and does not change too much size when dry.[7]

Table-2: Data Analysis of the Characteristics of Kepok Banana Peel Charcoal Briquettes

| Concentration of Adhesive (%) | 5 | 10 | 15 |
|---|---|---|---|
| Mass of adhesive/100 g of charcoal | 3.750 | 7.50 | 11.25 |
| Density (g / cm$^3$) | 0.596 | 0.569 | 0, 594 |
| Compressive Firmness (kg/cm$^2$) | 4,892 | 4,616 | 6,862 |
| Moisture Content (%) | 8,465 | 8,350 | 9,170 |
| Ash Content (%) | 27,850 | 25,588 | 24,888 |
| Volatile Substances (%) | 46,967 | 51,283 | 52,588 |
| Bonded Carbon Content (%) | 16,718 | 14,780 | 13,535 |
| Calorific Value (cal/g) | 10,815,944 | 10,795,181 | 10,063,326 |

### Density of Charcoal Briquettes

Density is the result of the ratio between mass and volume. The density value affects the burning rate and calorific value of the briquettes. The higher the density, the higher the firing rate, and the better the quality of the briquette. From Table-2 it can be seen that the charcoal briquettes that have the highest density are charcoal briquettes with an adhesive concentration of 5%, which is 0.5957 g/cm$^3$, while charcoal briquettes with an adhesive concentration of 10% have a density of 0.5689 g/cm$^3$ and adhesive concentration 15% had a density of 0.5941 g/cm$^3$.

The amount of pressure applied when printing briquettes and the particle size of raw materials and adhesives can affect density. In addition, it affects the efficiency of burning charcoal briquettes as fuel.[2,8] Therefore, before mixing it with the charcoal adhesive, it is sieved first using a 70 mesh sieve so that the particle size is the same and the resulting mixture is homogeneous. Charcoal briquettes density obtained ranged from

0.5689 to 0.5957 g/cm$^3$ has met the national standards of Indonesia. Similar density values have been reported for rambutan peel biomass briquettes.[2] The minimum density of charcoal briquettes is 0.4407 g/cm$^3$ (SNI, Table-3).

(a) (b) (c)

Fig.-1: (a) Banana Skin Charcoal Flour, Sago Flour Gel Adhesives, (c) Banana Skin Charcoal Briquettes

**Compressive Strength of Charcoal Briquettes Press**

Compressive Strength is the resistance of charcoal briquettes to external pressure so that the charcoal briquettes are broken or crushed. The higher the compressive strength value, the better the resistance to external pressure and the charcoal briquettes are not easily crushed.[6] The results obtained in this study are shown in Table-2. Charcoal briquettes which have the highest compressive strength are charcoal briquettes with an adhesive concentration of 15%, namely 6.8623 kg/cm$^2$, while the adhesive concentration of 5% has a compressive strength of 4.8920. kg/cm$^2$ and the concentration of adhesive 10% of 4.6164 kg/cm$^2$.

Compressive strength is measured using a Universal Testing Machine (UTM). Charcoal briquettes are stressed vertically and the pressure applied is measured until the charcoal briquettes are crushed. The compressive strength is related to density, the higher the density, the higher the compressive strength[5]. The density of charcoal briquettes decreased at 10% adhesive concentration then increased at 15% concentration. However, in this case the adhesive concentration of 15% had the highest compressive strength, while the highest density was the adhesive concentration of 5%. The differences obtained can be caused by several things, including the unequal arrangement of particles, the mixture between the material and the adhesive that has not been evenly distributed before printing and the pressure used in the printing of charcoal briquettes is different. In addition, the compressive strength of charcoal briquettes is influenced by the factor of compressive force and the surface area of the compressed plane, the size of the particles of the material and the adhesive used[9]. The results obtained in this study ranged from 4.6164 to 6.8623 kg/cm$^2$, meeting the national standards of Indonesia (SNI 19-4791-1998). The minimum compressibility of charcoal briquettes is 3 kg/cm$^2$ (SNI, Table-3).

