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UTILIZATION OF COFFEE GROUNDS INTO BIO-BRIQUETTES USING VARIOUS TYPES OF ADHESIVES WITH CARBONIZATION METHOD

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ABSTRACT

Coffee is one of the most widely produced and consumed agricultural commodities in Indonesia, with production rates increasing each year. This growing demand results in an increasing volume of spent coffee grounds, which are typically discarded as waste. One sustainable approach to managing this waste is by converting it into bio-briquettes, a form of solid fuel. This study aims to evaluate the physicochemical characteristics of coffee ground-based briquettes using different types of adhesives in accordance with the Indonesian National Standard (SNI 01-6235-2000) and to determine which adhesive yields the highest briquette quality. Three types of adhesives were tested: tapioca starch, sago starch, and polyvinyl alcohol (PVA), each mixed with carbonized coffee grounds in a 1:10 ratio. The briquettes were analyzed based on key performance indicators, including moisture content, ash content, volatile matter, density, fixed carbon, and calorific value. The carbonization process was applied prior to briquette formation to improve fuel quality. The results showed that the briquette using PVA as an adhesive exhibited the best overall performance, with a density of 0.449 g/cm³, ash content of 4.360%, moisture content of 1.480%, volatile matter of 33.974%, fixed carbon of 59.743%, and a calorific value of 6.861 cal/g. These findings suggest that PVA-based briquettes offer promising potential in reducing biomass waste and supporting the development of renewable energy in Indonesia.

Keyword: *Adhesive, Bio-Briquettes, Carbonization, Coffee Grounds, PVA*

1. INTRODUCTION

Indonesia is among the top coffee-consuming and producing countries globally. According to the United States Department of Agriculture (USDA), Indonesia ranked as the third-largest coffee producer in the world in the 2022/2023 period, with a production volume of 11.85 million bags of coffee [1]. This trend has shown a steady increase over the past five years. Based on a report by the Central Bureau of Statistics (BPS) in 2023, Indonesia's coffee production reached 794.8 thousand tons in 2022 [2]. However, this increase in production has also led to a corresponding rise in the amount of coffee grounds spent, which are often disposed of as waste.

Spent coffee grounds contain various toxic organic compounds such as alkaloids, tannins, and polyphenols, which inhibit natural decomposition processes in the environment [3]. One potential solution to address this issue is to convert coffee grounds into solid biomass fuel in the form of briquettes. Briquettes are renewable energy products known for their relatively high calorific value and low environmental impact. According to the Indonesian National Standard (SNI 01-6235-2000), high-quality briquettes should have a minimum calorific value of 5000 cal/g, a maximum ash content of 8%, and a moisture content not exceeding 8%. In addition to thermal stability and combustibility, good briquettes must be able to sustain combustion at 350 °C for extended durations [4].

The production of biomass briquettes not only requires raw materials such as biomass waste, but also suitable adhesives that bind the carbonized material effectively. Common adhesives include tapioca starch, sago flour, and synthetic polymers like polyvinyl alcohol (PVA) [5]. According to Azis et al. [6], the choice of adhesive significantly influences briquette properties such as moisture content, ash content,

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calorific value, and burn duration. Their study comparing different adhesive types in coconut shell briquettes found that arpus adhesive yielded the best performance, with the highest calorific value and longest burn time.

Another study conducted by Rajput and Thorat [7] demonstrated that combining recovered PVA with pregelatinized starch produced high-quality briquettes with reduced production costs. The use of recovered PVA from textile industry waste presents a sustainable solution for both waste management and energy production.

Nevertheless, there remains substantial room for improving the efficiency and quality of coffee ground briquettes, especially through optimization of adhesive composition and processing parameters. This study aims to evaluate the effects of three different adhesive types (tapioca flour, sago flour, and PVA) on the physicochemical properties of briquettes made from spent coffee grounds. The goal is to determine the most optimal adhesive formulation that meets the SNI standard and aligns with the growing demand for renewable energy alternatives in Indonesia.

