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Effect of Drying Temperature of Sawdust Biobriquettes with Used Lubricant Oil Adhesive Volume Variation over Carbonization Process

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ABSTRACT

Renewable energy is one way to deal with the scarcity of fossil energy. Biobriquette is an alternative energy that can be used as a substitute for fuel. This research aims to determine the characteristics of each variation of biobriquettes, namely moisture content, ash content, volatile matter content, bound carbon content, calorific value, and combustion test. The raw material is sawdust of Sungkai wood (*Peronema canescens Jack*) with carbonization method at 300 °C for 1 hour. This study used an experimental method by varying the sawdust weight of 8.7 g, 17.4 g, 26.1 g, 34.8 g with a ratio of 2:1 for each raw material and adhesive used lubricant oil. In addition, the drying temperature of the briquettes is also varied by 80 °C (A) and 100 °C (B). Biobriquettes 4B had the best moisture content and ash content with the lowest levels of 5.98% and 1.54 %, respectively. The levels of volatile matter and fixed carbon levels are closest to Energy and Mineral Ministry Regulation Number 47 of 2006 (PERMEN ESDM) namely 4A briquettes of 59.44% and 1B briquettes with a content of 31.57%. Almost all samples met the standard for calculating the calorific value of Energy and Mineral Ministry Regulation Number 47 of 2006 (minimum 4400 cal/gr) with a the result of 4512–4850 cal/g. The ignition time of all samples was in the range of 9.67–17.9 seconds, it is faster than the ignition time of coal in the range of 286 seconds. The fastest burning time was sample 3B with a time of 19.83 minutes and the longest was sample 4A with a time of 38.95 minutes. The briquettes that had the best performance in boiling 100 ml of water were 4B briquettes with a burning temperature of 462.3 °C, a burning rate of 0.4501 and a boiling time of 2.48 minutes.

Keywords: energy, biobriquette, wood sawdust, used lubricant oil, drying temperature.

INTRODUCTION

The increase of fuels demand, such as kerosene and liquified petroleum gas, is often experienced by the lower middle class community. Alternatives energy to overcome this phenomenon can be solved by utilizing biomass as a new renewable energy. The development of renewable energy based on biomass is expected to meet the dwindling energy needs. Biomass is a term used to refer to all organic compounds, including organic waste.

Based on Harnawan and Radityaningrum (2019), biomass has a heating value of 6000 cal/g according to the type of biomass used. The sungkai wood (*Peronema canescens Jack*) sawdust and the used lubricant oil are wastes from the wood processing industry and the automotive industry which are currently not widely utilized. Sungkai sawdust briquettes are expected to increase the calorific value and be able to reduce existing waste. Several studies have produced briquettes with several raw materials. Different biomass will produce different calorific values, such as oil palm shells having a calorific value of around 5774.3–5896.8 cal/g (Arbi and Irsad, 2018), bagasse and rice husks with a calorific value of 6869.85 cal/g (Sugiharto et al, 2021), cashew nut shells with a calorific value of 6386.1–6886.2 cal/g (Suhartoyo et al, 2019), and wood sawdust and aval cloth with used lubricant oil adhesive with a calorific value of 7501.43 cal/g (Ramadhan and Praswanto, 2022). Due to the high calorific value of sawdust and aval cloth in previous studies, a study was carried out without a mixture of aval cloth to determine the characteristics of biobriquettes.

Adhesive is needed to compact the briquettes and improve the quality of the briquettes so that they have a high calorific value. Used lubricant oil is used as an adhesive because it has flammable properties and has a high volatile matter content that can help speed up the ignition process. To increase the compact of briquettes, tapioca flour is needed in a little ammount. In this study, the raw material for Sungkai wood sawdust was obtained from the furniture industry. Briquettes were made by carbonization method at 300 °C for 1 hour. The ratio of raw materials and adhesives is 2:1 with variations sawdust weight of 8.7 g, 17.4 g, 26.1 g, 34.8 g. In addition, the drying temperature of the briquettes is also varied by 80 °C (A) and 100 °C (B).

MATERIALS AND METHODS

Preparation of raw materials and tools

The materials used in this research were furniture waste in the form of sawdust of sungkai wood (*Peronema canescens*) which wasobtained from one of the saw mills for wood processing (furniture) in Palembang, South Sumatra. Used lubricant oil as an adhesive and tapioca starch as an additive. The tools used are 30 mesh sieve, furnace, beaker glass, hot plate, aluminum mold, mortar, analytical balance, oven, and spatula.

Carbonization process

Sungkai sawdust was cleaned of impurities, then dried in the sun for ± 3 days to constant weight. The dry sawdust was put into the furnace to be carbonized. The carbonization process takes place at 300 °C for 1 hour.

