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Effect of Adhesive Variation on the Characteristic of Palm Shells‘ Biomass Briquettes

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***Abstract*— Palm oil shells are an example of the residual products of the palm oil processing industry which can be utilized asa new alternative renewable energy source in the form of briquettes. The oil palm shells in this study were first carbonized for 1 hour with a heating temperature in the muffle furnace of 600˚C, then crushed and mashed, then kneaded with each variation of adhesive and molded so that the dough can form a cylinder with a diameter of 2 cm and 4 cm high. The average calorific value obtained for cornstarch adhesive, rice flour adhesive and pine resin adhesive were respectively 6634.29 cal/gr,6702.47 cal/gr, and 7798.31 cal/gr. The average water content in cornstarch adhesive, rice flour adhesive, and pine resin adhesive were 5.1%, 5.0% and 3.7%, respectively. The average values of volatile matter content in the adhesives of cornstarch,rice flour, and pine resin were 30.90%, 31.70% and 60.73%, respectively. The results of this study indicate that any increasein the calorific value will be followed by a decrease in the water content and the varying values of the volatile matter content.**

Keywords— Briquettes, Palm Shells, Adhesive Variations, Calorific Value, Moisture Content, Volatile Matter

I. INTRODUCTION

Based on a report by the International Energy Agency (IEA), 30% of the main energy supply in several developing countries is obtained from biomass. Biomass comes from plants, animals, crops and garden waste which can be an alternative fuel source that has an important role in saving fossil fuels, reducing gas emissions and increasing energy security. Currently, biomass briquettes are one of the many methods used to convert biomass energy sources into other forms of biomass by being compressed so that they have a more regular shape [1]. Briquettes as an energy product from alternative biomass fuels can meet the needs of households and industries in producing heat.

These briquettes are basically used as fuel from household to industrial needs. Briquettes can be declared/classified of high quality if they have a smooth texture, are not easily broken, are hard, safe for humans and the environment and have good ignition properties such as easy ignition, a long flame time, low soot and smoke production, and have a calorific higher value can be categorized as superior briquettes. The calorific value is a quantity that can describe the heat contained in a material. Where, when the higher the calorific value contained, the easier it is to burn, the higher the calorific value, and the burning time will be even longer [2]. The calorific value itself is obtained from a number of heat units produced from the weight unit of the combustion process in the presence of oxygen. A briquette will be of higher quality if the calorific value is higher. This calorific value can be determined by the carbon content present in the briquette itself. To determine the calorific value of a briquette, a heat test is carried out using a Bomb Calorimeter with a predetermined procedure [1]. Not only the calorific value, the low water content and the volatile matter content are also generally used as parameters that determine the quality of a briquette. The water content in the briquettes is the ratio between the weight of the dry briquettes and the weight of the water contained in the briquettes themselves. This water content is the opposite of the calorific value, where if the water content contained is lower, the calorific value and combustion power will be higher, and vice versa. When the water content contained is higher, the greater the energy needed to be able to evaporate water [1]. While the levels of volatile substances are the result of a decomposition of the substances that make up the charcoal itself as a result of the heating process. This analysis aims to determine the number of compounds or the amount of substances that have not evaporated during the carbonization and activation processes. The absorption capacity of briquettes will decrease if there are high levels of volatile matter. Thus, the higher the level of volatile matter the easier it will be for briquettes to burn [1].

The use of briquettes has advantages in terms of the

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exhaust gas content of the combustion products which arerelatively safer than coal briquettes [1]. Over time, briquettes have become one of the alternative solid fuels from a mixture of biomass which is widely available in the surrounding environment. Briquettes are also considered relatively cheaper in terms of production and will allow it to be developed on a large scale in a relatively short time [3]. There are various raw materials that potentially can be used to make briquettes, one of which is palm kernel shells [4]. The main commodity of crude palm oil (CPO) is one of the pillars of the economic improvement of East Kalimantan in the third quarter of 2021 with demand for exports to European countries and South Asia, especially India, Bangladesh and Pakistan[5]when demand for exports is increasing, the by-product orwaste will be directly proportional to it. The average solid waste of palm shells produced for every 100 tons of fresh fruit bunches that have been processed is 20 tons accompanied by 7 tons of waste in the form of fiber and 25 tons for empty fruit bunches [6].