2. RESEARCH METHODOLOGY

This study was conducted using a structured and systematic approach to ensure the validity and reliability of the results. The methodology comprises a series of interconnected stages, beginning with a comprehensive literature review and concluding with data analysis and interpretation. Each step was designed to build upon the previous one, forming a coherent workflow that guided the entire research process. The overall sequence of activities undertaken in this study is illustrated in the flow diagram below (Figure 1). This study was conducted over a two-months period, from June to July 2024, at the Chemical Engineering Laboratory, Department of Chemical Engineering, Politeknik Negeri Bandung, Indonesia.

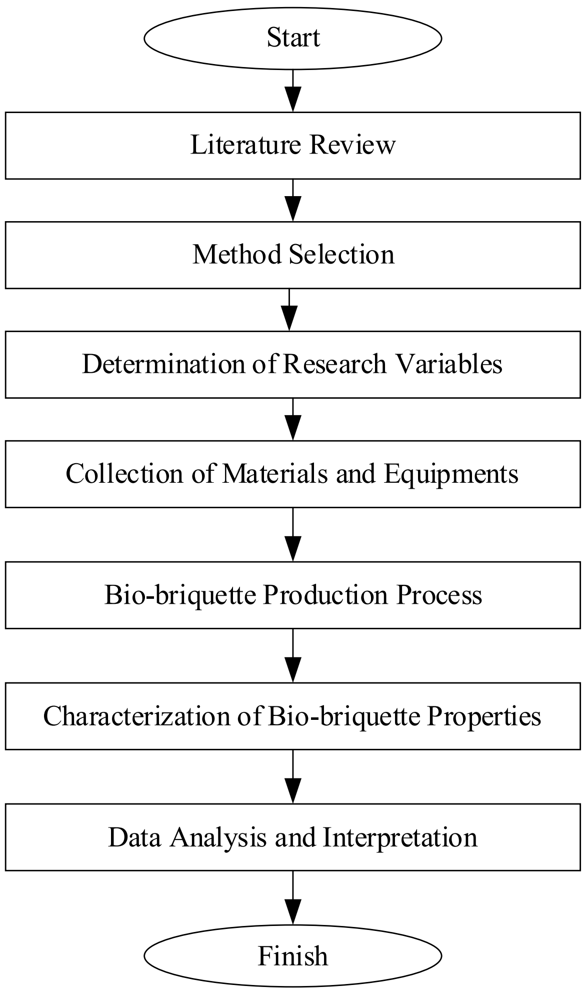

Figure 1. Flowchart of the Research Methodology

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2.1 Production Process of Bio-Briquette

To ensure clarity and reproducibility, the experimental steps involved in the production of activated carbon briquettes from spent Arabica coffee grounds are outlined in a structured sequence. The process began with raw material preparation, followed by carbonization, particle refinement, adhesive preparation, molding, and drying. Each stage was carried out under controlled conditions to maintain consistency in briquette quality. A flowchart diagram summarizing the research procedure is presented in Figure 2 below.

