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Biobriquettes from Rice Husks Using Molasses and Egg White Adhesives with Variations in Adhesive Concentration

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ABSTRACT

The use of rice husks as a raw material for briquettes helps reduce agricultural waste while providing added economic value to the product. Molasses is a by-product of the sugar-making process, which is abundant and often not utilized optimally. Molasses has the advantage of being a biobriquette adhesive because it is relatively cheap, easily biodegradable, and environmentally friendly. Albumin in egg white has the ability to form a gel when heated or dried, so it can potentially help bind biomass particles such as rice husks compared to other adhesives. The research operating conditions include raw materials, namely rice husk, carbonization temperature of 300°C, carbonization time of 1 hour, briquette size ≥ 150 mesh, type of adhesive (molasses and egg white) and adhesive concentration (12%, 13%, 14%, 15%, 16%, 17%, 18% and 19%). The optimum conditions were obtained by using 15% egg white adhesive, namely with a water content of 8%, ash content of 7%, volatile matter content of 1.5%, and bound carbon content of 83.5% which met SNI 01-6235-2000 and a calorific value of 4194.03 cal/g, and a combustion rate of 0.140 g/minute. The results of this study are expected to be applied in society or industry because they use raw materials of rice husks and molasses adhesive which are waste so that they will increase economic value.

INTRODUCTION

Biobriquettes are solid fuels produced from compacted organic materials, which have great potential to replace fossil fuels, reduce agricultural waste, and become a solution to more sustainable energy problems (Allo et al., 2018). Along with the increasing need for renewable energy sources, biobriquettes from agricultural and industrial waste such as rice husks are an attractive choice (Sulaiman, 2023). Rice husks are one of the abundant agricultural wastes in Indonesia. Rice husks are often only thrown away or utilized in a limited way, even though this waste contains very high cellulose content. This cellulose content makes rice husks an excellent raw material for making biobriquettes because cellulose has properties that are easily decomposed and can be used to increase the carbon content in briquettes (Maharani et al., 2022).

Many studies on making biobriquettes from organic waste materials have been conducted (Ariyanto et al., 2024; Dewi et al., 2023; Gantina, 2019; Jannah et al., 2022; Nworie et al., 2024; Putra et al., 2013; Suripto et al., 2023). Several studies have been conducted to assess the quality of rice husk biobriquettes against the physical characteristics and combustion of biobriquettes is still not fully understood. Characteristics that need to be considered in biobriquettes include density, hardness, water content, ash content, and combustion ability, each of which can be

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influenced by the proportion of the mixture of raw materials and adhesives used (Yonanda & Daryono, 2025).

Adhesives play an important role in improving product quality. Molasses has the advantage of being a biobriquette adhesive because it is relatively cheap, easily biodegradable, and environmentally friendly. Molasses also contains organic compounds that can help strengthen the bonds between particles of briquette raw materials, so that the briquettes become denser and stronger. The use of molasses in biobriquettes also serves to reduce industrial waste (Annafi et al., 2023).

Egg white consists of water and protein with the main content of albumin having the ability as an effective binding agent in food. Albumin has the ability to form a gel when heated or dried, so it has the potential to help bind biomass particles such as rice husks compared to other adhesives. The albumin content in egg white has strong adhesive power and can increase product stiffness. Albumin contains resin compounds that function as binders between materials and the more albumin mixture used, the better the adhesive power. In addition, the use of albumin can also increase compressive strength and reduce product density (Rizal et al., 2024). Protein as an adhesive is non-toxic, easily renewable and safe for the environment (Raydan et al., 2021).

In the manufacture of rice husk biobriquettes with molasses adhesive, the optimum condition is obtained at a powder size of 150 mesh with a molasses of 14%, namely a moisture of 19.48%, ash content of 11.53% but does not meet standard and a calorific value of 5097.19 cal/g which meets SNI 01-6235-2000 (Annafi et al., 2023). Briquettes from a mixture of castor seeds and rice husks have physical properties, namely a water content of 4.805-8.219%, a calorific value of 2.836-4215 cal/g and a combustion rate of 2.84-6.02 g/min (Pamungkas et al., 2014). Biobriquettes from a mixture of rice husks and wood ketaman with 15% cashew leaf adhesive have a calorific value of 3045 cal/g (Bestari et al., 2016). Biobriquettes from rice husk charcoal get a calorific value of 3892 cal/g at a composition of 7:3 glutinous rice flour (Masriatini et al., 2021). The use of rice husks for Biobriquette production gets the best water content of 4.63% at a ratio of 3:1 for durian seed flour (Putri et al., 2023). The manufacture of rice husk briquettes (oryza sativa l.) as an alternative fuel to replace firewood, gets a fixed carbon content of 29.03%-37.38% at an adhesive ratio of 1:1 (Amin et al., 2023).

