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NATURAL BASED CARBON BRIQUETTES: THE EFFECT OF COFFEE GROUND CARBONIZATION TEMPERATURES AS RENEWABLE ENERGY ALTERNATIVE

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ABSTRACT

Coffee consumption in Indonesia has been increasing over time. As a result of the high consumption and production, coffee waste often ends up in landfills. One potential solution to this problem is converting coffee waste into reusable products. Coffee grounds waste can be utilized as renewable energy in the form of briquettes. In this research, coffee grounds are used as briquette material. Briquettes are made by the carbonization method. Temperature plays a crucial role in determining the quality of briquette. This study aims to identify the optimum carbonization temperature, with variations of 350°C, 400°C, and 450°C. Each briquette sample was analyzed according to the Indonesian National Standard SNI 01-6235-2000. The results show that all carbonization temperatures produced briquettes with high calorific values (>5000 cal/g), that is 6981 cal/g at 350°C, 7037 cal/g at 400°C, and 7043 cal/g at 450°C. However, the resulting briquettes did not meet the standard criteria for density, fixed carbon, and volatile matter.

Keywords: *Briquette, Carbonization, Calorific value, Coffee waste, Renewable energy.*

1. INTRODUCTION

Coffee has become one of the most widely consumed beverages worldwide, including in Indonesia. According to data from the International Coffee Organization (ICO) for the 2020/2021 period, coffee consumption in Indonesia reached approximately 5 million 60-kg bags [1]. Robusta and Arabica are the most used coffee types, particularly coffee shops. However, the high consumption of coffee has resulted in a significant increase in ground waste. It is estimated that from 720 tons of coffee production, around 324 tons or approximately 45% ends up as coffee ground waste [2]. This indicates that the utilization of coffee waste remains suboptimal.

Coffee ground waste is often discarded or incinerated, contributing to environmental pollution. Although a small portion of the waste can be repurposed as animal feed or fertilizer, these applications are limited. One promising alternative to managing coffee waste is converting it into biobriquettes as a form of renewable biomass energy. Biobriquettes are solid, porous fuels produced from carbon-containing materials through high-temperature heating processes [3]. Coffee grounds, as well as other biomass sources such as coconut shells, sawdust, and corn stalks, can be used to produce biobriquettes through carbonization, followed by the addition of binders and molding into specific shapes.

Biobriquettes offer several advantages over coal briquettes, including being environmentally friendly, utilizing waste materials, and offering efficient and cost-effective combustion. In contrast, coal briquettes tend to have higher calorific values, more stable combustion, and greater availability. One of the most critical factors influencing the quality of biobriquettes is the carbonization temperature. Higher carbonization temperatures generally lead to an increase in calorific value [4].

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This study aims to determine the optimum carbonization temperature for coffee ground briquettes and evaluate their characteristics based on the Indonesian National Standard (SNI 01-6235-2000), which includes parameters such as moisture content, ash content, volatile matter, density, fixed carbon, and calorific value.

Previous studies have explored the use of carbonization temperature variations in briquette production. For example, Pratiwi and Mukhaimin used torrefaction temperatures of 200°C, 250°C, and 300°C to produce coffee ground briquettes with 40% pine resin binder. Their results indicated that a temperature of 300°C produced briquettes with a calorific value of 6124 cal/g and good durability [5]. Another study by Haryono et al. used corncob and polyethylene waste as binder materials, with carbonization temperatures of 350°C, 400°C, and 450°C. The best results were obtained at 450°C, producing briquettes with optimal properties [4].

This research is expected to contribute to the development of alternative energy by optimizing the quality of coffee ground briquettes. The findings are anticipated to support the utilization of biomass waste as a sustainable energy source for communities.

2. RESEARCH METHODOLOGY

This research was conducted at Laboratory in Chemical Engineering department and Mechanical Engineering department, Politeknik Negeri Bandung and Laboratory of Cement, Balai Besar Bahan dan Barang Teknik (B4T). The raw materials used for this research were coffee ground, tapioca flour, and water. Figure 1 below show the flowchart of making biobriquette.

