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The Utilization of Sago Due Waste as an Alternative Fuel

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ABSTRACT: Sago is a native plant of Indonesia, with an area of about 1.128 million ha or 51.3% of the world's sago area. Potential areas for producing sago (Metroxylon sp.) in Indonesia include Riau, South Sulawesi, Southeast Sulawesi, North Sulawesi, Maluku and Papua, where about 90% of the sago area in Indonesia is in Papua. From studies conducted by non-governmental organizations (NGOs) such as WWF which in May 2014 conducted various studies on the utilization of agricultural wastes that can still be used as alternative energy sources, which of course must be studied further. The study must of course be tested in the laboratory. Studies in the laboratory involve ultimate testing based on chemical content tests and proximation studies (thermal properties of fuel). This study must be carried out with the aim of knowing whether the sample to be used as fuel is feasible or not. This research is to do laboratory testing to determine the chemical composition of briquettes, thermal properties. The 60, 80 mesh size briquettes are molded in a cylindrical shape. The results of printing sago dregs charcoal briquettes consist of 60 mesh and 80 mesh, where the two briquettes have the following dimensions for a grain size of 60 mesh, briquette diameter b = 44.90 mm = 4,490 cm, briquette mass = 0.17 gr, briquette height = 69.80 mm = 6.980 cm. Then for mesh 80, - Diameter of briquettes b = 44.90 mm = 4.490 cm, mass of briquettes = 220.078 gr, height of briquettes = 69.80 mm = 6.980 cm. The results of the proximate analysis test produce: for mesh 60, among others, moisture 13.08%,; volatile matters 26.18%,; fixed carbon 27.88%, and calorific value above 4013 kcal/kg, while for mesh 80, among others, moisture 13.36%; volatile matters 23.52%,; fixed carbon 29.86%, and the calorific value of 4007 kcal/kg. The density of mesh 80 is 2,769 gr/cm3, mesh 60 is 1,998 gr/cm^3, the combustion efficiency of mesh 60 is 5.070% and mesh 80 is 3.58%.

KEYWORDS: Sago, Briquettes, composition, production

A. INTRODUCTION

Sago is a native plant of Indonesia, with an area of about 1.128 million ha or 51.3% of the world's sago area. Potential areas for producing sago (Metroxylon sp.) in Indonesia include Riau, South Sulawesi, Southeast Sulawesi, North Sulawesi, Maluku and Papua, where about 90% of the sago area in Indonesia is in Papua.

The agricultural and plantation industries generally produce by-products in the form of agricultural waste, which are obtained after harvest processing activities. Agricultural waste can be in the form of solid, liquid and gas. One of the agricultural wastes in solid form is sago dregs, which is obtained from the final process of harvesting sago trees (*Metroxylon sago*). Sago tree processing waste, especially sago pulp, has not been used optimally and only a small part is used as feed. In addition, sago dregs are disposed of in shelters or along rivers at the sago processing location which results in environmental pollution, especially watersheds.

The need for energy in the form of fuel oil such as gasoline and kerosene in the transportation, industrial, agricultural and household sectors is increasing, while the availability of domestic fuel sources is increasingly limited and their use has a negative impact on the environment. and human health. For this reason, renewable fuel sources are needed that are practical to use, relatively inexpensive and environmentally friendly. Based on its potential and utilization, sago is one of the commodities that can be used as raw material for making fuel in the form of briquettes.

From studies conducted by non-governmental organizations such as World Wide Fund for Nature **(**WWF), which in May 2014 conducted various studies on the utilization of agricultural wastes that can still be used as alternative energy sources, which of course must be studied further. The study must of course be tested in the laboratory. Studies in the laboratory involve ultimate testing based on chemical content tests and proximation studies (*thermal properties of fuel*). This study must be carried out with the aim of knowing whether the sample to be used as fuel is feasible or not.

In the World Wide Fund for Nature **(**WWF) activity, there were only a few samples of waste including rice husks and coconut shells. This sample is already in briquette fuel. It is known that rice husks and coconut shells by the Mechanical Engineering Department of UNMUS have been tested and analyzed, but it must be admitted that the information never reached the public.

B. LITERATURE REVIEW

1. Sago Dregs

Sago (Metroxylon sago) is a plant that spreads in Indonesia, and includes monocotyledonous plants from the Palmae family, Metroxylon genus, with the order Spadiciflorae. Sago has a higher starch content than other types of Metroxylon, so sago is widely used in various agricultural industries. Currently, the utilization of sago is only focused on the starch contained in it.

Petroleum is a non-renewable energy source and is used in everyday life, resulting in the depletion of petroleum reserves. Processed petroleum products used as fuel include, among others, Liquified Petroleum Gas (LPG), gasoline, kerosene, kerosene, diesel and others. The calorific value of petroleum is 45 kJ/gram (Sugianto 2009). Alternative energy that is commonly developed as a substitute for petroleum, includes natural gas, coal, wood charcoal, and biomass. Indonesia has enormous biomass energy potential with an estimated 146.7 million tons of biomass per year. Biomass is the main energy source for living things and is estimated to contribute 13% of the world's energy supply (Tsukahara and Sawayama 2005).

Biomass is biological material that is usually considered as waste, garbage, and is often destroyed by burning. Most of the plant biomass is lignocellulosic biomass which is composed of cellulose, hemicellulose, and lignin. In addition, pectin, protein, extractive substances, and ash are also present in plant biomass but in small amounts. One of the lignocellulosic biomass is sago waste.

2. Charcoal Briquettes

Charcoal is a porous solid material which is the result of burning carbon-containing materials (Djatmiko, 1985). While activated charcoal is charcoal that is activated by immersion in chemicals or by flowing hot steam into the material so that the pores of the material become more open with a surface area ranging from 300 to 2000 m2/g. The wider surface of activated charcoal has an impact on the higher absorption of the material to gases or liquids (Kirk and Othmer, 1964).