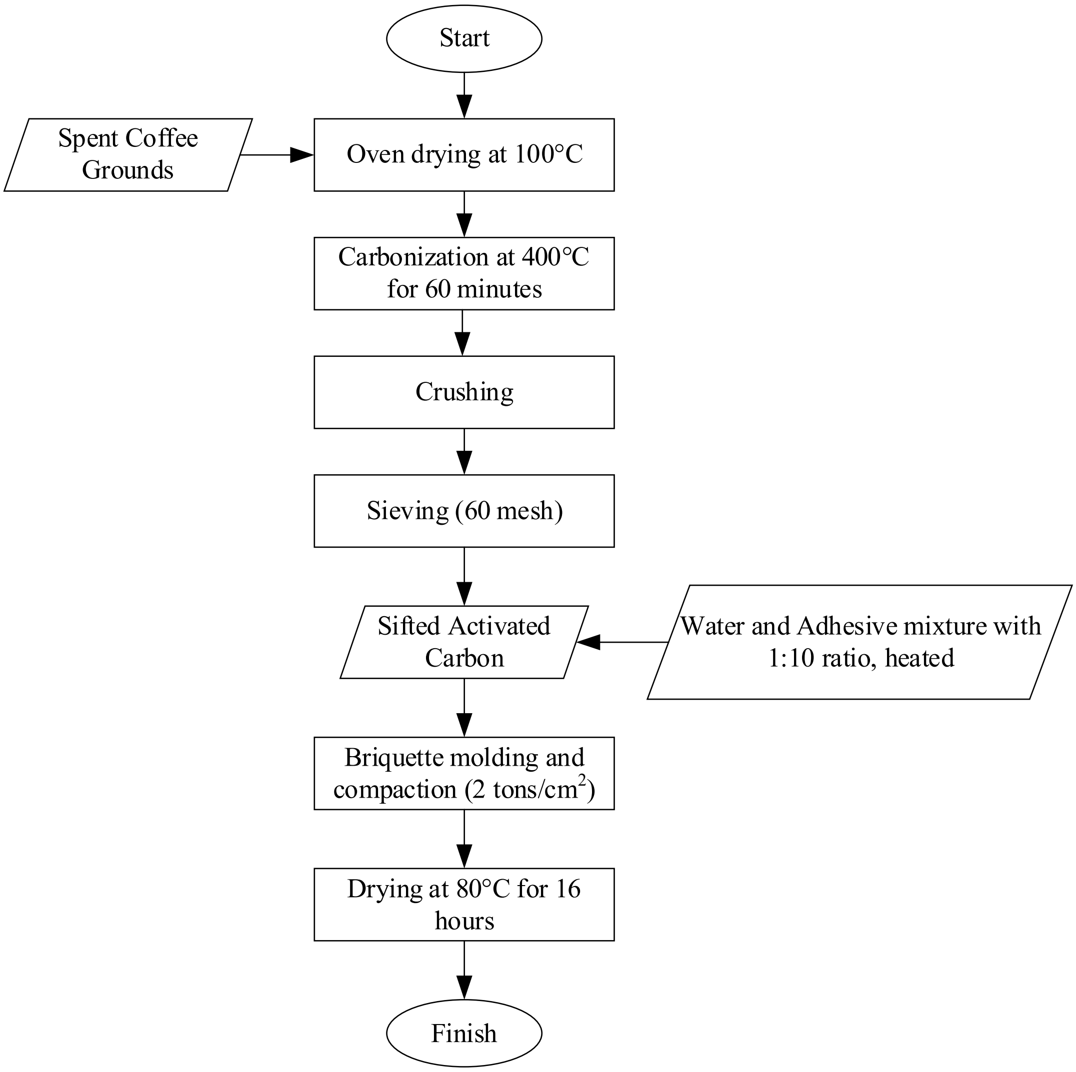

Figure 2. Flowchart of the Procedure for Bio-Briquette Production

2.2 Analytical Methods

Upon completion of the briquette production process, the resulting briquettes were comprehensively analyzed to evaluate their inherent characteristics. The following analytical methods were employed:

a. Density

The density is calculated by using equation (1)

$$\rho = \frac{m}{V} \qquad (1)$$

with,
ρ = density (g/cm^3)
m = mass (g)
V = volume (cm^3)

b. Ash Content

The density is calculated by using equation (2)

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$$\text{Ash Content (\%)}=\frac{W_2}{W_1}\times 100\% \quad (2)$$

with,
W_1 = sample weight (g)
W_2 = residual incandescent weight (g)

c. **Moisture Content**
The density is calculated by using equation (3)