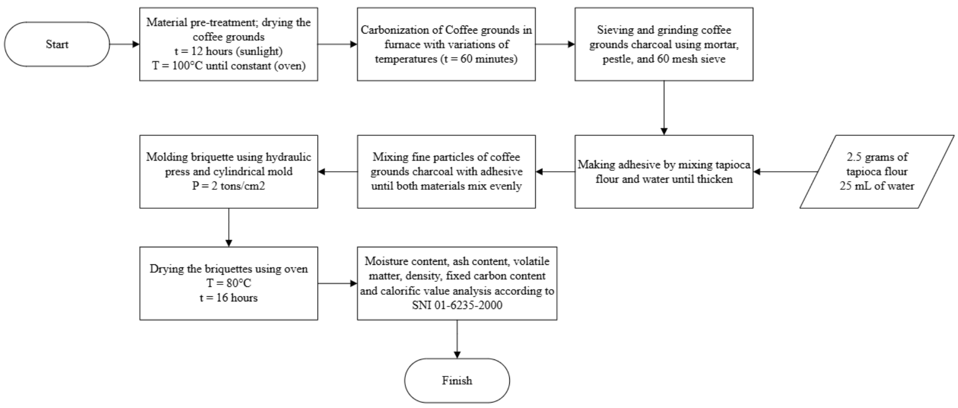

Figure 1. Flowchart of making biobriquette.

2.1 Coffee grounds pre-treatment

Coffee grounds have a highwater content. Therefore, drying coffee grounds to reduce the water content contained before proceeding to the next process. Drying of coffee grounds is done by two methods, which are sun drying and oven drying. Coffee grounds that have been dried by sunlight for approximately 12 hours are still moist and have many lumps, therefore drying is continued using an oven with a temperature of 100℃ and weighed periodically, drying is stopped when the weight is constant. The dried coffee grounds were sieved to separate them from impurities, the coffee grounds that did not pass the sieve were grinded and sieved again.

2.2 Coffee grounds carbonization

Carbonization is the process of physically transforming a raw material into black carbon. In addition, this process aims to increase the calorific value of the briquettes produced. Carbonization of coffee grounds is carried out with temperature variations at 350℃, 400℃, and 450℃. Coffee grounds were put into a closed porcelain cup and carbonized in the furnace for 60 minutes.

2.3 Sieving and grinding

Carbon or charcoal that has been cooled is then given treatments such as grinding and sieving. The charcoal formed is grinded using a mortar and pestle, then sieved using a 60mesh sieve, according to the results of research by Nisa, charcoal powder with a particle size of 60 mesh produces the highest density. Furthermore, the particles that did not pass were grinded and sieved again [6].

2.4 Adhesive making

The adhesive used is made from tapioca starch. The weight of tapioca starch is 5% of the weight of coffee ground charcoal and the ratio between tapioca starch and water following previous research is 1:10 [7]. The adhesive making process begins with weighing 2.5 grams of tapioca starch and dissolving it with 25 milliliters of water. The mixture was then stirred with a stirring rod to make it homogeneous. Furthermore, the tapioca solution is heated until it thickens enough.

2.5 Mixing of coffee grounds charcoal and adhesive

The adhesive that has been made is mixed with coffee grounds charcoal in a container using spatula until both of materials mix evenly.

2.6 Briquette molding

The mixture of coffee grounds charcoal and its binder is put into a cylindrical briquette mold. Then, the filled mold was pressed using a hydraulic press with pressure of 2 tons/cm^2. The briquettes are then dried, drying condition of the briquette were following research by Kustiawan et al. [8], where the briquette were dried using an oven at 80°C for 16 hours.