The novelty of the research is the use of egg white and molasses as adhesives. The adhesives commonly used in making biobriquettes are flours which are food ingredients, while molasses is sugar industry waste. The purpose of the study was to obtain the optimum conditions for the process of making rice husk biobriquettes with egg white and molasses adhesives related to the adhesive concentration. The research results are expected to produce rice husk biobriquettes that meet standard. The aim of further research is to be able to apply it in society or the biobriquette manufacturing industry to overcome fuel scarcity.

RESEARCH METHODS

Tools and Materials

Tools: molding tool, carbonization tool, 150 mesh sieve, beaker glass, furnace, grinder, porcelain crucible, digital scale, oven, and stirrer. Materials: rice husk, molasses, and egg white.

Research Variables

Control variable: rice husk comes from Pakisaji inbred Inpari 32 variety, carbonization temperature 300℃, carbonization time 1 hour, briquette particle size ≥ 150 mesh. Independent Variable: type of adhesive in the form of molasses and egg white and adhesive concentration of 12%, 13%, 14%, 15%, 16%, 17%, 18% and 19%.

Research Procedure

Conducting pretreatment by washing rice husks and then drying them for 3 days. The carbonization process of dry rice husks using a carbonization tool at a temperature of 300℃ for 1 hour. The resulting charcoal is ground into a powder with a size of at least 150 mesh using a grinder. A small amount of warm water will be added to a mixture of numerous adhesives with a specific concentration and carbon powder that is already ≥150 mesh. The dough was then agitated until it was smooth. The briquette molding step comes next. Following molding, the briquettes are allowed to cool for three days at room temperature. Tests for water content, ash content, volatile matter content, bound carbon content, and calorific value will be performed on dried and solidified briquettes (Yonanda & Daryono, 2025). Each variable was tested twice and the results were averaged.

Water Content

The biobriquette sample tested was weighed as much as 1 g. After that, the sample was cooked for three hours at 115°C in an oven. The sample will be reweighed following the completion of the heating procedure. The following formula (1) was used to determine the water content.

$$Water\ content\ (\%) = \frac{Initial\ sample\ weight - sample\ weight\ after\ drying}{Initial\ sample\ weight} x100\% \quad (1)$$

Ash Content

To measure the ash content, first a porcelain crucible without a lid was weighed together with a 2 g biobriquette sample. The sample was then heated at a temperature of 450-500℃ for 1 hour, followed by a temperature of 700-750℃ for 2 hours, and finally at a temperature of 800-900℃ for 2 hours. Following the ashing procedure, a desiccator was used to cool the porcelain crucible before it was weighed again. The following formula (2) was used to determine the amount of ash.

$$Ash\ content\ (\%) = \frac{Crucible\ and\ ash\ weight - empty\ crucible\ weight}{Sample\ weight} x100\% \quad (2)$$

Volatile Matter Content

To measure the volatile matter content, a porcelain crucible without a lid that has been weighed together with a biobriquette sample that has been tested for water content, then heated at a temperature of 950℃ for 7 minutes. The sample was heated, allowed to cool in a desiccator, and then weighed once again. The following formula was used to get the volatile matter content (3).

$$Volatile\ Matter\ content\ (\%) = \frac{Sample\ weight\ before - sample\ weight\ after}{Initial\ sample\ weight\ at\ water\ content} x100\% \quad (3)$$

Bound Carbon Content

The following formula was used to determine the bound carbon content based on the findings of tests for volatile matter, ash, and water content. The following formula (4) was used to determine the bound carbon content.

$$Bound\ carbon\ content\ (\%) = 100\% - (water\ content + ash\ content + volatile\ matter\ content) \quad (4)$$

Calorific Value

A bomb calorimeter was used to measure the biobriquette's calorific value, or the quantity of heat it released.