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

with,
W_1 = sample weight (g)
W_2 = sample weight after heating process (g)

d. **Volatile Matter**
The density is calculated by using equation (4)

$$\text{Volatile Matter (\%)}=\frac{W_1\text{-}W_2}{W_1}\times 100\% \quad (4)$$

with,
W_1 = sample weight (g)
W_2 = sample weight after heating process (g)

e. **Fixed Carbon**
The density is calculated by using equation (5)

$$\text{FC (\%)}=100\%\text{-}(M+V+A)100\% \quad (5)$$

with,
M = moisture content (%)
A = ash content (%)
V = volatile matter (%)

f. **Calorific Value**
Calorific value is determined by using a calorimeter bomb. The test involves placing a known mass of briquette sample in the calorimeter chamber, which is filled with excess oxygen to ensure complete combustion. The sample is then ignited, and the temperature change in the surrounding water is recorded. This temperature change is used to calculate the amount of heat released during combustion, which is then expressed as calorific value in cal/g. Prior to testing, all briquette samples were conditioned to ensure consistent moisture levels, as moisture significantly affects the accuracy of calorific value measurements.

2.3 Data Analysis and Interpretation

All experimental data were processed and interpreted using standard laboratory calculations and statistical evaluation where applicable. The analysis focused on identifying the impact of adhesive type on the quality of the resulting briquettes. Results were compared against the Indonesian National Standard (SNI 01-6235-2000) for wood charcoal briquettes, as outlined in Table 4.

Table 4. Quality Standard for Wood Charcoal Briquettes

Property	Unit	Requirement
Moisture Content	%	< 8
Volatile matter	%	< 15
Ash Content	%	< 8
Fixed Carbon	%	< 77
Density	g/cm^3	> 0.447
Calorific Value	cal/g	> 5000

Source: SNI 01-6235-2000

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3. ANALYSIS AND RESULT

3.1 Density

Density on briquettes aims to determine the density of briquettes using the ratio of mass and volume. The results of density testing of coffee ground briquettes with various types of adhesives are presented in Figure 3 below.

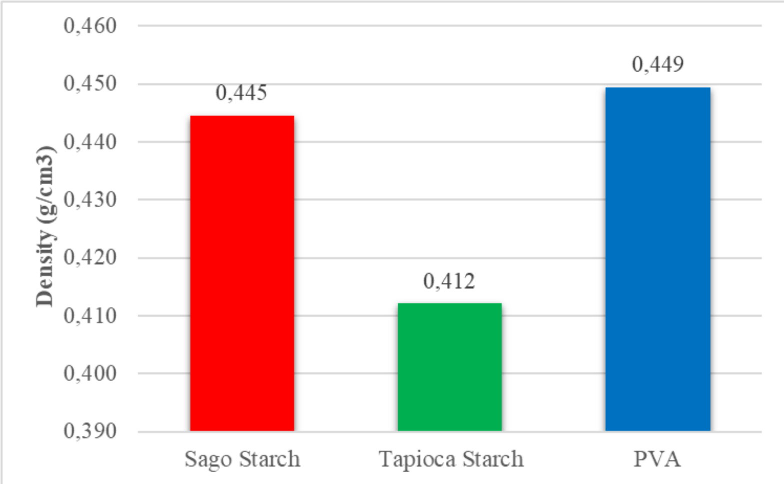

Figure 3. Correlation between Density and Adhesive Type

Briquettes with tapioca starch adhesive have the lowest density of 0.412 g/cm3, while briquettes with PVA 6 adhesive have the highest density of 0.449 g/cm3. According to Iriany et al. (2016) stated that a high-density value causes the briquette to be stronger against pressure but tends to be difficult to burn because the air cavity in the briquette is getting less because the bond between the powders is tight [8]. Meanwhile, briquettes with low density are easier to burn because they have a larger air gap so that oxygen can pass through in the combustion process. Briquettes with low density will burn out faster because there are too many air voids [9]. According to the SNI 01-6235-2000 standard, the density of good quality briquettes is above 0.447 g/cm3, so only PVA briquettes whose density meets the SNI criteria.

3.2 Ash Content

The ash content of the briquettes was determined using the direct ash method in a furnace with a combustion temperature of 850°C and a duration of 120 hours. The ash content of coffee grounds briquettes with different types of adhesives is presented in Figure 4.