2.7 Analytical methods

2.7.1 Moisture content

Based on the SNI 01-6235-2000 standard, testing the water content of briquettes follows the SNI 06-3730-1995 standard for technical activated charcoal by adding 1 gram of briquette sample to a weighing bottle. The weighing bottle is then put into the oven at 115°C for 3 hours and then cooled in a desiccator and weighed until the weight is constant. The value of water content can be obtained from calculations based on ASTM D-3173-03 as follows:

$$MC = \frac{W_1 - W_2}{W_2} \times 100\% \quad (1)$$

Where:
MC = moisture content (%)
W_1 = initial weight (gram)
W_2= weight after heating (gram)

2.7.2 Ash content

The sample is heated at hightemperature, the residual heating is counted as ash in the sample. The analysis is carried out by taking a 2gram sample of briquettes and placing it in a porcelain cup. The sample is slowly ignited, then the temperature in the furnace is increased to 800-900°C for 2 hours. Then the sample was cooled in a desiccator and weighed. The ash content value is obtained from the following calculation:

$$AC = \frac{W_1}{W_2} \times 100\% \quad (2)$$

Where:
AC = ash content (%)
W_1 = residual ignition (gram)
W_2= sample weight (gram)

2.7.3 Volatile matter

Based on the SNI 01-6235-2000 standard, the analysis of volatile matter follows the SNI 06-3730-1995 standard. In principle, organic matter contained in charcoal will evaporate on heating without oxygen at 950°C. Briquette samples are weighed as much as 1-2 grams into a porcelain cup of known weight. The cup containing the sample is closed and put into the furnace at 950°C for 7 minutes. After completion, the cup is cooled.

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$$VM = \frac{W_1 - W_2}{W_2} \times 100\% \quad (3)$$

Where:
VM = volatile matter (%)
W_1 = initial weight (gram)
W_2= weight after heating (gram)

2.7.4 Briquette density

Samples that have been dried at 80ºC are weighed and the diameter and height of the briquettes obtained are measured. The volume of the briquettes was calculated based on the tube volume formula.

$$Density = \frac{W}{V} \quad (4)$$

Where:
Density (g/cm^3)
W = sample weight (gram)
V = sample volume (cm^3)

2.7.5 Fixed carbon content

Determination of fixed carbon content is calculated by this equation:

$$FC = 100 - (MC + VM + AC) \quad (5)$$

Where:
FC = fixed carbon (%)
MC = moisture content (%)
VM = volatile matter (%)
AC = ash content (%)

2.7.6 Calorific value (ASTM D 5142-02)

The calorific value analysis was conducted at the Physical Chemistry Laboratory, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung. Based on SNI 01-6235-2000, minimum calorific value requirement for briquettes from wood charcoal is 5000 cal/g.

3. ANALYSIS AND RESULT

3.1. Briquettes Moisture Content

The results of the analysis of moisture content in briquettes for each variation of carbonization temperature are presented in Figure 2.

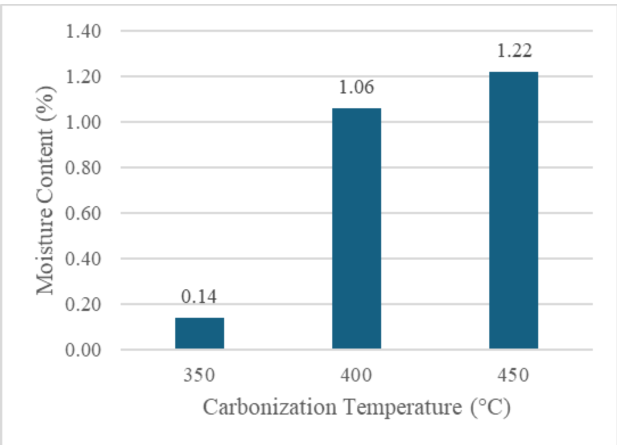

Figure 2. Moisture Contained in the Briquettes for Each Variation of Carbonization Temperature

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Figure 2 shows that the higher carbonization, the greater moisture content obtained. This happens because of the hygroscopic nature of coffee charcoal that can absorb water. Even though the briquettes have been dried for 16 hours at 80oC, it can absorb moisture and increasing its moisture content. Carbonization temperatures can also affect this since the higher temperature can increase the volume of micropores in briquettes [9]. High micropores volume indicate that briquette has more space to hold moisture within it. In addition, volatile matter was forced out of the charcoal at high carbonization temperatures resulting an opening in its structure [10].