Selection of raw materials will have an influence on the calorific value, moisture content, volatile matter content, ash content and bound/fixed carbon content of a briquette [7]. Oil palm shell is one of the main raw materials that has the potential to be used as an alternative fuel in the form of briquettes. Oil palm shells are considered feasible to be processed into raw materials formaking alternative charcoal other than wood because the oil palm shells contain an innate calorific value of 4465 cal/gr [8].

The quality of a briquette can also be affected by the type and amount of adhesive, as well as the test method tobe used [9]. Based on the results of previous studies, briquettes with cornstarch adhesive produced the best calorific value (5868 cal/gr) compared to tapioca adhesiveof 5700 cal/gr, cassava flour adhesive of 5779 cal/gr and sago flour adhesive of 5779 cal/gr [10] . Cornstarch comes from corn starch which contains 74% amylopectin and 26% amylose in it [11]. The ratio of amylose to amylopectin content will affect the solubility properties and also the degree of gelatinization, where the amylopectin content will cause stickiness [12].

Another study stated that the calorific value of briquettes with pine resin adhesive had the best calorific value, which was 7136.83 cal/gr compared to starch adhesive which had the highest calorific value of 7027.40 cal/gr and clay-resistant adhesive with the highestcalorific value of 6400.04 cal/gr [13]. Pine sap is a concentrated liquid substance resulting from tapping pine trees which belongs to the oleoresin group or commonly known as soft resin. The resin produced by pine resin is anatural resin which has the characteristics of being insoluble in water, melting easily when exposed to heat, flammable, hardens when exposed to air, and emits smoke and a distinctive odor when burned. The advantage of briquettes using pine resin adhesive lies in their strong impact power even if they are dropped from a high place the briquettes will remain intact. Apart from what was mentioned, briquettes with pine resin adhesive will also ignite easily when burned [14]. It is also known in other studies that briquettes using rice flour adhesive tend to cause less smoke and last longer when ignited [15].

Through testing the calorific value, moisture content, and volatile matter content, briquettes from palm shells along with three variations of adhesives such as cornstarch, rice flour, and pine resin will be processed into other alternative energy sources in the form of briquettes with the purpose of helping reduce solid waste of the palm oil industry and converting them into more economical products.

II. METHOD

A. Tools and Materials

The main raw materials used in this study were palm shells and three variations of adhesives, namely cornstarch, rice flour, and pine resin. The tools used in the briquette manufacturing process include electric drying ovens, muffle furnaces, mortar & pestle, blenders, 60 mesh sieve, digital scales, PVC pipes, briquette pushers, hydraulic presses, stoves, pans, calipers, basins,and spatulas.

B. Briquette Making Process

The process of making briquettes can be done in the following stages:

1) The prepared oil palm shells are first dried using an electric drying oven for 3 hours at a temperature of 125˚C [16].
2) Palm oil shells are carbonized using a temperature of 600˚C for 1 hour in a muffle furnace [3].
3) The carbonized palm shell charcoal fragments will then be ground using a mortar and pestle and blended to get a smoother texture.
4) Sieving of palm shell charcoal using mesh sieve number 60 as ASTM E:11 standard.
5) Briquette mixing is divided into two, first dry-based adhesive (cornstarch and rice flour) by heating the dry-based adhesive along with water using a ratio of 1:10 then the adhesive is mixed with 90% coconut shell charcoal [17]. As for second briquettes with a wet-based adhesive, briquettes with melted pine resin adhesive mixed at 1:1 to palm shell charcoal ratio [18].
6) Briquettes are shape using a molding PVC pipe with a diameter of 2 cm and a height of 4 cm [19] accompanied by pressure using a hydraulic press of 25 kg/cm2.