Mixing with adhesive

Raw materials was carbonized, crushed the charcoal using a mortar and sifted with a size of 30 mesh to become powder. Sifted sawdust, mixed with sawdust and used lubricant oil adhesive ratio of 2:1. Vary with the volume of used lubricant oil each 5 ml, 10 ml, 15 ml and 20 ml. Added tapioca flour adhesive until the briquettes agglomerate and can be casted.

Briquette molding and drying process

Sawdust with used lubricant oil and tapioca flour adhesive are mixed until homogeneous. The mixture was then formed, weighed to obtain the initial weight. Then, it was dried in an oven with a temperature variation of 80 °C and 100 °C for 1 hour. The printed briquettes were oven dried (Memmert Gmbh & Co, Germany). Dry briquettes are weighed to obtain the final weight of the briquettes. Briquette products are analyzed for several characteristics such as proximate analysis such as moisture content, ash content, volatile matter content, fixed carbon and calorific value as well as performance analysis, such as ignition time, combustion time, and the ability of briquettes to boil water. To determine the morphology and component on briquette was analyzed by scanning electron microscope-energy dispersive X-ray (SEM-EDX).

BRIQUETTE QUALITY ANALYSIS

Carbon characterization based on Sungkai wood sawdust

Scanning electron microscope (SEM) is widely used to observe the morphological structure of sample surfaces at high magnification using high energy electron beams (Nazhip-kyzy et al, 2022). SEM characterization was carried out on Sungkai wood sawdust. The results obtained on the SEM characterization with a magnification of 8,000 times.

Moisture content determination

Moisture content is the ratio of moisture to the dry weight of the solid fuel. The moisture content determination his test was occurred by drying the sample with the UNB Memmert Oven. 400 that has been calibrated at 105–110 °C, using the minimum free space and oven volume is 1.4 L. The gas flow rate is approximately 15 times/h at a volume of 350 mL/min and counted of the lost mass after heating using briquettes ASTM D-3173 2017 standards are as follows by Equation (1):

$$Moisture\ content = \frac{Wo - W}{Wso} \times 100\ \% \qquad (1)$$

where: W_0 – sample and saucer weight before drying (g), W – sample and saucer weight after drying (g), W_{S0} – the initial sample weight (g).

Ash content determination

The measurement of ash content was carried out by weighing the sample before heating it in the Carbolite Chamber Furnace AAF 1100 and weighing it after it was cooled. The value of ash content is calculated using the ASTM D-3174 2012 standard formula using Equation (2):

$$Ash\ content = 100 - \frac{Wo - W}{Wso} \times 100\ \% \quad (2)$$

Volatile matter determination

Volatile materials (VM) were determined by heating the sample in the Carbolite Chamber Furnace VMF 1000 at 900 °C for 7 minutes, and the volatile content was calculated using standard ASTM D-3175 2018. The amount of volatiles was calculated based on the weight loss after deducting the water content with the formula Equation (3) and Equation(4).

$$Lost\ weight = \frac{Wo - W}{Wso} \times 100\ \% \quad (3)$$

$$VM\ \% = lost\ weight - moisture\ content \quad (4)$$

where: W_0 – sample weight and initial cup (g), W – the weight of cup and ash after heating (g).

Fixed carbon determination

Fixed carbon (FC) content was determined using data previously obtained in proximate analysis. In this study, based on (Garcia et al, 2012), the released water content was calculated in the volatile matter with the formula Equation (5):

$$FC = 100 - (\ ash + volatile\ matter) \quad (5)$$

Calorific values determination

Calorific value calculated according to ASTM-D5865-13. Parr 6200 equipment and bomb ID 39905 and bomb calorimeter M39889 are used to measure the calorific value of a one-gram sample briquette put into a pallet, placed in a sample container (crucible), then transferred to the steel capsule of the bomb calorimeter.

Ignition time determination

The biobriquette sample was burned with a lighter. The time needed for each biobriquette to burn was recorded as the ignition time using a stopwatch.

RESULTS AND DISCUSSION

The briquettes produced are cylindrical in shape and have an average length, diameter and weight of briquettes ranging from 2.50 cm, 2.50 cm and 5.0 g. Biomass charcoal samples were mixed as follows ratios to obtain different briquette samples such as 1A, 2A, 3A and 4A with a sawdust weight 8.7 g, 17.4 g, 26.1 g, 34.8 g respectively with a sawdust and used lubricant oil ratio of 2:1. Likewise with samples 1B, 2B, 3B, and 4B. The sample denoted by symbol A shows a briquette drying temperature of 80 °C. Meanwhile, sample B shows a briquette drying temperature of 100 °C.

Biobriquette proximate analysis

Proximate analysis of biobriquettes includes calculating the percentage of water content (liquid state), volatile matter and fixed carbon, percentage of ash content, and calorific value of biomass energy. Comparing the briquette samples, briquette 4B has the best characteristics because it has the lowest water content (5.93%) and ash content (1.54%). Table 1 shows the variation of moisture content, ash content, volatile matter, fixed carbon and calorific value in briquette samples and Table 2 represents the combustion performance and heating temperature of briquette samples.