Burning Rate

A stopwatch was used to measure the briquette's rate of burning, and the amount of time till the maximum heat temperature was attained was then noted. The analysis comprises the mass of the briquette after it has been extinguished and weighed, as well as the amount of time it takes

for the combustion to achieve its maximum temperature. Calculations were then performed using the acquired data. The formula (5) was used to calculate the burning rate.

$$Burning\ rate\ (\frac{g}{\text{minute}}) = \frac{Initial\ briquette\ weight - final\ briquette\ weight}{Burning\ time} \quad (5)$$

RESULTS AND DISCUSSION

The biobriquette manufacturing process has reached the quality testing stage with adequate results. The biobriquettes produced are expected to meet the SNI 01-6235-2000 standard. SNI 01-6235-2000-based biobriquette quality testing includes a minimum bound carbon content of ≥ 79%, a minimum calorific value of 5000 cal/g, a maximum water content of ≤ 8%, a maximum ash content of ≤8%, a volatile matter content of ≤17%, and a combustion rate. Figure 1 shows the rice husk biobriquette product resulting from the research.

Figure 1. Rice husk biobriquettes

The resulting biobriquettes have a tube shape with a diameter of 3 cm and a height of 3 cm. Biobriquettes are produced from a carbonization process at a temperature of 300℃ for 1 hour. During carbonization, mass shrinkage occurs. Carbonization of 5 kg of rice husks produces 3 kg of charcoal. This indicates that there is a shrinkage of around 40% of the mass of rice husks.

Water Content

Water content is the percentage of water mass contained in the briquette to the total mass of the briquette. High water content can reduce combustion efficiency because energy is used to evaporate water before producing heat. Ideally, biobriquettes have a low water content for maximum combustion (Pamungkas et al., 2014). The calculation of water content has been carried out to determine the amount of water content in biobriquettes with molasses and egg white materials at certain concentrations in this study. The results of the study showed that the water content in molasses with concentrations of 12%, 13%, 14%, 15%, 16%, 17%, 18% and 19% were respectively 10%, 8%, 8%, 8%, 7%, 7%, 7% and 7%. While in egg white with concentrations of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% were respectively 8%, 7%, 8%, 8%, 8%, 4%, 4% and 5%.

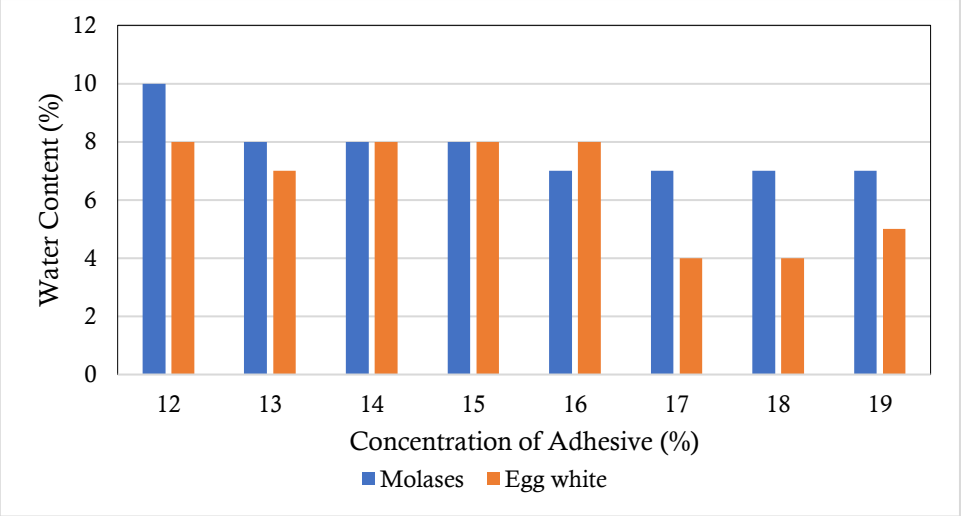

Figure 2. Relationship between molasses and egg white adhesive concentrations and water content

