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Characterization of Bio-Briquettes from Oyster Mushroom Bag Waste in Terms of the Effect of Carbonization Temperature

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ABSTRACT

Biomass is an alternative energy source derived from organic materials and agricultur waste that has not been optimally utilized in Indonesia. One potential use for this waste to convert it into solid fuel in the form of biobriquettes, which serve as an alternative conventional fuels. Biobriquettes are produced through a carbonization process, whic involves burning biomass with controlled oxygen levels to produce charcoal. This stud analyzes the effect of carbonization temperature on the quality of biobriquettes made fro oyster mushroom baglog waste. The parameters analyzed include moisture content, as content, volatile matter, fixed carbon, and calorific value. Optimal results were obtaine at a carbonization temperature of 500 °C, with a moisture content of 3.61%, ash content 7.03%, volatile matter of 22.27%, fixed carbon of 67.09%, and calorific value of 5643.8 Cal/g. These results meet the SNI 01-6235-2000 standards for moisture content, as content, and calorific value, although the volatile matter and fixed carbon values do n fully meet the standards.

Keywords: *Bio-briquettes, Oyster mushroom baglogs, Briquette molding, Carbonizatic temperature*

1. INTRODUCTION

Energy shortages were a major challenge faced by almost all countries in the world. As the availability of fossil fuels decreased, humans were increasingly driven to discover and develop alternative energy sources that could replace fossil fuels, particularly renewable energy [1]. One of the major renewable energy potentials in Indonesia was biomass [2]. Biomass was an alternative energy source derived from organic materials and waste produced as a by-product of a process [3]. In Indonesia, there was a lot of agricultural waste that had not been optimally utilized. This waste could be converted into solid fuel in the form of bio-briquettes, which could be used as an alternative solution to replace conventional fuels.

Briquettes were a solid form obtained through a compaction process using a certain amount of pressure and produced little smoke when burned. The manufacturing process was carried out using a pressing method and utilizing adhesive materials. Various types of biomass waste were often used as raw materials for bio-briquettes, including waste from the agricultural, plantation, forestry, and agro-industry sectors [4]. One of the most abundant organic wastes came from oyster mushroom baglog residues, which were wastes from MSME-scale mushroom cultivation [5].

Mushroom cultivation in Indonesia grew rapidly. According to a report from the Central Statistics Agency in 2023, mushroom production in Indonesia had reached 60,000 kg. Many micro, small, and medium enterprises (MSMEs) focused on the cultivation and processing of oyster mushrooms. One of the main wastes produced from this activity was used baglog, which was planting media that was no longer usable. If this waste was not handled properly, it could have a negative impact on the environment, including causing unpleasant odors [6]. Therefore, appropriate management measures were needed so that this waste could be reused and have added value.

The quality of briquettes was influenced by the raw materials, the composition of the raw materials with the binder, the type of binder used, the composition of the raw material mixture, and the carbonization temperature of the raw materials. Research conducted by [7] stated that the carbonization temperature affected the characteristics and quality of the briquettes produced. The most optimal results were obtained in experiments with a carbonization temperature of 500 °C, moisture content of 0.41%, ash content of 32.40%, volatile matter of 24.38%, and calorific value of 4621 Cal/g. Research conducted by [8] found the most optimal results in experiments using

the chimney carbonization method with a moisture content of 11.57%, ash content of 28.69%, bound carbon content of 32.46%, volatile matter of 34.44%, and a calorific value of 4282.23 Cal/g. Research conducted by [9] obtained the most optimal results in experiments using cornstarch adhesive with a calorific value of 4388.36 Cal/g.

Based on previous research, it could be seen that the use of oyster mushroom baglog waste to make bio-briquettes was still rarely applied. This study was conducted as a step in optimizing the use of oyster mushroom baglog waste as the main material for making charcoal bio-briquettes by determining the most optimal carbonization temperature.

2. MATERIAL AND METHODS

This research was conducted at the Energy Engineering Laboratory of Sriwijaya State Polytechnic and proximate analysis at the Chemical Engineering Laboratory of Politeknik Negeri Sriwijaya.

2.1 Material

The raw material used in this study was oyster mushroom baglog waste. The bio-briquettes were tested for their characteristics based on SNI No. 01-6235-2000, which consisted of analysis of moisture content, ash content, volatile matter content, and carbon content. The equipment used was a briquette molding machine equipped with a molding chamber or hopper, a screw for applying pressure and compacting the biobriquettes, a motor as the power source generating rotation, a pulley transmitting rotation via a belt (v-belt), the v-belt connecting the pulley to the motor, and a gearbox transducer regulating the rotation ratio

2.2 Methods

This study involved the following variables: Fixed variables: total mass of charcoal briquettes 300 grams, 10% wheat flour used as adhesive, and drying process under sunlight for 3 x 24 hours. Independent Variables: Variations in carbonization temperature: 300°C, 350°C, 400°C, 450°C, 500°C.