Low water content is influenced by the porosity formed from the briquettes and the drying temperature of the briquettes. The lower water content also produces higher calorific value and higher heating temperature. The hydrophilic nature of sawdust might increase the porosity of briquettes (Ajimotokan et al., 2019) and ease the drying process to evaporate the water (Ilochi., 2010).

Scanning electron microscope characterization of Sungkai wood sawdust

The results of the SEM characterization of each biobriquette of pure Sungkai wood sawdust and sawdust briquette are shown in Figures 1 and 2 show. The SEM image shows the difference in the surface condition of sawdust against the adhesive mixture used. The use of adhesives on briquettes can produce strong bonds. In pure sawdust it can be seen that the surfaces are not bonded together, in contrast to briquettes which use adhesives and additives, the surface morphology is denser.

Table 1. Proximate analysis of sawdust biobriquettes

No.	Sample	Analysis proximate					
		IM (%)	Ash (%)	VM (%)	FC (%)	Calorific value	
						HHV experimental (cal/gr)	HHV calculated (cal/gr)
1.	1 A	7.39	2.49	60.69	29.43	2903.30	4749
2.	2 A	7.27	2.39	60.22	30.12	3094.00	4782
3.	3 A	7.52	2.35	59.86	30.27	3051.68	4789
4.	4 A	6.95	2.25	59.44	31.36	3167.34	4840
5.	1 B	6.87	1.99	59.57	31.57	3324.48	4850
6.	2 B	7.08	1.87	59.74	31.31	3835.27	4837
7.	3 B	6.93	1.63	68.13	23.31	4031.89	4512
8.	4 B	5.98	1.54	63.14	29.34	4373.89	4696
9.	SNI	≤ 8	≤ 8	≤ 15	≥ 77	≥ 5000	≥ 5000
10.	Energy and mineral ministry regulation	≤ 15	≤ 10	≤ 15	≥ 77	4400	4400

Table 2. Combustion performance of Sungkai sawdust biobriquette

No.	Sample	Combustion temperature (°C)	Ability to boil water (min)	Ignition time (s)	Combustion time (min)	Burning rate (g/min)
1.	1 A	225.0	10.15	13.20	28.57	0.3325
2.	2 A	274.7	9.04	14.32	28.80	0.3263
3.	3 A	276.6	8.55	14.71	30.05	0.3128
4.	4 A	296.0	6.35	17.09	38.95	0.2413
5.	1 B	302.5	6.39	15.59	35.88	0.2619
6.	2 B	348.6	4.42	14.92	31.85	0.2982
7.	3 B	413.0	3.56	9.67	19.83	0.4740
8.	4 B	462.3	2.29	12.95	20.88	0.4501

Based on the results of EDX analysis, it can be confirmed that pure sungkai wood sawdust and 4B briquettes contain carbon, oxygen, sulfur and potassium compounds. Most of the compounds contained in pure sungkai wood sawdust and carbonized sawdust briquettes are in the form of carbon. Based on research by Zhao et al (2015), at temperatures below 500 °C in biobriquettes, dehydroxylation and refining of small molecules will occur which are released through the pores of the biobriquettes. This is in line with the decrease in sulfur, oxygen and potassium content resulting from SEM-EDX analysis as shown in Table 3.

Based on Table 3, EDX analysis of samples of sungkai wood briquettes with oil adhesive has a composition of high carbon values and other compounds such as potassium and sulfur in small amounts compared to pure sungkai sawdust briquettes. This case shows that the small fraction indicates low ash content (Campos et al, 2020).

Effect of briquette drying temperature and adhesive volume variations on moisture content

The moisture content of fuels affects combustion characteristics. Thus, it should be as low as possible because the high moisture content is a challenge when burning and would require excessive energy for drying. The result of moisture content of Sungkai sawdust biobriquettes represents in Figure 3. It can be seen that the drying temperature of 100 °C biobriquettes resulted in lower moisture content, namely 6.87%, 7.08%, 6.98% and 5.93% for samples 1B, 2B, 3B and 4B. The biobriquette drying temperature of 80 °C resulted in a higher moisture content, namely 7.39%, 7.27%, 7.52%, 6.95% for samples 1A, 2A, 3A and 4A. Drying at a higher temperature tends to reduce the water content in biobriquettes more efficiently. Low water content in biobriquettes will increase the calorific value of the fuel and increase combustion efficiency.