Based on Figure 2, the results of the study show that the highest water content is 12% molasses adhesive with 10% water content and the lowest is 17% and 18% egg white adhesive with 4% water content. The water content in the adhesive affects the quality of the briquettes. The results of my study are inversely proportional to Anafi's study, 2023, which states that the higher the molasses adhesive content, the higher the water content in the briquettes. This is because at low concentrations the addition of more water as an adhesive mixture compared to other concentrations causes a higher water content (Annafi et al., 2023). The water content in molasses is around 25% (Larangahen et al., 2017) and the water content in egg white is around 80% (Agustina et al., 2013). Egg white when heated will form gelatin so that the trapped water is difficult to evaporate (Cholilie & Zuari, 2021). This is what causes biobriquettes with egg white adhesive to have a lower water content. However, there is only one briquette that does not meet the water content and the rest have shown that the values obtained are in accordance with the SNI-01-6235-2000 standard, which is ≤ 8%. In addition, the white adhesive has a protein content where most of the water contained will evaporate more easily than molasses which still has moisture after heating.

Ash Content

The calculation of ash content is carried out to determine the amount of ash content in biobriquettes with molasses and egg white materials at certain concentrations in this study. The less ash left, the better the quality of the biobriquettes, because it means that more material is actually burned and turned into heat energy (Suripto et al., 2023). The results showed that the ash content in molasses with concentrations of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively were 7%, 7.5%, 7.5%, 7%, 7.5%, 7.5%, 8% and 8%. While in egg white with a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 7%, 7.5%, 7.5%, 7%, 7.5%, 7%, 7% and 7.5%.

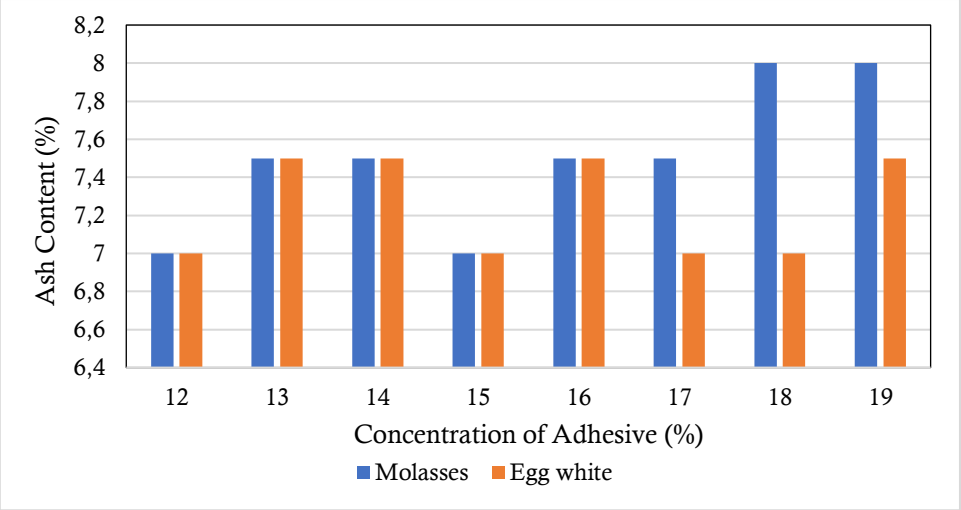

Figure 3. Relationship between molasses and egg white adhesive concentrations and ash content

According to Figure 3, the study's findings indicate that 12% egg white and molasses adhesive has the lowest ash percentage (7%), while 19% molasses adhesive has the greatest ash content (8%). The investigation demonstrated that the ash content increased with the adhesive concentration. This is consistent with Anafi's studies, which found that the ash concentration increases with adhesive strength (Annafi et al., 2023). It can be seen in the picture where the two adhesives do not have a significant difference in ash content, due to the influence of the type of adhesive used, as well as the concentration of the adhesive itself. All ash content results have met standards. Molasses contains high mineral content (Larangahen et al., 2017). High mineral content will affect the results of ash content analysis.

Bound Carbon Content

The calculation of bound carbon content was carried out to determine the amount of bound carbon contained in biobriquettes with molasses and egg white materials at certain concentrations in this study. The higher the bound carbon content, the better for long-term combustion efficiency (Suryaningsih et al., 2018). The results showed that bound carbon in molasses with concentrations of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% were respectively 80.0%, 81.2%, 81.8%, 82.7%, 84%, 84%, 83.1% and 83.2%. While in egg white with concentrations of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% were respectively 80.5%, 81.7%, 82.6%, 83.5%, 83.4%, 87.7%, 87.6% and 85.8%.