3.2. Briquettes Ash Content

Ash is a residue that is formed because of inorganic matter that are non-combustible. One of the main component of ash is silica. Low ash content can effect calorific value of the briquette. The greater ash content obtained, the smaller calorific value will obtained [11]. This happens because silica is a component that is difficult to burn. The energy generated from burning briquettes will be absorbed to burn silica which ends up as ash or residual combustion products. A small ash content value indicates that the briquettes can burn completely. The results of the analysis of ash content in briquettes for each variation of carbonization temperature are presented in Figure 3.

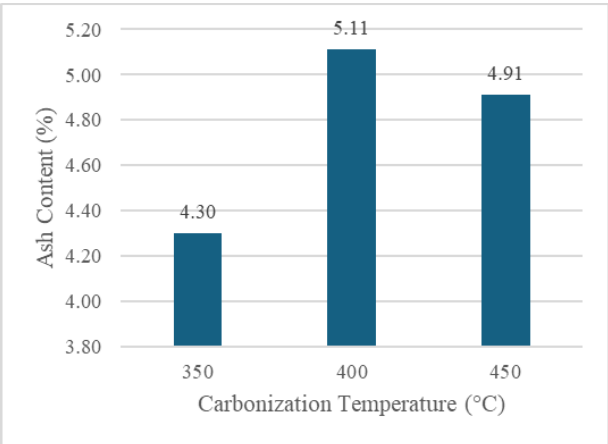

Figure 3. Ash Contained in the Briquettes for Each Variation of Carbonization Temperature

Figure 3 shows that the ash content increases when the temperature also increases. Then, the ash content decreases as the temperatures increase from 400°C to 450°C. The increasing trend happens because at higher carbonization temperatures, inorganic and organic components experience critical devolatilization which increases the amount of ash content [12].

3.3. Briquettes Volatile Matter

The results of the analysis of volatile matter in briquettes for each variation of carbonization temperature are presented in Figure 4.

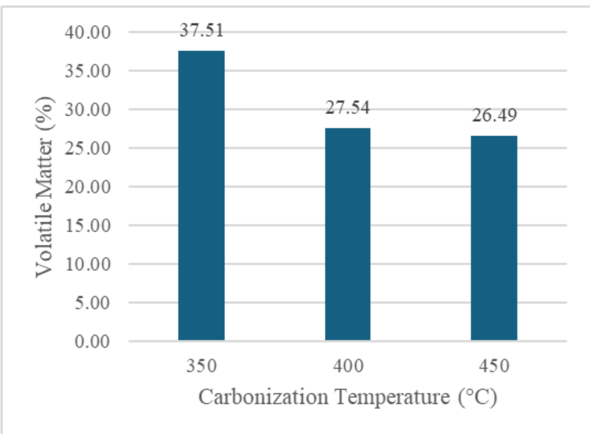

Figure 4. Volatile Matter Contained in the Briquettes for Each Carbonization Temperature Variation

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Volatile matter is a form of decomposition of compounds that are still present in the briquette besides water [13]. High levels of volatile matter can cause the amount of smoke produced to be higher [14]. Based on the results of the three briquette samples with different carbonization temperatures, the briquette with the highest volatile matter content is the briquette carbonized at 350oC and the lowest is the briquette carbonized at 450oC. Volatile matter content will decrease as the carbonization temperature increases, the higher the carbonization temperature will cause more organic compounds to be lost, so that the content of volatile substances in the briquette will be smaller [15]. Even so, the volatile matter content of the three samples did not meet the SNI standard where the value exceeded 15%. The high and low levels of volatile matter can be caused by the perfection of the carbonization process which is influenced by temperature and time. In addition, the addition of adhesive, which is an organic material, can increase the volatile matter content of briquettes. Adhesives that have not been carbonized will cause higher volatile matter levels than charcoal, therefore the addition of adhesives will increase volatile matter levels [16].