Activated charcoal is an amorphous solid that has a very large surface area and number of pores (Baker et al., 1997). Activated charcoal is non-graphite carbon whose pores have undergone a process of developing the ability to absorb gases and vapors from a mixture of gases and substances that are not dissolved or dispersed in a liquid through activation (Jankowska et al., 1991).

3. Briquettes

Briquettes are solid fuels with a certain shape and size, which are composed of fine particles of charcoal (coke/semi coke) that have undergone a compression process with a certain compressive power, so that the fuel is easier to handle in its utilization.

Charcoal briquettes are solid fuels made from charcoal with a mixture of clay and tapioca obtained from the carbonation process. The composition of charcoal briquettes usually consists of 80% coal, 10% clay and 10% tapioca. Clay serves as a heat stabilizer and gives the briquettes physical strength. While tapioca functions as an adhesive during the printing process.

Charcoal briquettes have advantages, which are cheap, easy to use, high calorific value, no risk of explosion and no noise. The downside is that the initial startup time takes a little longer, about 5-10 minutes and is more efficient to use, over a long period of time.

The main purpose of charcoal briquette is to make useful solid fuels from charcoal briquettes with better packaging and composition for easy and convenient use. To obtain good charcoal briquettes, "good" charcoal is needed, especially those with low ash content. Additives must also be selected of good quality so that they can function optimally as adhesives, accelerate flame and absorb emissions and other harmful substances. The charcoal and additives (mixer) are pulverized individually to a certain size, mixed using a mechanical mixer, and then "printed" (briquetted) into certain packages. This is what is called charcoal briquettes.

Several factors are used as the standard for charcoal briquettes according to Enik Sri Widarti (2010), including:

a. Water content (moisture),

The water content in fuel, water contained in wood or wood products is expressed as water content.

b. Ash content (Ash)

Ash or referred to as mineral material contained in solid fuel which is a material that cannot be burned after the combustion process. Ash is the material that remains when solid fuel (wood) is heated to a constant mass.

c. Volatile matters

Volatile matters (substances that easily evaporate) is one of the characteristics contained in a briquette. The more volatile matters in bio briquettes, the easier it is for bio briquettes to burn and ignite so that the rate of combustion is faster.

d. Fixed Carbon

Fixed carbon content or it can also be called fixed carbon content (KT) contained in solid fuels in the form of charcoal (char). ie components that when burned do not form gas.

e. Heating value/calorific value

The calorific value of solid fuels consists of GHV (gross heating value) and NHV (net heating value). The calorific value of fuel is the amount of heat generated or generated by one gram of the fuel by increasing the temperature of one gram of water from 3.5°C to 4.5°C, with units of calories. The tool used to measure the calorific value is called a bomb calorimeter.

4. Moisture Measurement

Measurement procedure:

1. Weigh 1 g of the sample into a cup of known mass.
2. Heat the sample in a muffle furnace at 105oC for 1 hour.
3. Remove the cup from the furnace, place it in a metal plate and close it.
4. Cool it for 10 minutes then put it in a desiccator
5. After cooling at room temperature then weighed

Calculation:

Moisture = $[((A-D))/C]x100\%$

With :

A = mass of the sample with the cup

C = mass of the sample, namely (A-B), where B is the mass of the cup

D = mass of the cup with residue

5. Volatile Matters (VM) Measurement

Measurement procedure:

1. The sample is weighed as much as 1 g and put into a porcelain cup and then closed.
2. Then the sample is put into the furnace and heated at a temperature of 815 oC for 7 minutes
3. The sample is removed and cooled in a desiccator and then weighed again.

Calculation:

Volatile matters (%) = $[((A-D))/C]x100\% - F(\%)$

With :

A = mass of the sample and cup (gr)

C = A-B

B = mass of the cup (gr)

D = mass of the cup and residue (gr)

F = moisture in sample analysis (%)

6. Ash Measurement

Measurement procedure:

1. Weigh 1 gram of the sample into a cup of known mass.
2. Heat the sample in a muffle furnace starting from low temperature, then raised to 250oC, from 250oC - 500oC for 30 minutes, from 500oC to 815oC for 60 minutes.
3. Remove the cup from the furnace, place it in a metal plate and close it.
4. Cool for 10 minutes then put in a desiccator.
5. After cooling at room temperature then weighed.

Calculation:

Ash (%) $= F/C\ x100\%$

With :

B = mass of the cup and lid (gr)

A = mass of the cup and lid and sample (gr)

D = mass of cup and lid and residue (g)

C = mass of sample = (A-B)

F = residual mass = (D-E)

7. Fixed carbon (FC) measurement

Fixed carbon is calculated from 100% minus the moisture content minus the ash content, minus the volatile matter content.

FC (%) = 100 % – (*moisture* + ash content + *volatile matters*)%

8. Thermal properties (Heating value)

Measurement of calorific value using the PARR 1261 bomb calorimeter. Calorific value measurement procedure;

1. The sample is weighed 1 gram and then put into a cup
2. Connect the two poles of the bomb calorimeter with 10 cm of nickel chrome burning wire.
3. Fill the bomb calorimeter with oxygen at a pressure of 30 atmospheres.
4. Insert the calorimeter bomb into a vessel containing 2 kg of water then insert the vessel into the water jacket.
5. Run the electricity for the heater and cooling device and then adjust the scale from "initial balance" until the lights and ampere meter from the heater run automatically (the temperature of the vessel and jacket is the same).
6. Automatic measurements are carried out to measure the initial temperature, temperature rise and the equivalent calorific value of the combustion results in the bomb calorimeter.