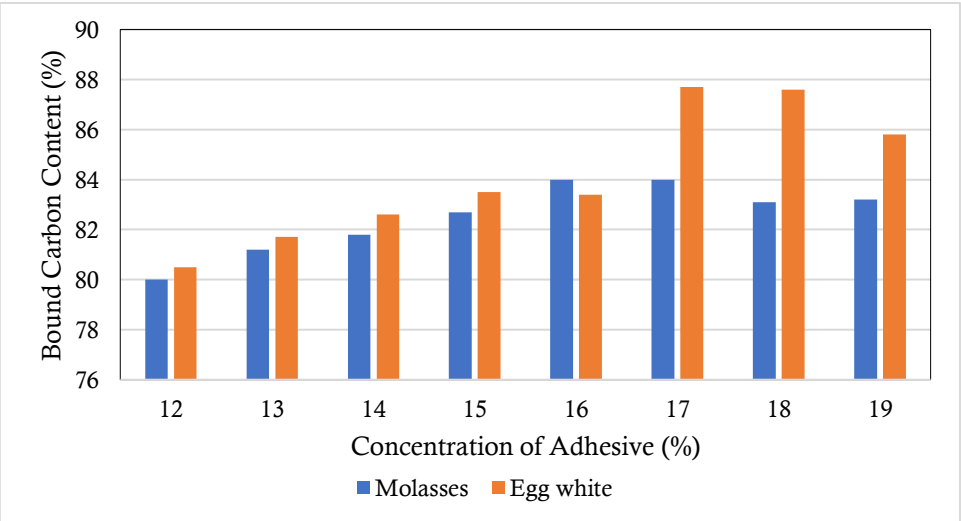

Figure 4. Relationship between molasses and egg white adhesive concentrations and bound carbon content

Based on Figure 4, the research results show that the highest bound carbon content is egg white 17% with a bound carbon content of 87.7% and the lowest egg white adhesive and 12% molasses with a bound carbon content of 80%. In accordance with the Alfian 2025 study, molasses as a sugar-based adhesive is more easily decomposed during combustion which can cause a lower residual carbon content (Alfian et al., 2025). While egg white contains albumin protein which can function as a binder in various mixtures (Maharani et al., 2022). The amount of water, ash, and volatile materials that are present in biobriquettes affects their bound carbon concentration. According to the study, the amount of bonded carbon will decrease as the amount of adhesive increases (Allo et al., 2018). All bound carbon levels in both adhesives have all met SNI 01-6235-2000 ≥79%.

Volatile Matter Content

The calculation of the volatile matter content that has been carried out to determine the amount of volatile substance content in biobriquettes with molasses and egg white materials at certain concentrations in this study. The volatile substance content must be balanced, not too high or too low so that the flame is achieved quickly and the combustion process takes place optimally (Masriatini et al., 2021). The results showed the volatile substance content in molasses with a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 3%, 3.3%, 2.8%, 2.3%, 1.5%, 1.5%, 1.9% and 1.8%. While in egg white with a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 4.5%, 3.8%, 1.9%, 1.5%, 1.1%, 1.3%, 1.4% and 1.7%.

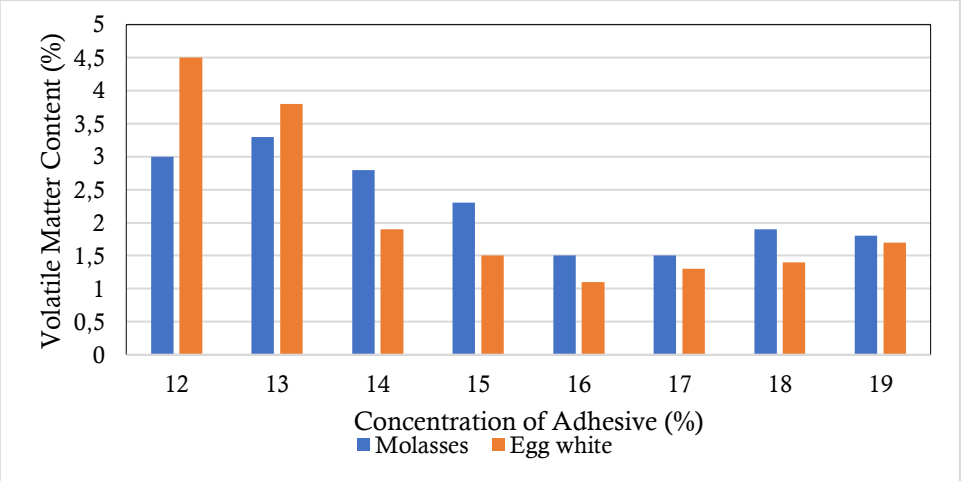

Figure 5. Relationship between molasses and egg white adhesive concentrations to volatile matter content