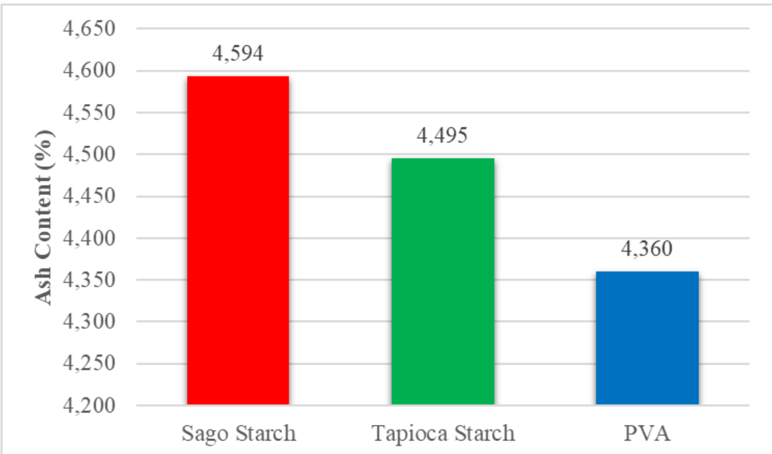

Figure 4. Correlation between Ash Content and Adhesive Type

Briquettes with PVA adhesive have the lowest ash content of 4.360%, while briquettes with sago starch adhesive have the highest ash content of 4.594%. All samples have ash content that has met the SNI 01-

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6235-2000 standard, which is below 8%. Ash content is one of the important parameters because it cannot burn well. High ash content affects the amount of calorific value produced [10].

3.3 Moisture Content

The moisture content was determined by calculating the weight loss after heating the samples at 110°C until a constant weight was achieved. The results of the moisture content analysis are shown in Figure 5, which illustrates the relationship between adhesive type and residual water content in the briquettes.

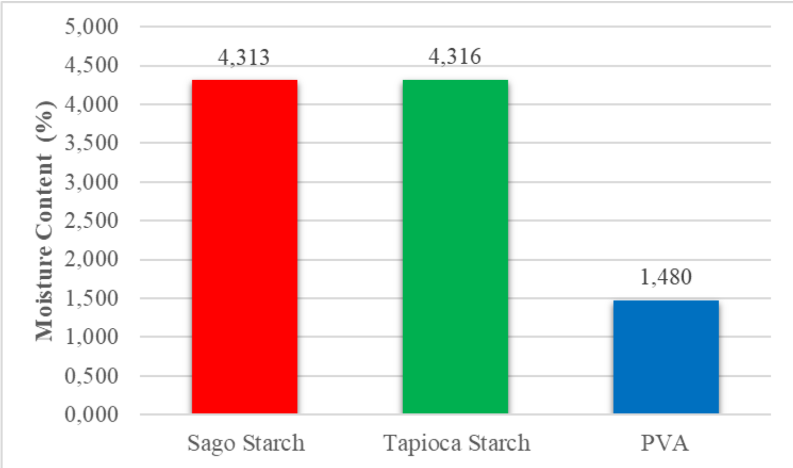

Figure 5. Correlation between Moisture Content and Adhesive Type

Moisture content in briquettes is determined by calculating the weight lost after the sample is heated at a temperature of 110°C. The moisture content of briquettes is influenced by the type of raw material, type of adhesive and the test method used [11]. The moisture content of coffee grounds briquettes with various types of adhesives is presented in Figure 3. Briquettes with PVA adhesive have the lowest moisture content of 1.48%, while briquettes with tapioca starch adhesive have the highest moisture content of 4.316%. Briquettes with low moisture content are considered better because they produce less smoke and have more efficient combustion. All samples have moisture content that has met the SNI 01-6235-2000 standard, which is below 8%.

3.4 Volatile Matter

Volatile matter is the percentage of volatile and combustible materials in a briquette. Volatile substances in this category are carbon and hydrogen [12] [13]. Volatile matter levels are presented in Figure 6.