The research procedure was conducted in several stages, as follows: preparing the raw material of oyster mushroom baglog waste in a dry state, carbonizing the raw material of oyster mushroom baglog waste in a furnace with varying temperatures (300°C, 350°C, 400°C, 450°C, 500°C) for 60 minutes, weighing the carbonized charcoal at 300 grams for each temperature variation, mixing the weighed charcoal with wheat flour adhesive at 10%, then mixing it in a briquette mixer at a speed of 35 rpm while adding water as needed, feeding the charcoal mixed with adhesive into a briquette molding machine at a speed of 10 rpm. Cutting the molded briquettes into the desired shape.

Bio-briquette characteristic testing aims to assess the quality and performance of bio-briquettes to determine their suitability as an alternative fuel. Bio-briquette testing uses the ASTM (American Society for Testing and Materials) equation:

1. Moisture Content Analysis

The method used to measure moisture content is in accordance with ASTM D D3302/D3302M-12. It involves weighing ± 1 gram of charcoal biobriquettes. The biobriquettes are then placed in an oven and heated for 1 hour at a temperature of 110ºC. After that, they are weighed again to calculate the moisture content using the equation:

$$\% \text{ Moisture Content } = \frac{w - w1}{w - w2} x100 \quad \ldots. (1)$$

where:

W : Weight of crucible + sample before heating (gr)
W1 : Weight of crucible + sample after heating (gr)
W2 : Weight of crucible + lid (gr)

2. Ash Content Analysis

The method used to determine ash content in accordance with ASTM 3174-02 involves weighing 1 gram of charcoal bio-briquette sample using a crucible without a lid. The crucible is then placed in a furnace for 1 hour and heated at a temperature of 450-500ºC for 2 hours, followed by heating at a temperature of 700-750ºC for 2 hours. The process continues with combustion for 2 hours at a temperature of 900-950ºC. After that, the crucible is removed from the furnace, cooled in a desiccator, and immediately weighed to calculate the ash content using the equation:

$$\% \text{ Ash Content } = \frac{W1 - W2}{W} \text{ x } 100 \quad \ldots. (2)$$

where:

W : Weight of sample before incineration (gr)
W1 : Weight of crucible + lid + ash residue (gr)
W2 : Weight of crucible + lid (gr)

3. Volatile Matter Analysis

The method used to determine the volatile matter content is in accordance with ASTM D 3175-20. The specimen obtained from the water content calculation is placed in a crucible with its lid and

weighed, then placed in a furnace. The specimen is heated in the furnace for 7 minutes at a temperature of 950ºC, then cooled in a desiccator and weighed. The volatile matter content can be calculated using the following equation:

$$\% \text{ Loss of Sample Mass} = \frac{B - C}{B - A} x100 \quad \ldots (3)$$

$$\% \text{ Volatile Matter Content} = D - E \quad \ldots (4)$$

where:

A : Weight of crucible + lid (gr)
B : Weight of crucible + sample before heating (gr)
C : Weight of crucible + sample after heating (gr)
D : Mass of sample lost (%)
E : Moisture content (%)

4. Fixed Carbon Content

The method used to determine the fixed carbon content is in accordance with ASTM 3172-89 2002:

$$FC\ (\%) = 100\% - [W + A + V] \quad \ldots(5)$$

where:

W : Water content (%)
A : Ash content (%)
V : Volatile matter content (%)

5. Calorific Value

The method used to measure heat value is in accordance with ASTM D-5865, which is to used a bomb calorimeter.

3. RESULT AND DISCUSSIONS

This study was conducted experimentally to analyze the characteristics of oyster mushroom baglog waste biobriquettes in terms of the effect of carbonization temperature. The raw material used was oyster mushroom baglog waste charcoal. The proximate analysis of oyster mushroom baglog charcoal before the addition of adhesive is shown in Table 1.

Table 1. Proximate Analysis Data of Raw Materials

Component	Oyster Mushroom Baglog
Moisture Content (%)	2,14
Ash Content (%)	6,29
Volatile Matter Content (%)	44,01
Fixed Carbon (%)	6,29

(Source: Sriwijaya State Polytechnic Chemical Engineering Laboratory Analysis, 2025)

3.1 Analysis of Bio-briquette Products

Research conducted on testing the characteristics of bio-briquettes, namely proximate analysis and calorific value, can be viewed in Tables 2 and 3.