Based on Figure 5, the results of the study show that the highest volatile matter content is 12% egg white adhesive with a volatile matter content of 4.5% and the lowest is 16% egg white adhesive with a volatile matter content of 1.1%. in the picture in egg white the volatile content is high at low concentrations and decreases consistently with increasing adhesive concentration because the albumin protein in egg white binds water better, reducing evaporation. While in molasses the volatile content is high at low concentrations and decreases at certain concentrations and then increases slightly. Because the binding of compounds is more effective in the adhesive mixture with increasing concentration. The volatile content can affect combustion efficiency. The rate of combustion increases and more smoke is produced with a higher volatile content (Yonanda & Daryono, 2025). All test results are classified according to standards ≤ 15%.

Calorific Value

The calculation of the calorific value that has been carried out to determine the amount of calorific content in biobriquettes with molasses and egg white materials at certain concentrations in this study. The results showed the calorific value of molasses with a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 3938.01 cal/g, 3886.8 cal/g, 3758.79 cal/g, 3810 cal/g, 3912.4 cal/g, 3707.59 cal/g, 3912.4 cal/g and 3681.98 cal/g. While in egg white with

a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 4014.81 cal/g, 3861.2 cal/g, 4117.22 cal/g, 4194.03 cal/g, 4066.02 cal/g, 4040.41 cal/g, 4014.81 cal/g and 4142.28 cal/g.

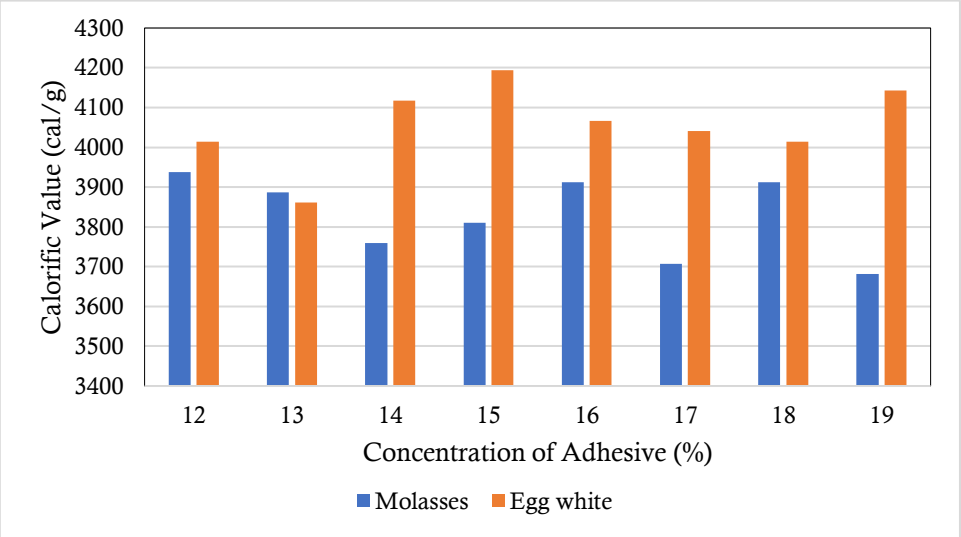

Figure 6. Relationship between molasses and egg white adhesive concentrations to calorific value