Calculation:

The calorific value of the briquette sample can be calculated by the following equation:

$$\text{Heating Value (cal/g)} = \frac{[(\Delta t)xEEV]-(e_1+e_2)}{m} - e_S$$

With :

Δt = increase in combustion temperature inside the bomb calorimeter(oC)

EEV = equivalent energy at the time of combustion (cal/oC)

e_1 = heat correction due to acid formation (cal)

e_2 = corrected heat of combustion of the burner wire (cal).

ice is a correction of sulfur present in the fuel (cal/gr)

m = mass of the sample (g)

9. Density Calculation

This calculation is carried out to determine the effect of particle density on the hardness of briquettes. This test is carried out by determining several density of briquettes by comparing the mass of the briquettes with the volumetric dimensions of the briquettes.

Calculation procedure:

1. Measure the diameter of the briquettes (db) with a caliper.
2. Measure the diameter of the large hole (dlb) and the small hole (dlk) of the briquettes with a caliper.
3. Weigh the mass of briquettes.
4. Measure the height of the briquettes (t) with a caliper.
5. Calculate the volume.

Calculation:

Density, $\rho = \frac{m}{v}$ (kg/m^3)

With :

ρ = density (kg/m3)

m = mass of object (kg)

v = volume of the object (m3)

$v = ¼ \pi D^2 . t$

With :

π = 3.14

d = diameter (m)

t = height of briquette (m)

10. Combustion Efficiency

The method used for testing the overall thermal efficiency for burning briquettes on a briquette stove refers to one of the recommended methods, namely the method of boiling water testing.

This method is done by heating a certain amount of water until it boils on the stove using briquette fuel.

$$\eta th = \frac{Q_{use}}{Q_{input}}$$

With :

η_{th} = thermal efficiency of burning briquettes on a briquette stove (%)

Q_{use} = heat used in combustion

$Q_{use} = m_a \, Cp \, \Delta T$ (kJ)

With :

m_a = mass of water(kg)

Cp = specific heat of water 4.176 (kJ/kg C)

ΔT = difference between initial and final temperature (C)

Q_{input} = heat used to heat water (kJ)

$Q_{input} = m_b$ LHV (kJ)

With:

mb = mass of briquettes used up for combustion (kg)
= initial mass - final mass.

LHV = bottom calorific value of briquettes (kcal/kg).

So the combustion efficiency can be calculated using the equation,

$$\eta_{th} = \frac{m_a C_p \Delta T}{m_b LHV}$$

C. METHOD

1. Time and Place of Research
   a. This research was carried out starting in February 2022
   b. The research site is at the Laboratory of Mechanical Engineering, Musamus University and the approximation test is at the Laboratory of Inorganic Chemistry, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University, Makassar.
2. Making sago pulp charcoal briquettes
   a. Identification of raw material for sago pulp
      a.1. Sago dregs were taken from Muram Sari village, Semangga district
      a.2. The sago pulp used comes from the residue/waste of milling that has been dried.
   b. The process of making sago pulp charcoal
      b.1. Sago dregs are dried in the sun.
      b.2. Sago pulp is put in a carbonation drum and then burned. After the flame occurs, it is added again and keeps the flame from happening by opening and closing the lid of the carbonation drum.
      b.3. Sago dregs that have been burned (formed charcoal) are removed from the carbonation drum and put in a closed container to be cooled for a while.
   c. The process of making sago pulp charcoal briquettes
      c.1. The Sago Dregs Charcoal obtained from the combustion is crushed slowly and then sieved using a 40 mesh sieve and 80 mesh to obtain charcoal powder, which is left to grind again and then sifted again.
      c.2. The resulting charcoal powder is put into a mixing container starting from the coarsest size (which remains on a 40 mesh sieve) to be mixed with 10% clay and then stirred evenly. After that, tapioca flour 10% of the weight of the sago dregs charcoal is dissolved in hot water at a temperature of about 70oC as much as 900 grams, then poured into a mixture of charcoal powder and clay, then stirred until smooth.
      c.3. After the sago dregs charcoal powder, clay, tapioca flour and hot water are well mixed in a mixing container, the dough is removed and then the briquettes are molded.
      c.4. Repeat from number c with different grain sizes (which remain on the 60 mesh and 80 mesh sieves)

D. RESULT AND DISCUSSION

1. Result

Briquettes are molded in the form of a cylinder without holes, and are made of two types based on the grain size of the charcoal or mesh. The emphasis or press of the briquettes at the time of printing aims to glue the adhesive material to the activated charcoal briquettes so that their shape becomes solid.

The specifications for the shape of the three types of sago waste charcoal briquettes are as follows:

1. For grain size 60 mesh

Height x diameter: 69.80 mm x 44.90 mm x 0.17 gr briquette mass.

The average mass is 220.78 grams, 10% tapioca is 22.078 grams, 59% clay is 110.39 grams, hot water is 600 ml.

2. For grain size 80 mesh

Height x diameter: 69.80 mm x 44.90 mm x 1.25 gr briquette mass.

The average mass is 305.94 grams, 10% tapioca is 30.594 grams, 59% clay is 152.97 grams, hot water is 650 ml.

The results from the printing and specification of the two types of sago waste charcoal briquettes above can be seen that the larger the mesh size (the finer the granules) of charcoal raw material for briquettes, the greater the mass of the briquettes. with others.

Proximation testing has been carried out at the Laboratory of Inorganic Chemistry, Department of

Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University Makassar. The results are as follows:

a. For grain size 60 mesh
1. Moisture, M = 13.08 % by weight
2. Volatile Matters, VM = 26.18% by weight
3. Ash, A = 33.67% by weight
4. Fixed Carbon, FC = 27.88 wt%
5. Calorific value of HHV = 4013 Kcal/kg

b. For grain size 80 mesh
1. Moisture, M = 13.36% by weight
2. Volatile Matters, VM = 23,52 wt %
3. Ash, A = 32,74 % by weight
4. Fixed Carbon, FC = 29.86 % by weight
5. Calorific value of HHV = 4007 Kcal/kg