C. Analysis

For each adhesive variation, three random samples were given for each test. The quality of the briquettes to be analyzed includes testing the calorific value, moisture content, and volatile matter content. The sample was burned under closed conditions for calorific value test and added about 30 - 40 ATM of oxygen gas into the bomb calorimeter reactor. The calorific value test was carried out at the Palm Oil Laboratory, Samarinda State Agricultural Polytechnic.

The water content test was carried out with reference to the ASTM D 3173-03 standard, where the sample was heated to 107˚C for 1 hour. This water content test was carried out at the Integrated Laboratory of the Kalimantan Institute of Technology. The test standard for volatile matter levels uses SNI 1689:2021, by heating the sample in the muffle furnace for 7 minutes using a heating temperature of ±950˚C. This volatile matter level test was carried out at the Integrated Laboratory of the Kalimantan Institute of Technology.

D. Research Design

One-way inferential statistical analysis method was used (ANOVA) with a significance level of 5% for conclusion in this research. Hypothesis testing is carried out comparatively in one-way ANOVA for interval and ratio data types with samples that correlate with one factoror influence. This ANOVA is similar to the T test, in the T test the mean difference tested is only from two groups,but for ANOVA it can test the difference between two groups or even more at once [20].

If a significant interaction is found in the ANOVA test,it will be continued with the Tukey HSD test. The HSD tukey test (honestly significant difference) or the honest significant difference test (BNJ) is one of the Anovafollow-up tests when the data results and Anova analysis fail to accept H0. Basically, the Tukey test is used to findout which treatment pairs are significantly different, or simply which method/treatment pairs will have a different average effect [21]. Tukey test is included in the type of multiple comparison test (Multiple comparison). The selection of this advanced test was chosen based on the fulfillment of the similarity of the population variance andhaving the same sample size from each group (normal distribution) so that it can provide more accurate results [22].

III. Results and Discussion

A. Calorific Value

Based on Figure 1, the average water content values for the variations of cornstarch adhesive (CA), rice flour adhesive (RF), and pine resin adhesive (PR) were 5.1%, 5.0%, and 3.7% respectively. The average calorific values for the variations of cornstarch adhesive (CA), rice flour adhesive (RF), and pine resin adhesive (PR) were respectively 6634.29 cal/gr, 6702.47 cal/gr, and 7798.31 cal/gr. The average value of volatile matter content in thevariations of cornstarch adhesive (CA), rice flour adhesive (RF), and pine resin adhesive (PR) were 30.90%, 31.70%,and 60.73% respectively.

In Figure 2, it can be seen that the average calorific value of cornstarch (CA) adhesive is 6634.29 cal/gr, the average calorific value of rice flour (RF) adhesive is 6702.47 cal/gr, and the calorific value the average for pine resin (PR) adhesive is 7798.31 cal/gr.

Table 1 shows that there are two adhesive pairs that are significantly different in terms of calorific value, namely, pine resin adhesive pairs with cornstarch adhesives, and pine resin adhesive pairs with rice flour adhesives. which is much higher than the other two adhesives. This occurs due to the hydrocarbon compounds present in pine sap [23]. Just like diesel and gasoline, in general, hydrocarbons are one of the types of fuel most often used by humans [24].