The study's findings, as shown in Figure 6, show that molasses adhesive has the lowest calorific value at 19%, with a calorific value of 3681.98 cal/g, and egg white has the highest at 15%, with a calorific value of 4181.98 cal/g. Because it contains protein, the egg white adhesive has a higher calorific value than molasses, improving the biobriquette's sticky power. Molasses's low calorific value is caused by its high water content. This is consistent with research that shows molasses has a comparatively high moisture content as a binder due to its increased water and sugar content (Gantina, 2019). Because the biobriquette's calorific value is less than 5000 cal/g, it is evident that the findings of the biobriquette test in this study do not fulfill the SNI 01-6235-2000 standard. Combustion Rate The amount of combustion rate contained in biobriquettes containing molasses and egg white materials at specific concentrations in this investigation was ascertained by the computation of the combustion rate. The results of the study showed the calorific value of molasses with a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 0.172 g/minute, 0.210 g/minute, 0.277 g/minute, 0.236 g/minute, 0.262 g/minute, 0.280 g/minute, 0.250 g/minute and 0.227 g/minute. While in egg white with a concentration of 12%, 13%. 14%, 15%, 16%, 17%, 18% and 19% respectively are 0.160 g/minute, 0.189 g/minute, 0.130 g/minute, 0.140 g/minute, 0.155 g/minute, 0.160 g/minute, 0.211 g/minute and 0.150 g/minute. The amount of water content in biobriquettes greatly affects the calorific value (Anti et al., 2022). Biobriquettes with molasses adhesive have a lower calorific value than egg white adhesive because white binds water.

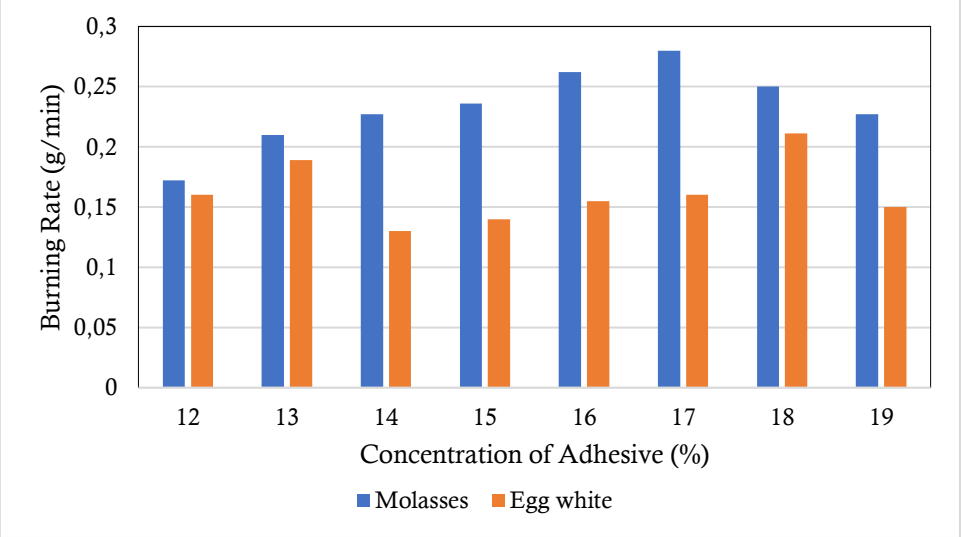

Figure 7. Relationship between molasses and egg white adhesive concentrations to the burning rate

According to Figure 7, the study's findings show that 17% molasses burns at the fastest pace, 0.280 g/minute, while 14% egg white burns at the slowest rate, 0.130 g/minute. When the water content of the biobriquettes is high, the briquettes will burn more quickly and the heat will be dispersed uniformly over their surface (Fajari et al., 2024). This graph shows that molasses burns quickly because molasses, which is a sugar-based adhesive, has the ability to increase ease but can also increase the water content in briquettes, which slightly affects the efficiency of the combustion process. The characteristics of the optimal burning rate for briquettes are determined by the balance between the length of the burning time and the efficiency of fuel use. A burning rate that is too high can cause the briquettes to burn out quickly (Alfian et al., 2025).

CONCLUSION

According to the study's findings, the best biobriquettes were made with a 15% concentration of egg white adhesive, resulting in 8% water, 7% ash, and 1.5% volatile matter. The bound carbon content was 83.5%, with a calorific value of 4194.03 cal/g and a combustion rate of 0.140 g/minute. Despite not meeting the 5000 cal/g calorific value required by SNI 01-6235-2000, this combination of features indicates that, out of all the studied variations, biobriquettes containing 15% egg white have the best quality. The calorific value of the majority of samples still falls short of the minimal requirements, even though certain quality metrics, including water content, ash content, volatile matter content, and combustion rate, have satisfied the SNI 01-6235-2000 standard. Further research can consider more diverse variations in carbonization temperature and time to optimize the biobriquette making process. This can help improve the calorific value and combustion quality of the briquettes.

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