From the results of the briquette proximation analysis above, several things were obtained as follows:

a. Moisture (water content),
The moisture content of the briquettes is related to the initial ignition of the fuel, the higher the moisture content, the more difficult it is to ignite the fuel, this is due to the energy required to evaporate moisture from the fuel.
The moisture content in the briquettes is 13.08 % for mesh 60 and for mesh 80 is 13.36% and this price shows that the moisture content in the briquettes is greater than the standard for commercial briquettes, imported briquettes, Japanese briquettes, USA briquettes and UK briquettes.

b. Ash (ash content),
Ash in solid fuels is a combustion residue that cannot be burned anymore.
The ash content in the briquettes is 33.67% for mesh 60, and 32.74% for mesh 80. This ash content is not included in the UK, USA briquette standards, commercial briquette standards, imported briquette standards and Japanese briquette standards.

c. Volatile matters,
Volatile matters in the fuel function to stabilize the flame and accelerate the combustion of charcoal.
The volatile matters content in the briquettes is 26.18% for mesh 60 and 23.52% for mesh 80. These volatile matters are included in the standard for imported briquettes and Japanese briquettes, except for the commercial briquette standard, British briquette and USA briquette standard.

d. Fixed carbon,
The fixed carbon content in the briquettes is 27.88 % for mesh 60 and 29.86 % for mesh 80. This price indicates that these briquettes are not included in the commercial briquette standard, imported briquette standard, UK briquette, USA briquette, and UK briquette standard. .
The physical properties of the Sago Dregs waste briquettes above can be made a comparison table of the quality of the briquettes with the recommended quality standards of briquettes. The comparison table can be presented below:

Calorific value (HHV), the test was carried out at the Inorganic Chemistry Laboratory, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University Makassar The calorific value of briquettes is 4013 kcal/kg for mesh 60 and 4007 kcal/kg for mesh 80. This value is lower than the standard minimum calorific value of briquettes (6000 kcal/kg), so it does not meet the quality standard value for briquettes, this is because the briquettes Sago pulp charcoal has a high moisture and ash content. From the results of the calorific value test above, it can be seen that the grain size of 60 mesh has the highest heating value compared to 80 mesh.

Test the physical properties of briquettes, carried out at the Inorganic Chemistry Laboratory, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University Makassar. The results are as follows:

a. The results of the briquette compressive strength test:
Mesh grain size 60 ;
$P_{ma}x = 4.80\ kg/cm^2$
Mesh grain size 80 ;
$P_{max} = 3.80\ kg/cm^2$

b. The results of the calculation of the density of briquettes:
The calculation of briquette density is carried out using equation 2.6 is as follows:
Dimensions of briquettes:
Briquette Diameter : ϕ_b = 44,90 mm
= 4,490 cm

1. For mesh grain size 60;
a. Mass of briquettes = 48,051 gr.
b. Briquette height = 69.80 mm
= 6.980 cm.
c. The volume of briquettes (Vb) is:
Vbr = Volume of cylinder x height

$$V_{br} = \left(\frac{\pi}{4}\Phi_b{}^2\right) \text{ x height}$$

$$V_{br} = \left(\frac{\pi}{4}(4{,}490)^2\right) x\ 6{,}980$$

$$V_{br} = 110{,}463\ cm^3$$

The density of briquettes (ρ) is:

$$\rho = \frac{m}{v}$$

$$\rho = \frac{220.78}{110.463}$$

$$\rho = 1{,}998\ \left({}^{gr}/{}_{cm^3}\right)$$

2. For mesh grain size 80;
a. Mass of briquettes = 48.714 gr.
b. Briquette height = 69.80 mm = 6.980 cm
c. The volume of briquettes (Vb) is:
Vbr = Volume of cylinder x height

$$V_{br} = \left(\frac{\pi}{4}\Phi_b{}^2\right) \text{ x height}$$

$$V_{br} = \left(\frac{\pi}{4}(4{,}490)^2\right) \text{ x } 6{,}980$$

$V_{br} = 110.463\ cm^3$

The density of briquettes (ρ) is:

$$\rho = \frac{m}{v}$$

$$\rho = \frac{305.95}{110.463}$$

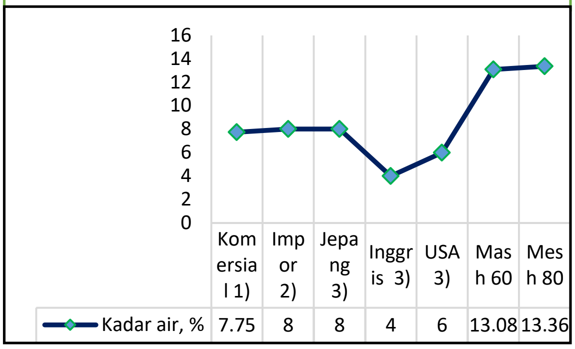
$$\rho = 2.769\ \left({}^{gr}/_{cm^3}\right)$$

So the density of briquettes is obtained:
Mesh grain size 60 ; = 1.9985 gr/cm3
Mesh grain size 80 ; = 2.769 gr/cm3

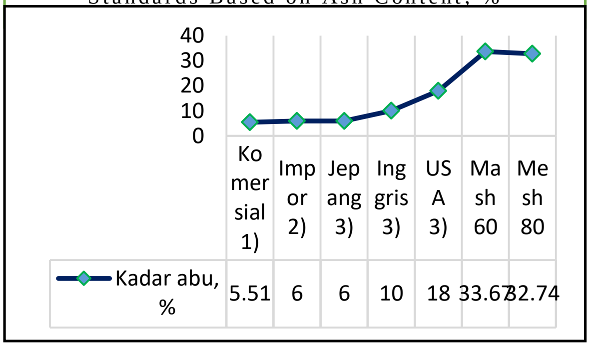
Compressive strength and density of briquettes are physical properties of briquettes related to the strength of briquettes to withstand deformation. The physical properties of these briquettes are not included in the existing briquette quality standards except for the density meeting the commercial briquette standards.

The quality standards of briquettes can be seen in table 1 and on the comparison chart of the quality standards of briquettes with Sago Dregs briquettes from the test results.