From Table 1 it can also be seen that the adhesive pairing of cornstarch with rice flour does not show a significant effect on the calorific value. Nevertheless, a number of amylopectin content has an important role in determining the calorific value. Where the amylopectin content has properties that are difficult to absorb water [25]. The amylopectin content in rice flour is 88.22% [26] which is slightly higher when compared to the amylopectin content in cornstarch which is only 74% [11], so, the average calorific value produced in rice flour be slightly higher than the average yield on briquettes with cornstarch adhesive, this occurs as a result of the difference in amylopectin between the two. Where when the higher the amylopectin contained, the less water absorbed will be, thus having an impact on increasing the calorific value. Not only amylopectin, when compared to carbohydrates and protein, fat content even in a small percentage is a more effective source of energy than the two [27]. The fat contained in corn starch flour is 0.39% [28] which is smaller than the fat in rice flour which is 1.001% [25]. The difference in the fat content of rice flour (1.001%) which is greater than the fat content of corn starch flour (0.39%) also plays a role in determining the calorific value.

Table 1.
Tukey’s Test For Calorific Value

Adhesive Variation	Calorific Value (Cal/gr)
Cornstarch Flour Adhesive (CA)	6634.29 ± 35.36[a]
Rice Flour Adhesive (RF)	6702.47 ± 5.02[a]
Pine Resin Adhesive (PR)	7798.31 ± 243.21[b]