**Water Content of Charcoal Briquettes**

The water content is contained in charcoal briquettes. Water content affects the quality of charcoal briquettes. The lower the water content value, the better the quality of the charcoal briquettes. The high water content will make the charcoal briquettes more difficult to ignite and the calorific value will be lower.[10] Table-2 shows the highest water content possessed by briquettes with an adhesive concentration of 15%, namely 9.17%, while the adhesive concentration of 5% has a water content of 8.465% and an adhesive concentration of 10% of 8.35%.

The high water content obtained is thought to be due to the drying process of charcoal briquettes using sunlight for 4 days so that the water in the charcoal briquette pores cannot evaporate completely. Banana peels used as charcoal briquettes have a moisture content value of 10.76%[9]. Another factor that causes the high moisture content of charcoal briquettes is the adhesive content. Before it is mixed with charcoal briquettes, the adhesive is first cooked with boiling water so that it forms a gel. The results obtained were due to the fact that the mixture was not evenly stirred on the charcoal briquette material before printing. In addition, the adhesive properties used are easy to absorb water from the air because it is not resistant to moisture and sago starch itself has a moisture content of 14%.[6] The results obtained did not meet the standards (SNI 01-6235-2000), where the maximum water content was 8%. The resulting charcoal briquettes have a moisture content above 8% with a range of 8.35% -9.17% (SNI, Table-3). The value of the water content produced is still lower than the value of the water content of coconut shell briquettes (11.7%).[11]

**Ash Content of Charcoal Briquettes**

Ash is an inorganic compound other than carbon that is left behind after the complete combustion of charcoal briquettes at a temperature of 600°C. Ash content affects the quality and calorific value of charcoal briquettes. The higher the ash produced by a charcoal briquette, the lower its calorific value. High ash content indicates non-combustible material and remains as an impurity.[10] It can be seen in Table-2 that the highest ash content is owned by charcoal briquettes with an adhesive concentration of 5% of 27.850% then decreases at an adhesive concentration of 10% of 25.588% and continues to decrease at an adhesive concentration of 15% of 24.888%.

The ash content decreases with increasing adhesive concentration. The resulting high ash content is thought to be from the material used. The charcoal of raw materials uses a conventional carbonization process so that the resulting temperature does not reach the optimum temperature. This is because the materials burned in charcoal conventionally have a tendency to interact with the air in the environment so that the biomass is decomposed into ash.[10] The results obtained were not in accordance with the standards (SNI 01-6235-2000), the maximum ash content of the briquettes was 8%. While the ash content produced in this study is far from standard, namely in the range of 24.888% -27.850% (SNI, Table-3). The ash content value obtained was much higher than the ash content value for charcoal briquettes from rambutan skin (6,21%)[2], corncob{6,39%)[7], madan wood (3,9%) and coconut shell (4,5%).[11]

**Content of Volatile Charcoal Briquettes**

Substances are ingredients in charcoal briquettes that are volatile as a product of decomposition compounds other than water.[2] The level of volatile substances affects the intensity of the flame and also the perfection of combustion. The higher the volatile substance content, the charcoal briquettes will be more flammable and will cause a lot of smoke when ignited.[10] Table-2 shows that charcoal briquettes have the highest level of flying substance with an adhesive concentration of 15% of 52.588%, while for the adhesive concentration of 10% is 51.283% and adhesive concentration of 5% is 46.967%.

The high and low levels of charcoal briquette volatile matter produced are influenced by the type of raw material so that the different types of raw materials have a significant effect on the content of charcoal briquette volatile matter.[2] The raw material used is banana peel which has a volatile content of 90.03% in the dry sample analysis of the raw material, this value is very high so that this material burns quickly and the ignition time is shorter. This raw material is good for the ignition process.[12] The content of the briquettes of the banana peel charcoal briquettes increased with the increasing concentration of the adhesive used. The high level of volatile substances is thought to be due to the conventional carbonation process by burning banana peels in a closed tube so that the burning time and temperature cannot be controlled. As a result, the charcoal process does not occur optimally. The high and low levels of volatile substances are influenced by time and temperature in the carbonation process which is used is 500 ° C for an optimal carbonation process.[10] The results of the volatile content obtained from this study did not meet the standards (SNI 01-6235-2000). Where the standard for volatile substances is a maximum of 15%, while the results obtained are far from the standard range of 46.967% -52.588% (SNI, Table-3). The value of volatile matter obtained was much higher than the value of volatile matter content of charcoal briquettes from rambutan peel (16.33%)[2], corn cobs (16.72%)[7], madan wood (20.3%) and coconut shell (11,3).[11]