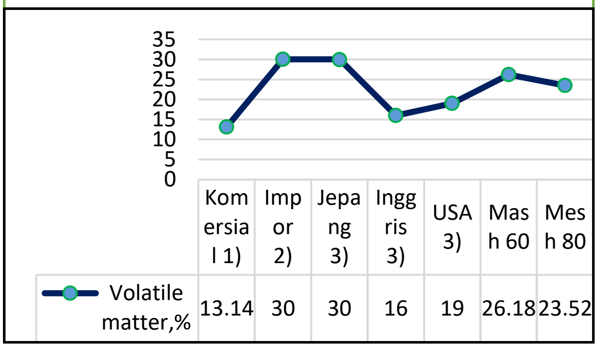
Graph 1. Comparison of Briquette Quality Standards Based on Moisture Content, %



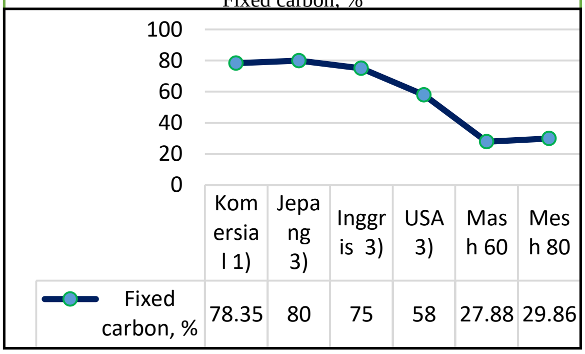
Graph 2. Comparison of Briquette Quality Standards Based on Ash Content, %



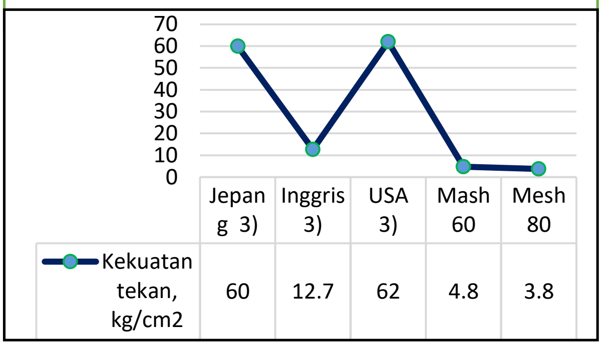
Graph 3. Comparison of Briquette Quality Standards Based on Volatile Matter, %



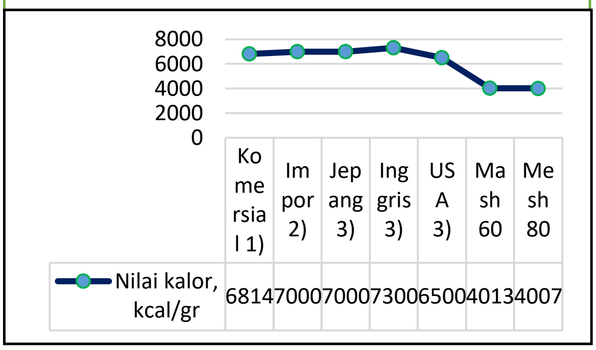
Graph 4. Comparison of Briquette Quality Standards Based on Fixed carbon, %



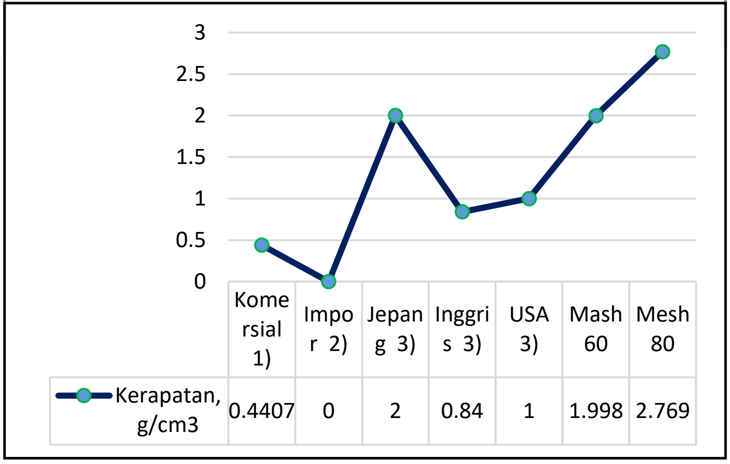
Graph 5. Comparison of Briquette Quality Standards Based on Compressive Strength, kg/cm²



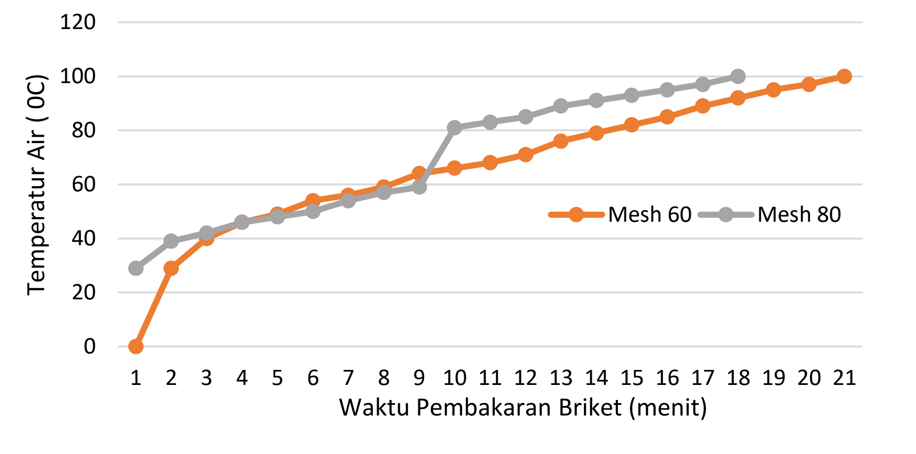
Graph 6. Comparison of Briquette Quality Standards Based on Calorific Value, kcal/gr