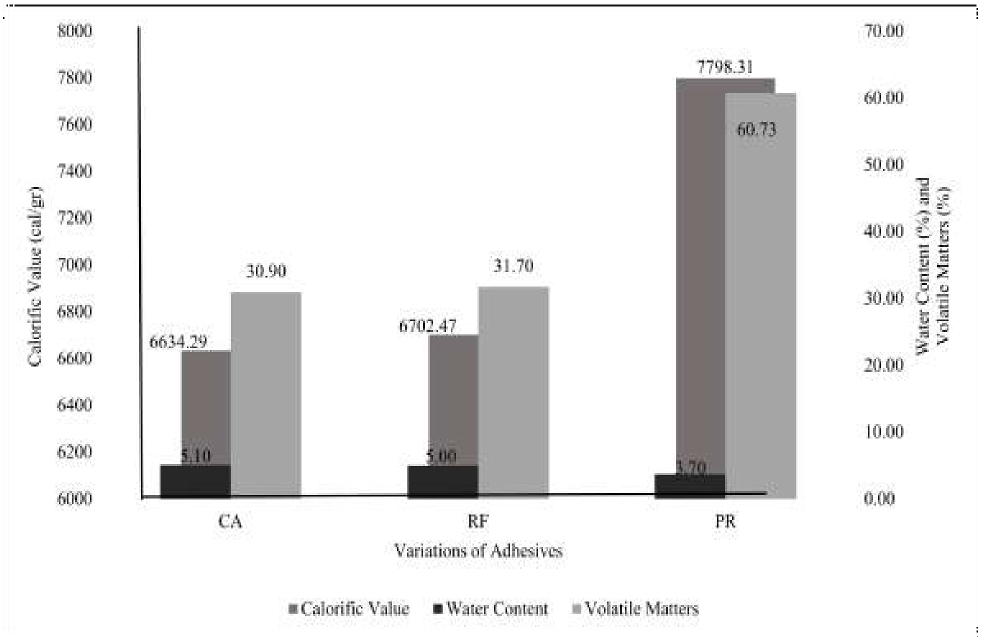

Figure. 1. Briquette Test Result

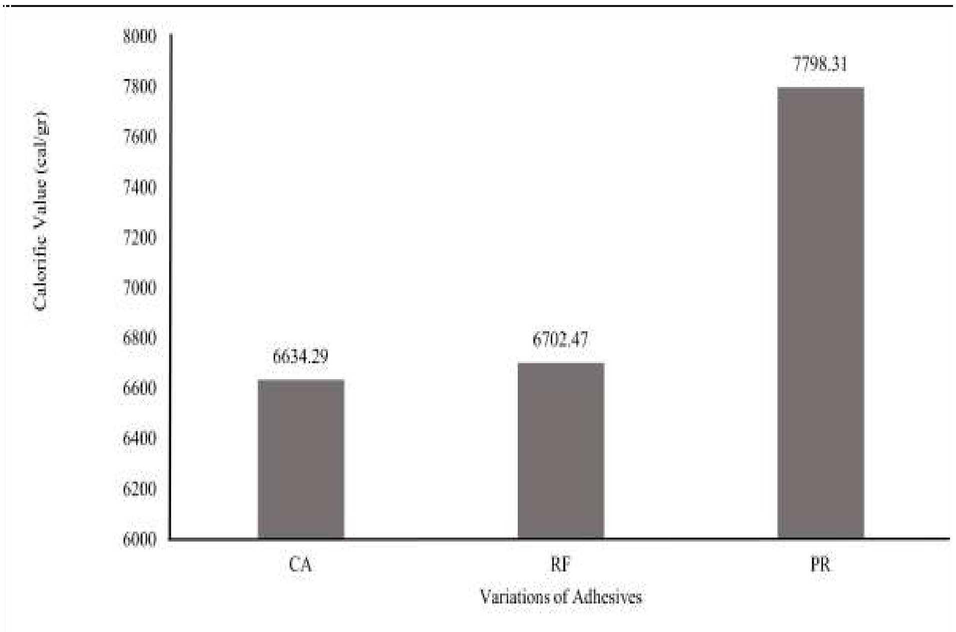

Figure. 2. Calorific Value Graph Test Result (cal/gr)

B. Water Content

The water content graph presented in Figure 3 shows that the average water content in cornstarch adhesive (CA) is 5.1%, the average water content in rice flour adhesive (RF) is 5.0%, and the average water in pine resin adhesive (PR) of 3.7%.

Based on Table 2, it can be seen that there are two adhesive pairs that have a significant effect, namely, pine resin adhesive pairs with cornstarch adhesives, and pine resin adhesive pairs with rice flour adhesives. This real difference occurs because pine resin has characteristics that are very difficult to interact with water (hydrophobic)[29], so the water content contained in the pine resin adhesive briquettes is much less compared to the other two types of adhesives. Even though it is difficult to interact with water, it doesn't mean that pine sap doesn't have some water in it. When tapping, leaves, twigs, flowers or even rainwater will fall into the pine resin reservoir as a result of the absence of a cover that protects the pine resin during the tapping process [30], so that in the processing process to become briquette adhesive, This pine resin is first melted until it becomes liquid and boilswith the intention of being able to evaporate some of the water involved in the tapping process so that it can glue the raw materials perfectly.

In pairing cornstarch with rice flour adhesive, there was no significant effect between the two. However, the percentage of water content contained still has a different average value. This occurs due to differences in the percentage of amylose content contained in each adhesive.

Where the amylose contained in corn/maize starch is 26% [11], whereas in rice flour the amylose content contained is only 11.78% [26]. This amylose has properties that arevery easy to absorb and release water [25]. The amylose content is a determinant of the water absorption capacity of a starch (a type of complex carbohydrate) because amylose is dissolved in water [31]. So that the water content in the dry-based adhesive with the corn starch variation has a slightly higher percentage (5.10%) compared to the rice flour adhesive variation (5.00%) due to the difference in the amount of amylose content in each of these adhesive variations.

TABLE 2.
_TUKEY'S TEST FOR MOISTURE CONTENT

Adhesive Variation	Water Content (%)
Cornstarch Flour Adhesive (CA)	5.10 ± 0.20^a
Rice Flour Adhesive (RF)	5.00 ± 0.10^a
Pine Resin Adhesive (PR)	3.70 ± 0.46^b