**Carbon Bonded Content of Charcoal Briquettes**

Carbon is the fraction of carbon (C) bound in charcoal briquettes in addition to the fraction of water, vaporizers and ash. The content of bound carbon affects the quality of the charcoal briquettes produced. The higher the value of bonded carbon, the better the quality of the charcoal briquettes and the higher the calorific value. The content of bound carbon is influenced by the ash content and the content of volatile substances, if the value of both is low, the resulting bound carbon content is high. High value of bonded carbon will result in less smoke.[10, 13] Table-2 shows that the highest bonded carbon content is owned by charcoal briquettes with an adhesive concentration of 5% of 25.183%, while the adhesive concentration of 10% is 23.130% and an adhesive concentration of 15% is 22.525%.

The results of carbon content bound to charcoal briquettes tended to be low, given the high ash content and volatile substances content of charcoal briquettes. Presumably because the charcoal process is less than optimal because it is carried out using conventional methods as previously discussed in the volatile matter content test.[10] The bonded carbon content obtained did not meet the standards (SNI 06-3730-1995) at all adhesive concentrations. The bound carbon content according to the standard is 80% (SNI, Table-3).

**Calorific Value of Charcoal Briquettes**

The calorific value is the main test parameter in making charcoal briquettes. The calorific value can determine the quality of charcoal briquettes. The higher the calorific value obtained, the better the quality of the charcoal briquettes produced. The factors that influence the high and low calorific value of the briquettes are moisture content, ash content, fly substance content and bound carbon content. In addition, raw materials and adhesive materials also affect the calorific value of charcoal briquettes.[10] Table-2 shows the highest calorific value obtained by charcoal briquettes with a concentration of 15% of 13,063.3264 cal/g, then the adhesive concentration of 5% is 10,815.9437 cal/g and the adhesive concentration of 10% is 10,795,1807 cal/g. The results obtained are not in accordance with research[8,] which used the raw material of nipah fruit peel with sago starch adhesive, where the calorific value decreases along with the increasing concentration of adhesive on charcoal briquettes. Paisal's study[6] also found that the calorific value of sago stem bark charcoal briquettes decreased with the increasing concentration of sago starch adhesive. The difference in the results obtained is presumably because the raw materials used are different because the raw materials have their respective characteristics.

The calorific value generated in this study ranged from 10,795,1807-13,063,3264 cal/g fulfilling the standard (SNI01-6235-2000) with a minimum calorific value of 5000 cal/g (SNI, Table-3).

Table-3: Comparison of Test Results with Standardization of Charcoal Briquettes from Japan, England, America, Indonesia

| Characteristics of Charcoal Briquettes | Japan | America | England | SNI |
|---|---|---|---|---|
| Density (g/cm$^3$) | 1.0–2.0 | 0.84 | 1 | 0.4407 |
| Compressive strength (kg/cm$^{2)}$ | 60 | 12.7 | 62 | 3 |
| Moisture content (%) | 6–8 | 3–4 | 6 | 8 |
| Ash content (%) | 3–6 | 8–10 | 18 | 8 |
| Volatile substance content (%) | 15-30 | 16 | 19 | 15 |
| Bound carbon content (%) | 60-80 | 75 | 58 | 80 |
| Calorific value (cal/g) | 6000 – 7000 | 6500 | 7000 | ≥5000 |

## CONCLUSION

Charcoal briquettes produced in this study meet several characteristics in accordance with SNI. From the test results, the best adhesive concentration is 5%. The characteristics of charcoal briquettes produced by charcoal briquettes with a concentration of 5% that meet the SNI are a density of 0.5957 g/cm$^3$, a compressive strength of 4.8920 kg/cm$^2$, and a calorific value of 10,815.9437 cal/g. While the characteristics that did not meet the SNI were water content of 8.465%, ash content of 27.850%, volatile matter content of 46.967% and bound carbon content of 25.183%.

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