Graph 7. Comparison of Briquette Quality Standards Based on Density, g/cm3



Graph 8. Burning time of sago waste briquettes when boiling water

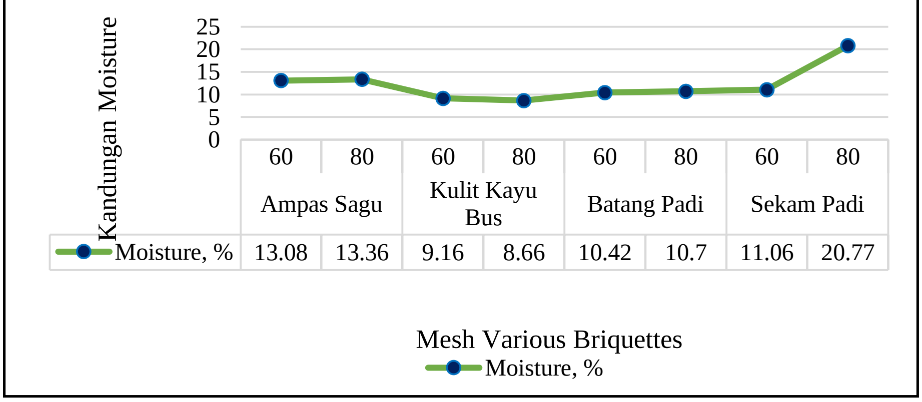


2. Sago Dregs Briquette Burning Test.

a. Burning briquettes on a briquette stove.The data on the results of the combustion test on the briquette stove can be seen in graph 8.

A. Briquette Burning Test Data on Briquette Stoves
For grain size 60 mesh (mass = 220.78 grams)

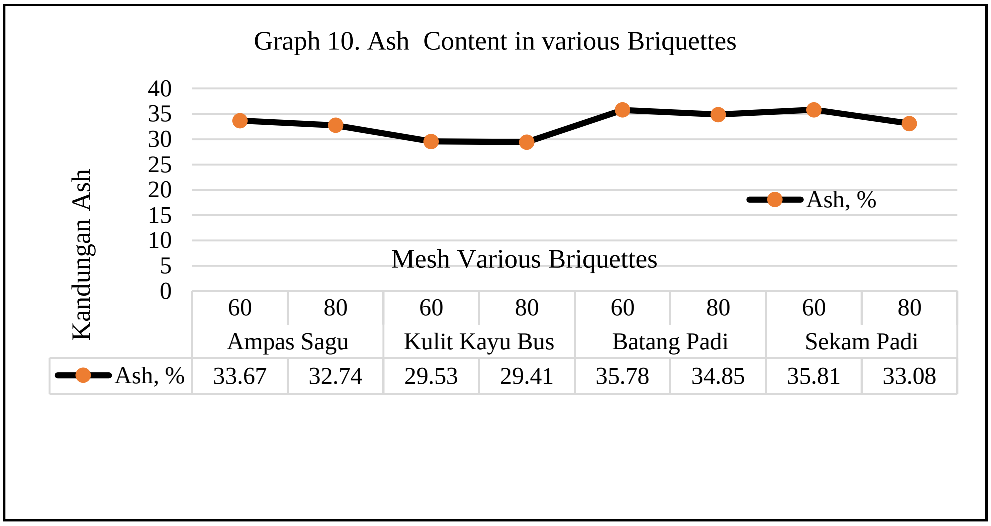
Graph 9. Moisture Content in Various Briquettes



3. Ultimacy And Thermal Properties Of Various Briquettes

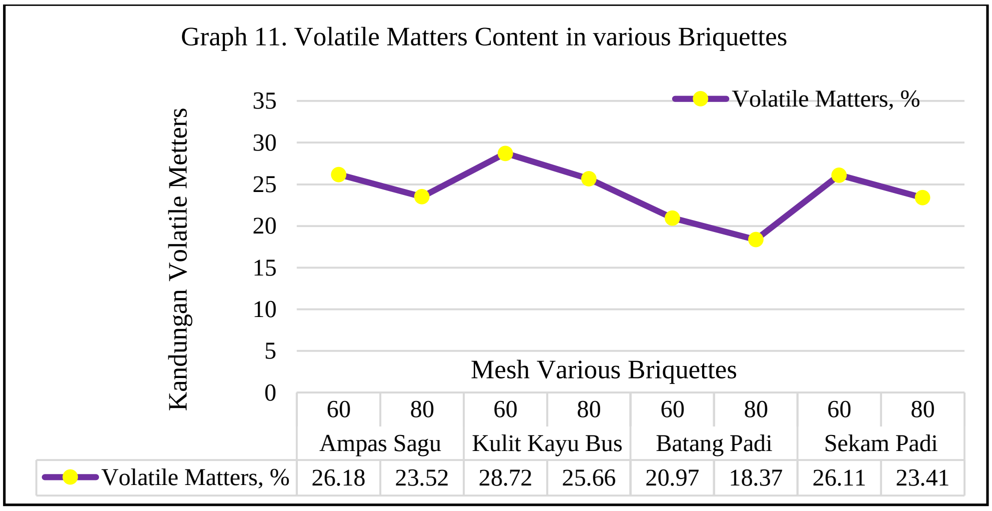
Various thermal properties and the results of ultimate tests carried out by various briquettes in the laboratory are not the same. This indicates that each material or waste used for the manufacture of activated charcoal has a different chemical content. can be seen in graph 9.

The ash or ash content contained in each briquette which has the highest value is rice stem briquettes where mesh 60 is at a value of 35.78% while sago dregs waste with ash or ash content at a value of 32.74% is in mesh 80 and skin Bus wood has the lowest ash or ash content, namely mesh 60 with a value of 29.53% and mesh 80 with a value of 29.41%. can be seen in graph 10.