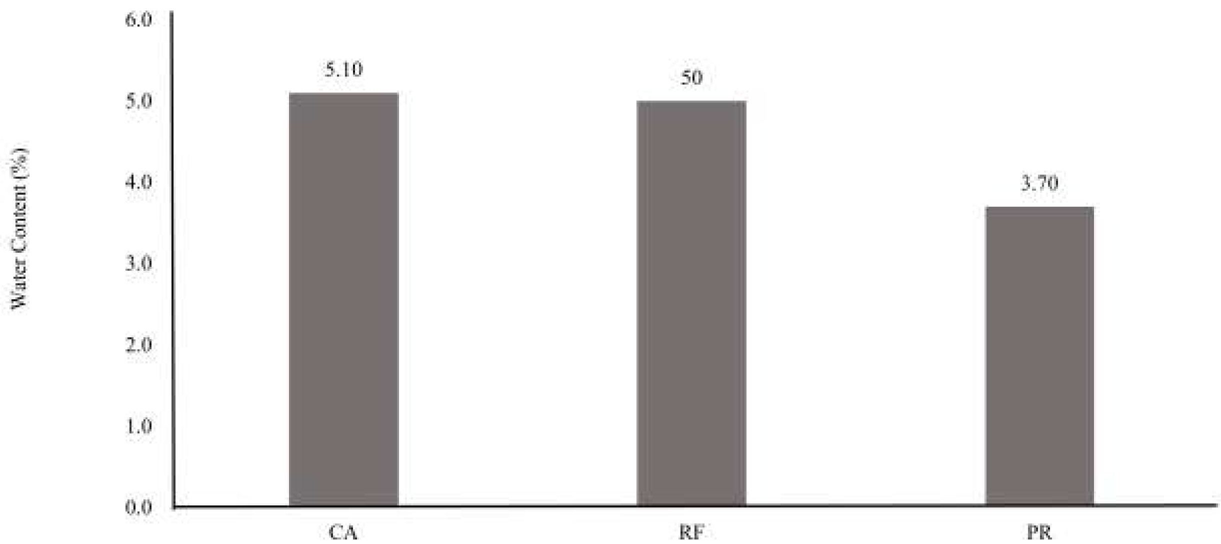

Figure. 3. Water Content Value Graph Test Result (%)

C. Volatile Matter

The graph of volatile matter levels presented in Figure 4 shows that the average volatile matter content value for cornstarch adhesive (CA) is 5.1%, the average volatile matter level for rice flour adhesive (RF) is 5.0%, and the average volatile matter content in pine resin adhesive (PR) is 3.7%.

In testing the levels of volatile matter is carried out with reference to the standard testing procedure for SNI 1683-2021 where in the testing process the sample is heated to a temperature of 950°C for 7 minutes in a closed combustion furnace.

Based on the Tukey test in Table 3, it can be seen that there were two adhesive pairs that showed a significant effect, namely, pine resin adhesive pairs with cornstarch adhesives, and pine resin adhesive pairs with rice flour adhesives. The pairing of cornstarch adhesive with rice flour adhesive showed no significant effect.

Figure 1 shows that the higher the water content, the lower the calorific value, which is accompanied by the varying levels of volatile matter as a result of differences in the compounds contained between one adhesive and another. This is in line with previous studies, which stated that high levels of volatile matter in a sample would identify the magnitude of the sample's reactivity during the heating or combustion process, this is due to a number of volatile matter contents which would affect the perfection and intensity of the combustion itself. [32].

Other sources state that briquettes with pine resin adhesivehave higher levels of volatile matter because pine resin isincluded in a type of resin and also tree oil which produces15% - 25% turpentine ($C_{10}H_{16}$) [33]. According to [34] the turpentine contained in pine resin has volatile characteristics. Pine sap will begin to change in volume when subjected to heating with temperatures above 150˚C, this change in volume is a sign that the turpentinecontent in the pine resin is beginning to evaporate. The higher the heating temperature, the higher the evaporationof turpentine in the pine sap. Whereas the variation of cornstarch adhesive did not have a significant effect on rice flour adhesive. However, the percentage of volatile matter content between the two still has a different average value. The average value of the volatile matter content in the cornstarch adhesive and rice flour is not much different, this is due to the organic compounds contained in the flour adhesive. Starch content affects thelevel of volatile matter [35], where the higher the starch content contained in a type of adhesive, the more volatilematter will be produced. In line with the results of this study which showed that the volatile matter content in rice flour had a slightly higher value (31.70%) when compared to cornstarch adhesive (30.90%). This occurs as a result of differences in starch content, where the starch content in corn starch adhesive is 64% [11] while in rice flour adhesive the starch content contained is 67.68%.