3.4. Briquettes Density

The results of the analysis of briquettes density for each variation of carbonization temperature are presented in Figure 5.

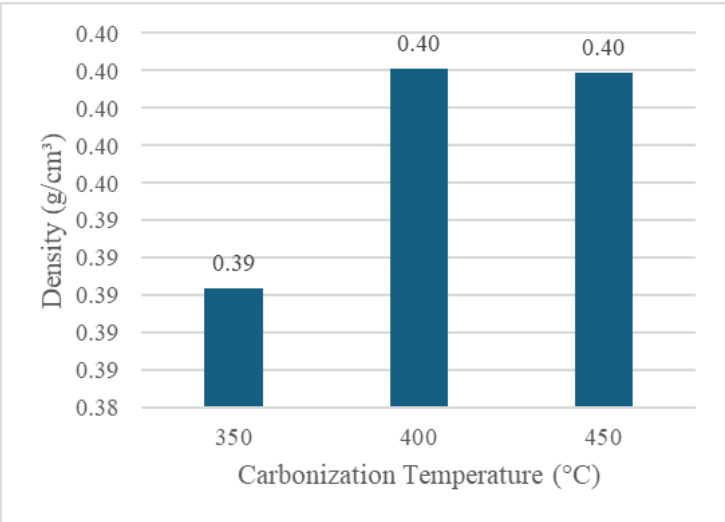

Figure 5. Briquettes Density for Each Carbonization Temperature Variation

The results of the briquette density analysis did not meet the SNI standard, where the SNI standard minimum briquette density is 0.447 g/cm3. Carbonization temperature can affect the particle size of the carbonized coffee grounds. The higher the temperature, the more complete the carbonization [17]. Therefore, briquettes with a carbonization temperature of 400℃ & 450℃ have a density that is close to SNI standards. Finer particle size also enlarges the bonding area of charcoal powder thus increasing its density [18]. In addition, moisture content can also affect the density of the briquettes. Both briquettes with carbonization temperature of 400℃ & 450℃ have density and moisture content that similar to each other. According to Abdel Aal et al.[19], the higher moisture content, the denser and smoother briquettes obtained. However, briquette that is too moist can also decrease its density by making it too soft to be molded and cause huge crack on its surface.

3.5. Briquettes Fixed Carbon Content

The results of the analysis of fixed carbon in briquettes for each variation of carbonization temperature are presented in Figure 6.

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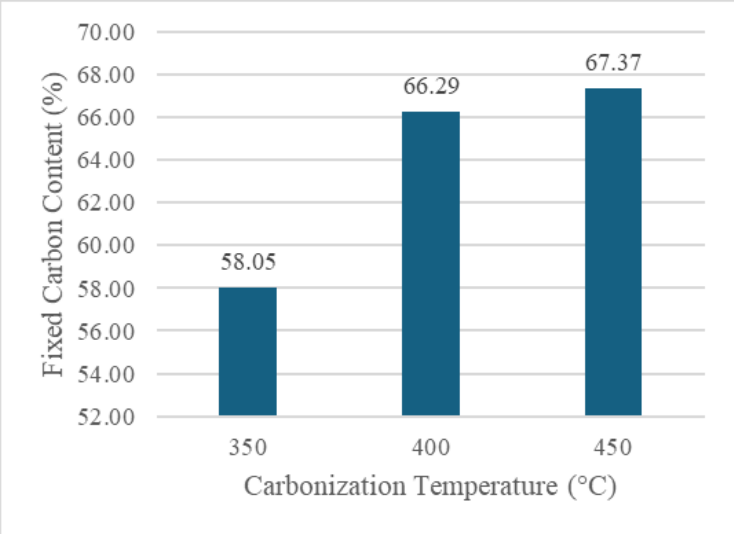