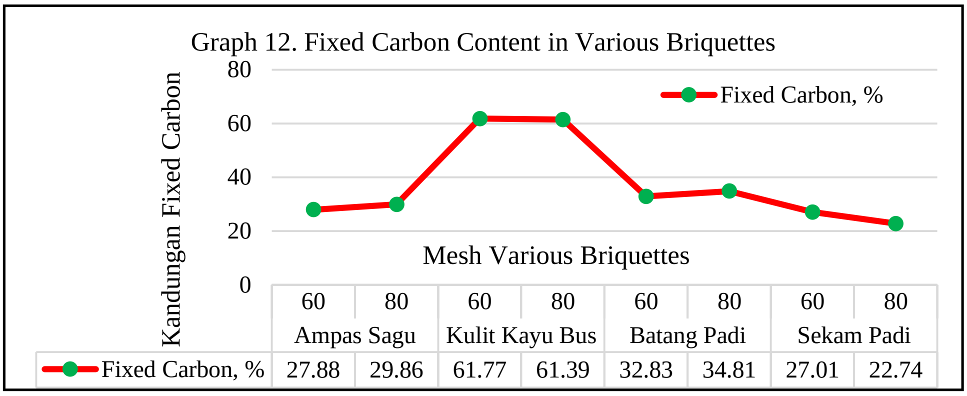
Graph 10. Ash Content in various Briquettes

The volatile matters content contained in each briquette has the highest value, namely bus bark briquettes where mesh 60 is at a value of 28.72% while sago dregs waste with volatile matters content at a value of 23.52% is at mesh 80 and rice husk briquettes have the lowest moisture content, each of which is mesh 80 with a value of 23.41%. can be seen in graph 11.



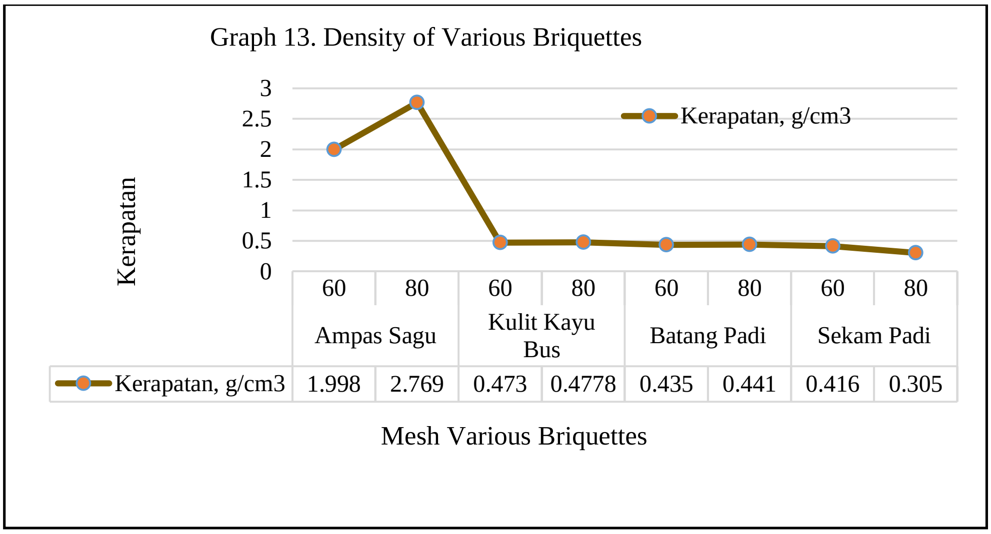
Graph 11. Volatile Matters Content in various Briquettes

The fixed carbon content contained in each briquette has the highest value, namely bus bark briquettes where mesh 60 is at a value of 61.77% while sago dregs waste with fixed carbon content at a value of 27.88% is at mesh 60 and rice husk briquettes have the lowest moisture content, each of which is mesh 80 with a value of 22.74%. can be seen in graph 12.



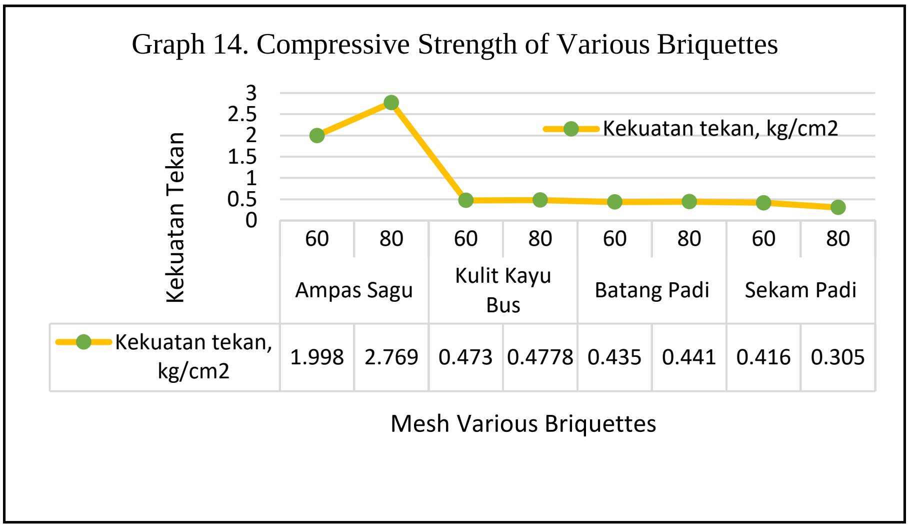
Graph 12. Fixed Carbon Content in Various Briquettes

The density contained in each briquette has the highest value, namely sago pulp briquettes where mesh 60 is at a value of 1.998 g/cm3 and mesh 80 at n value is 2.769 g/cm3 while rice husk briquettes with a density at a value of 0.305 g/cm3 are in mesh. 80. can be seen in graph 13.