Table 2. Proximate Analysis of Bi-briquettes

Temperature research	Moisture Content (%)	Ash Content (%)	Volatile Matter Content (%)	Fixed Carbon (%)
SNI 01-6235-2000	Max. 8	Max. 8	Max. 15	Min. 77
300	6,5734	5,0901	27,9406	60,396
350	5,8852	5,6431	26,7754	61,696
400	5,1697	6,1520	24,0092	64,669
450	4,0275	6,6290	23,3365	66,007
500	3,6087	7,0283	22,2743	67,089

(Source: Sriwijaya State Polytechnic Chemical Engineering Laboratory Analysis, 2025)

Table 3. Calorific Value of Bio-briquette

Temperature / Methods	Calorific Value (cal/gr)
SNI 01-6235-2000	Min. 5000
300	4068,7602
350	4415,9507
400	5021,1581
450	5399,9302
500	5643,8513

(Source: Sriwijaya State Polytechnic Chemical Engineering Laboratory Analysis, 2025)

Based on Table 2 and 3, the proximate analysis and calorific value of bio-briquettes made from oyster mushroom baglog waste meet the standards set in SNI 01-6235-2000.

3.2 Proximate Analysis of Raw Materials Prior to Carbonization Process

Proximate analysis of raw materials prior to carbonization was conducted to determine whether the carbonization process was successful by examining the bound carbon content before and after carbonization. Based on the results of the proximate analysis of the raw material before carbonization, the bound carbon content was 6.29%, which was still very low. After carbonization for 1 hour at 300 °C, the bound carbon content increased to 60.36%, at 350 °C it increased to 61.69%, at 400 °C it increased to 64.66%, at 450 °C it increased to 66%, and at 500 °C it increased to 67.08%. This was because the bound carbon content was inversely proportional to the moisture content, ash content, and volatile matter content.

3.3 The Effect of Carbonization Temperature on Biobriquette Characteristics

Characterization analysis aimed to determine the value of moisture content, ash content, volatile matter content, and fixed carbon content of the carbonization results.

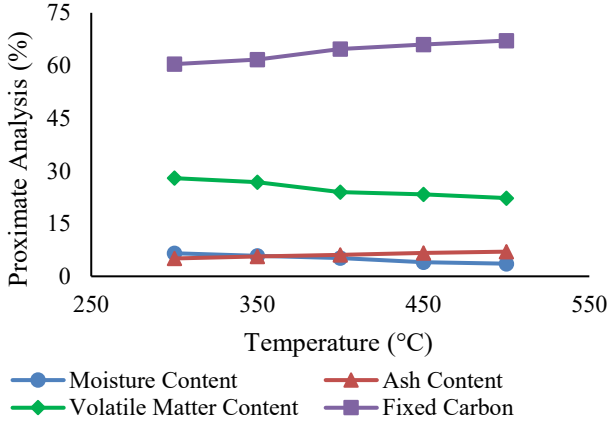


Figure 1. Analysis of Proximate Products

Moisture Content

Moisture content was the amount of water contained in a material. Moisture content greatly affected the calorific value or heat produced. The lower the moisture content, the higher the calorific value obtained, and conversely, the higher the moisture content, the lower the calorific value obtained. This was because combustion occurred more slowly and the temperature of the fire produced tended to be lower [7].

In Figure 1, it could be seen that the higher the carbonization temperature, the lower the moisture content of the briquettes. This occurred because during carbonization, the moisture content in the material evaporated. The higher the carbonization temperature, the more moisture evaporated and the lower the moisture content became. This resulted in charcoal with a higher carbonization temperature being drier, thereby reducing its ability to absorb water. Consequently, when charcoal with a high carbonization temperature was mixed with a binder, it absorbed water from the binder with a lower capacity [7].

The research conducted by [8] found the lowest moisture content in the experiment using the roasting method, which was 11.57%. The highest moisture content in this study was obtained in the experiment at a temperature of 300 °C, which was 6.57%, and the lowest moisture content in the experiment at a temperature of 500 °C, which was 3.61%. Based on the research results, all carbonized charcoal produced met the maximum moisture content standard according to SNI (01-6235-2000) with a maximum value of 8%. It was suspected that the carbonization temperature and drying time of the briquettes influenced the moisture content in the briquettes.

Ash Content

Ash content was an indicator of the amount of ash produced after combustion. Ash was an undesirable component of fuel. Ash could not react or burn and accumulated at the bottom of the boiler or flew away with the gas [7].