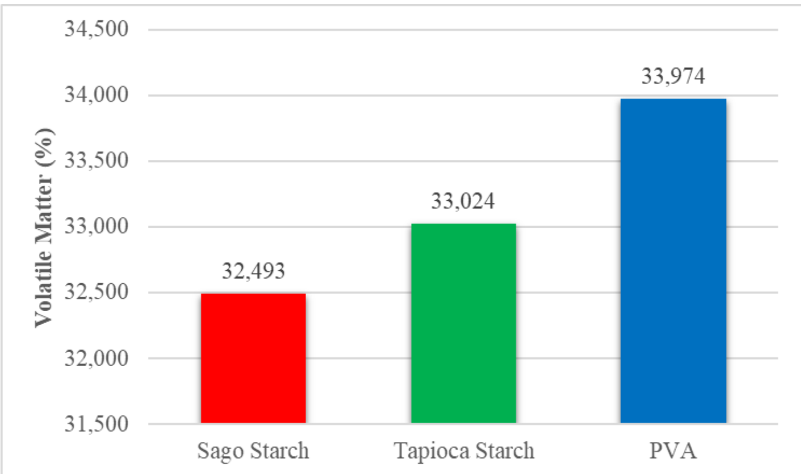

Figure 6. Correlation between Volatile Matter and Adhesive Type

Briquettes with sago starch adhesive have the lowest volatile matter content of 32.493%, while briquettes with PVA adhesive have the highest volatile matter content of 33.974%. Low volatile matter content indicates better briquette quality because less smoke is produced. Raw materials that have undergone carbonization process have lower volatile matter content because the content of flying

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substances has been reduced through the combustion process. All samples did not meet the SNI 01-6235-2000 standard of less than 15% volatile matter.

3.5 Fixed Carbon

Based on the analysis results, the effect of adhesive type on fixed carbon can be seen in Figure 7.

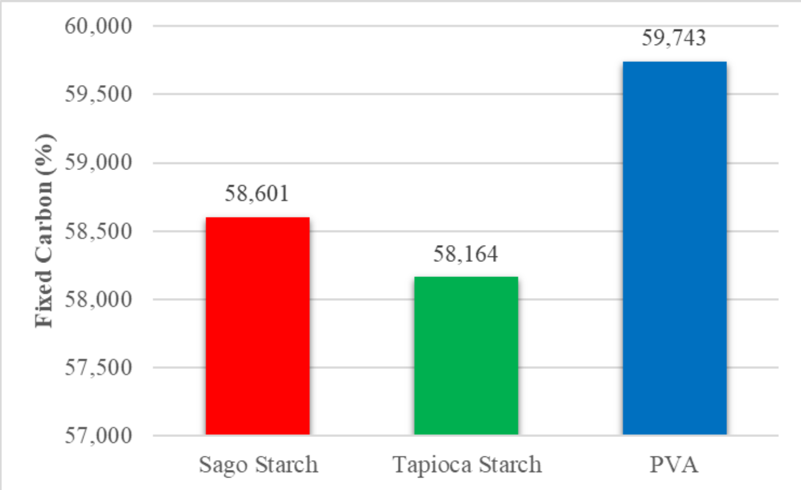

Figure 7. Correlation between Fixed Carbon and Adhesive Type

Fixed carbon content is the percentage of carbon remaining from the devolatization process of the material contained in the briquette [14]. Briquettes with the highest fixed carbon value are briquettes with PVA adhesive, which is 59.743%, followed by briquettes using sago adhesive, 58.600% and the lowest fixed carbon value is briquettes using tapioca adhesive, 58.164%. The higher the bound carbon content indicates better briquette quality because the more C or carbon content in bio-briquette raw materials, the better the combustion process because carbon will react with oxygen, or in other words, the more C content, the more C will react with oxygen [15]. Factors that affect the fixed carbon value are ash content, moisture content and volatile metter. Bound carbon will have a greater value if the ash content and volatile matter content are low. Vice versa, the value of bound carbon is lower if the percentage of volatile 9 matter content is high [16]. Bound carbon will decrease if the water content increases [17].