Figure 6. Fixed Carbon Contained in the Briquettes for Each Carbonization Temperature Variation

Based on the analysis results, the highest fixed carbon content is owned by briquettes carbonized at 450oC and the lowest is briquettes carbonized at 350oC. These results show that the higher the carbonization temperature can increase the fixed carbon content of the briquettes. This is corroborated by the opinion of Alam [20], the increase in fixed carbon content can be due to increasing temperature, which can cause constituent compounds such as water and other vaporized substances to decompose due to high temperatures, so that what remains is carbon. Fixed carbon content is influenced by volatile matter content, moisture content, and ash content. High levels of volatile matter, moisture, and ash can reduce fixed carbon levels.

3.6. Briquettes Calorific Value

The results of briquette calorific value for each variation of carbonization temperature are presented in Figure 7.

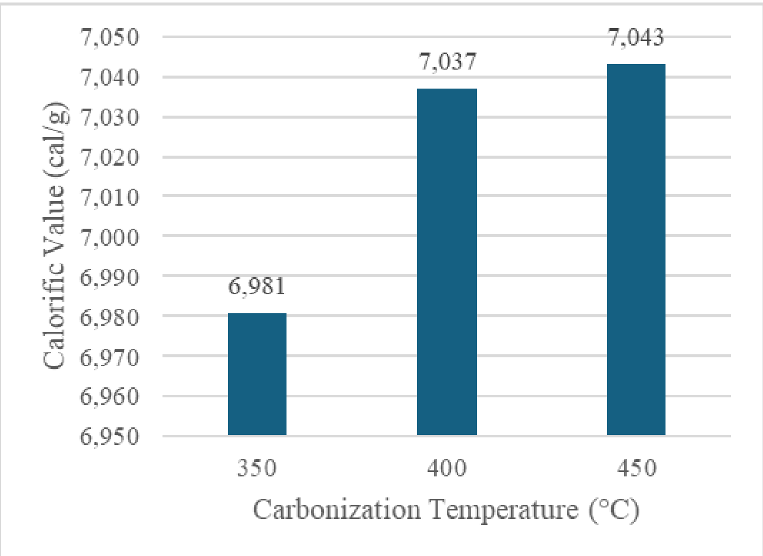

Figure 7. Briquettes Calorific Value for Each Carbonization Temperature Variation

The briquettes have met the standards set by SNI where the minimum calorific value for briquettes is 5000 cal/g. The sample that has the highest calorific value among the three temperature variations is the briquette with a carbonization temperature of 450°C, which is 7043 cal/g. Increasing carbonization temperature will increase the total carbon content in briquettes [4]. In addition, the calorific value is also influenced by carbon content, where the oxidation reaction of carbon will produce calories [21].

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Therefore, the higher the carbonization temperature, the higher the calorific value of the briquettes. Calorific value can be influenced by moisture content and ash content, ash content and moisture content obtained are very small, so the calorific value obtained is quite high.

4. CONCLUSION

Based on the results of the study, among the three carbonization temperatures tested (350℃, 400℃, and 450℃), the briquettes produced at 450℃ showed the highest calorific value of 7,043 cal/g. Although several parameters, including volatile matter content, density, and fixed carbon content, did not fully comply with the Indonesian National Standard (SNI 01-6235-2000), the briquettes at 450℃ demonstrated the closest alignment. These findings suggest that higher carbonization temperatures significantly improve the quality of coffee ground briquettes, making them a promising alternative to renewable energy. It is recommended that future studies investigate the effects of binder composition, particle size, and carbonization duration to further enhance briquette quality in compliance with national standard.

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