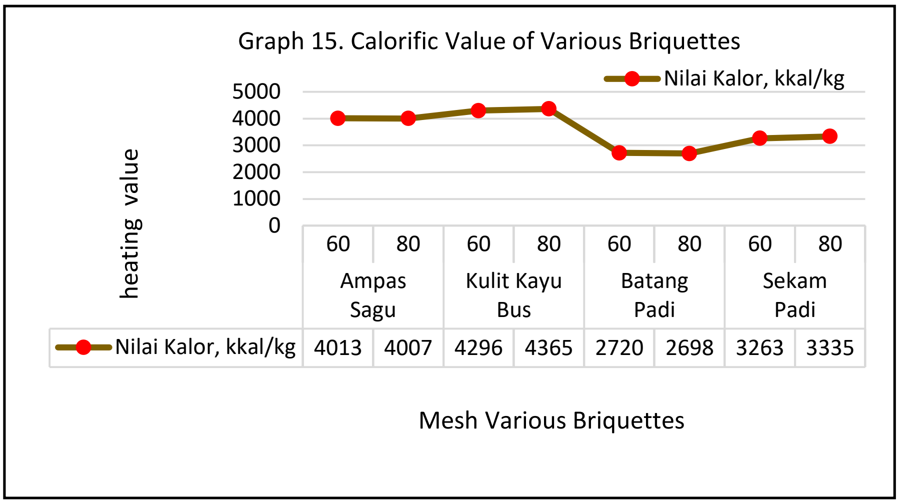
Graph 13. Density of Various Briquettes

The compressive strength of various briquettes which has the highest value is sago pulp briquettes where mesh 60 is at a value of 1,998 kg/cm2 and mesh 80 is at a value of 2,769 kg/cm2 while the lowest/smallest compressive strength value is rice husk briquettes with a compressive strength of 0.416 kg/cm2 is at mesh 60 and 0.305 kg/cm2 is at mesh 80. can be seen in graph 14.



Graph 14. Compressive Strength of Various Briquettes

The calorific value content contained in each briquette has the highest value, namely bus bark briquettes where mesh 60 is at a value of 4296 kcal/kg and mesh 80 is at a value of 4365 kcal/kg while sago pulp waste contains a calorific value of 4013 kcal/kg. kg is at mesh 60 and 4007 kcal/kg at mesh 80. Rice stem briquettes have the lowest calorific value content, namely mesh 60 has a value of 2720 kcal/kg and mesh 80 has a value of 2698 kcal/kg. can be seen in graph 15.



Graph 15. Calorific Value of Various Briquettes

4. Combustion efficiency

The results of the calculation of the efficiency of briquettes and their calculations For briquettes with a grain size of 60 mesh.

$m_{b\ awal}$ = 220,78 gram ; $m_{b\ akhir}$ = 5 gram ; m_{air} = 500 gram.

T_{maks} = 100°C ; T_0 = 29°C ; ΔT_1 = 71°C

$Q_{berguna}$ = m_{a1} .Cpa . ΔT_2
= 0,5 kg . 4,176 kJ/kg°C .71°C
= 148,248 kJ.

Q_{input} = m_b . LHV
= m_b . (HHV – 3240(kJ/kg))
= 0,21578 kg [($4013\frac{kcal}{kg}$.$4{,}184\frac{J}{cal}$)- 3240 kJ/kg]

= 0,21578 kg .[16.790,392 – 3240] kJ/kg
= 2923,9036 kJ.

Its thermal efficiency is :

$$\eta_{th} = \frac{Qberguna}{Q\ input}$$
$$= \frac{148{,}248}{2923{,}9036}$$
$$= \frac{388{,}368}{3089{,}20304} = 0{,}0507 = 5{,}070\ \%$$

For briquettes the grain size is 80 mesh.

$m_{b\ awal}$ = 305,94 gram ; $m_{b\ akhir}$ = 10 gram ; m_{air} = 500 gram.

T_{maks} = 100°C ; T_0 = 29°C ; ΔT_1 = 71°C

$Q_{berguna}$ = m_{a1} .Cpa . ΔT_1
= 0,5 kg . 4,176 kJ/kg°C .71°C
= 148,248 kJ.

Q_{input} = m_b . LHV
= 0,30594 kg .[($4007\ \frac{kcal}{kg}$.$4{,}184\frac{J}{cal}$) $- 3240\ kJ/kg$)]
= 0,30594 kg [(16765,288 – 3240) kJ/kg.
= 4137,93 kJ.

Its thermal efficiency is :

$$\eta_{th} = \frac{Qberguna}{Q\ input} = \quad = \frac{148{,}248}{4137{,}93} = 0{,}0358 = 3{,}58\ \%$$

E. CONCLUSION

Based on the results of calculations and discussions, the following conclusions can be drawn:

1. The results of the printing of charcoal briquettes from Sago Dregs Waste consist of mesh 60 and mesh 80, where the two briquettes have the following dimensions for a grain size of 60 mesh, briquette diameter b = 44.90 mm = 4,490 cm, briquette mass = 0.17 gr, briquette height = 69.80 mm = 6.980 cm. Then for mesh 80, - Diameter of briquettes b = 44.90 mm = 4.490 cm, mass of briquettes = 220.078 gr, height of briquettes = 69.80 mm = 6.980 cm.
2. The results of the proximate test indicate that the charcoal briquettes of the Sago Dregs Waste as a whole do not meet the quality standards of briquettes, except for volatile matters which are included in the standards of imported and Japanese briquettes. The results of the calorific value test are lower than the minimum standard value, which is 6000 kcal/kg. So it is not included in the briquette quality standard. The results of the physical properties test are not included in the briquette quality standard, unless the density value meets the commercial quality standard. The results of the calculation of combustion efficiency showed that the briquettes with a size of 60 mesh had the highest efficiency (14.66%), and the lowest was 80 mesh (13.54%).
3. The briquette firing test was carried out by boiling water, it turned out that briquettes with 60 mesh could boil water (500 grams) in 38 minutes. As for briquettes with a size of 80 mesh, it takes 34 minutes

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