3.6 Calorific Value

Calorific value is the heat that moves when the result of complete combustion or the maximum amount of heat energy released by a fuel through a complete combustion reaction [18]. Based on the analysis results, the effect of adhesive type on fixed carbon can be seen in Figure 8 below.

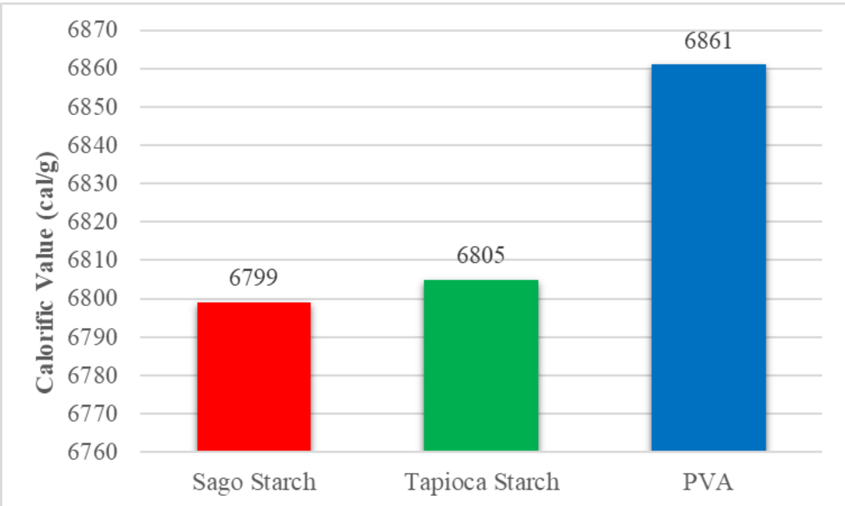

Figure 8. Correlation between Calorific Value and Adhesive Type

The higher the calorific value in bio-briquettes indicates the better the quality of the bio-briquettes produced [9]. Briquettes with PVA adhesive have the highest calorific value of 6.861 cal/g, followed by briquettes using tapioca adhesive at 6.805 cal/g and the lowest calorific value is owned by briquettes using sago adhesive at 6,799 cal/g. Based on the calorific value, each briquette sample meets the SNI 01-6235-2000 standard, which has a calorific value of more than 5000 cal/g. The factor that affects the calorific value of a briquette is ash content, according to research conducted by Hadiasyah et al. (2021) the greater the ash content, the smaller the calorific value of the briquette [19]. This can be seen in briquettes with sago adhesive which has the highest ash content of 4.594% which has the lowest calorific value of 6,799 cal/g. Another factor that affects the calorific value is the temperature of the carbonization process because the synthesis temperature is directly proportional to the calorific value of the briquettes [20]. Carbonization temperature affects the percentage of water content in briquettes [21]. If the moisture content of bio-briquettes is high, the energy produced from the briquettes is mostly used to evaporate water so that the calorific value is low or decreases, for this reason, the higher the moisture content, the lower the calorific value [22].

4. CONCLUSION

Based on the results of the analysis, it can be concluded that the three briquettes with tapioca starch, sago starch, and PVA adhesives have met SNI 01-6235-2000 standards for water content, ash content and carbon value. While briquettes that met SNI 01-6235-2000 standards for density values are only briquettes with PVA adhesives, with these briquettes that have test results that almost fulfill SNI 01-6235-2000 standards are briquettes with PVA adhesives.

Based on the findings of this study, it is recommended to continue the research by exploring other parameter variations, such as pressing pressure, drying temperature and duration, as well as a more varied proportion of adhesive mixture. This step is expected to produce briquettes with more optimal quality. This research also opens up opportunities to explore the use of other natural adhesives that are more environmentally friendly and locally available. This approach will not only increase the added value of the product but also support the development of sustainable renewable energy in Indonesia.

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