TABLE 3.
TUKEY'S TEST FOR VOLATILE MATTER

Adhesive Variation	Volatile Matter (%)
Cornstarch Flour Adhesive (CA)	30.90 ± 0.50^a
Rice Flour Adhesive (RF)	31.70 ± 0.44^a
Pine Resin Adhesive (PR)	60.73 ± 0.50^b

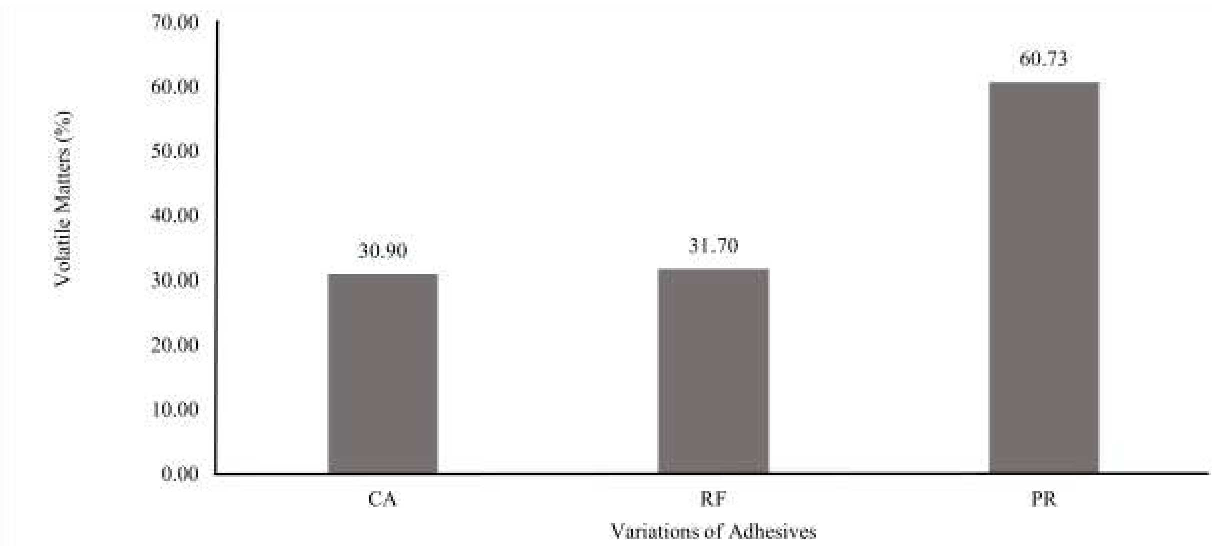

Figure. 4. Volatile Matter Value Graph Test Result (%)

IV. Conclusion

Based on the analysis of adhesive variation testing on calorific value, the average calorific value of corn starch adhesive, rice flour adhesive and pine resin adhesive were respectively 6634.29 cal/gr; 6702.47 cal/gr; and 7798.31 cal/gr.

Based on the analysis of adhesive variations on the percentage of water content, it can be concluded that the average percentage of water content contained in the briquettes with corn starch adhesive, rice flour adhesive, and pine resin adhesive respectively was 5.10%; 5.00%; and 3.70%.

Based on the test analysis of adhesive variations on the percentage of volatile matter content, it was concluded that the average percentage of volatile matter content contained in briquettes with corn starch adhesive, rice flour adhesive, and pine resin adhesive respectively was 30.90 %; 31.70% and 60.73%

A relationship was obtained between the average test results, where the higher the calorific value of a briquette with a variety of adhesives, the lower the water content and the average volatile matter content varied as a result of differences in the content of each adhesive.

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