From Figure 1, it could be seen that the higher the carbonization temperature, the higher the ash content of the briquettes. The increase in ash content, in line with the increase in temperature and burning time, caused more material to decompose into ash [10]

In a study conducted by [9], the lowest ash content was found in the meranti wood powder experiment using cornstarch adhesive, at 2.41%. The highest ash content in this study was obtained in the experiment at 500 °C, at 7.02%, and the lowest ash content was obtained in the experiment at 300 °C, at 5.09%. Referring to the SNI standard (01-6235-2000) with a maximum ash content limit of 8%, all carbonized charcoal produced met the established standard. In addition to temperature and burning time, ash content also depended on the type of raw material used to make charcoal [11].

Volatile Matter Content

The level of volatile matter could be used as a parameter to measure the amount of smoke produced during combustion. The higher the level of volatile matter in a fuel, the higher the amount of smoke produced. The smoke produced could be in the form of carbon and ash particles. Volatile matter content referred to substances that could evaporate as a result of the decomposition of compounds still present in charcoal, excluding water [12].

The higher the temperature and the longer the carbonization time, the more volatile substances were lost, so that when the volatile substance content was tested, the value was smaller [13].

The highest volatile substance content was obtained in the experiment with a temperature of 300 °C, which was 27.94%, and the lowest volatile matter content was obtained in the experiment at 500 °C, which was 22.27%. Based on the research results, all the carbonized charcoal produced did not meet the maximum moisture content standard according to SNI (01-6235-2000), which was 15%.

Fixed Carbon Analysis

The fixed carbon value (bound carbon content) was inversely proportional to the water content, ash content, and volatile matter content. The higher the

fixed carbon content, the better the quality of the charcoal. The carbon content was the fraction of carbon present in the charcoal excluding the ash content. Thus, the extractive content in biomass influenced the carbon content in charcoal and was one of the determinants of charcoal quality, as it was related to the calorific value [14].

The highest fixed carbon content was obtained in the experiment at 500 °C, at 67.09%, and the lowest fixed carbon content was obtained in the experiment at 300 °C, at 60.40%. In the study conducted, none of the experiments met the SNI standard (01-6235-2000) with a minimum value of 77%.

3.4 The Effect of Carbonization Temperature on Bio-Briquette Quality Based on Calorific Value

The main parameter for measuring the quality of biomass fuel was calculated from its calorific value. The calorific value of biomass varied greatly and increased with the carbon content. The higher the calorific value of charcoal briquettes, the better the quality of the charcoal briquettes produced [7].

Figure 2 showed that the highest calorific value obtained from briquettes made from oyster mushroom baglog charcoal with varying carbonization temperatures was 5643.85 Cal/g for briquettes carbonized at 500 °C, while the lowest calorific value was obtained from briquettes carbonized at 300 °C and 350 °C, which did not meet the SNI (01-6235-2) standard of 4068.76 Cal/g.

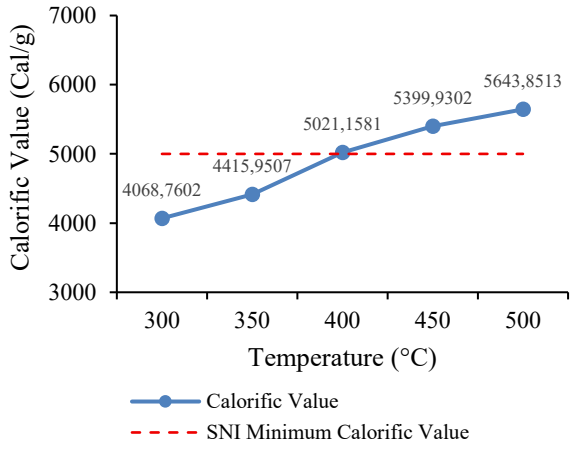


Figure 2. Calorific Value of Bio-briquettes

For experiments at temperatures of 300 °C and 350 °C, the results did not meet the SNI standard (01-6235-2000) with a minimum value of 5000 Cal/g. However, experiments at temperatures of 400 °C, 450 °C, and 500 °C met the SNI standard. This was because as the carbonization temperature increased, the fixed carbon content in the charcoal increased, while the moisture content decreased, resulting in an increase in the calorific value of the briquettes [15].

4. CONCLUSIONS

In the experiments conducted, the best characteristic analysis was obtained in the experiment at a temperature of 500 °C, with a moisture content of 3.60%, ash content of 7.02%, volatile matter content of 22.37%, and fixed carbon content of 67.07%. The moisture content and ash content values met the SNI (01-6235-2000) standard with a maximum value of 8%. However, the volatile matter and fixed carbon content values did not meet the SNI (01-6235-2000) standard, which specified a maximum of 15% for volatile matter and a minimum of 77% for fixed carbon.

In the experiments conducted, the best calorific value was obtained at a temperature of 500 °C, amounting to 5643.85 Cal/g, which was in accordance with the SNI standard (01-6235-2000).

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