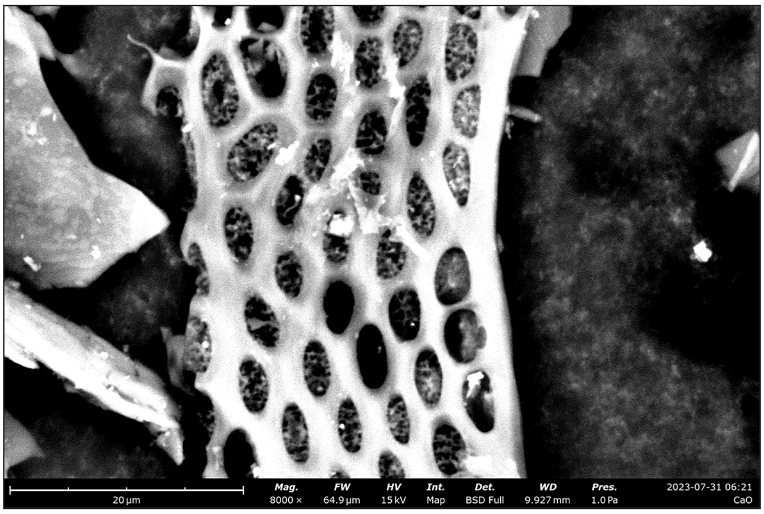

Figure 1. SEM characterization of pure Sungkai wood sawdust

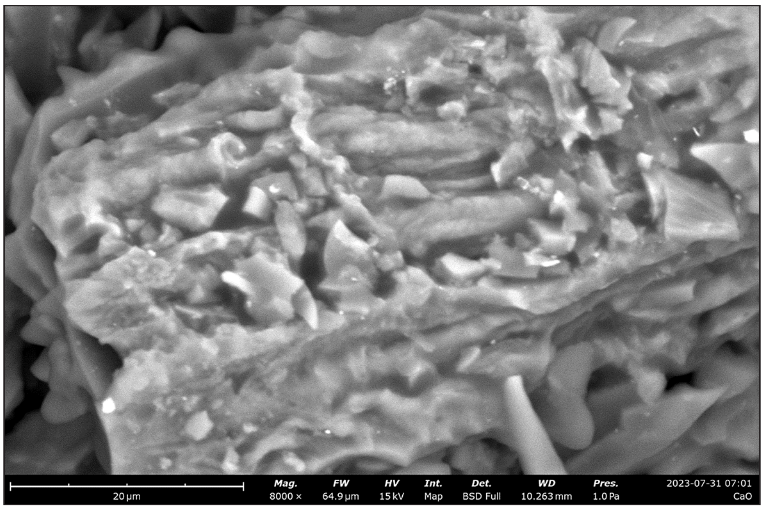

Figure 2. SEM characterization of Sungkai sawdust briquette

Table 3. Result of EDX analysis of pure Sungkai wood sawdust and sawdust briquette

Variation	Compound	Atomic concentration	Heavy concentration
Pure sungkai sawdust	Carbon	82.541	73.874
	Oxygen	14.272	17.017
	Sulfur	0.335	0.801
	Potassium	2.851	8.308
Sawdust briquettes	Carbon	88.720	82.517
	Oxygen	9.272	11.489
	Sulfur	0.161	0.400
	Potassium	1.848	5.94

Briquettes made with sungkai sawdust showed lower water content among other biomass briquette samples. This may be caused by the relatively high lignin content, good porosity, good drying, and high sawdust residual density as supported by (Sunday et al, 2020) who reported that the higher the lignin content, the finer the oil palm bark material, and lower water content compared to corncob residue.

Moisture content data obtained at a drying temperature of 80 °C or a drying temperature of 100 °C has a fluctuative trend. This case occurs because the used lubricant oil lubricant that applied is contaminated with undefined water

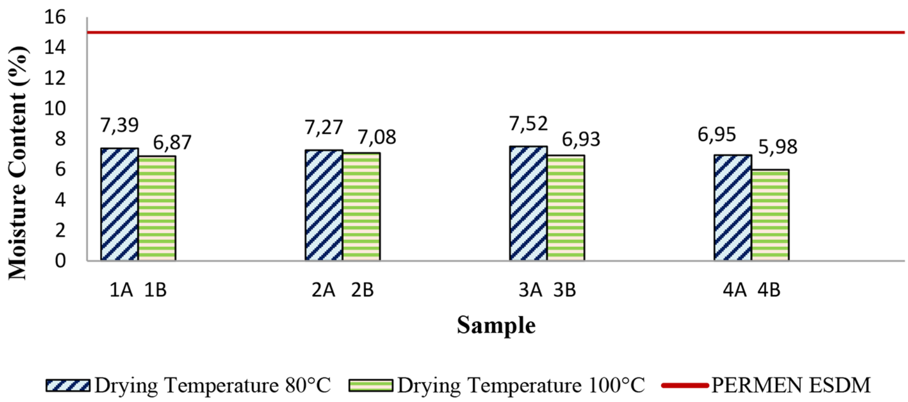

Figure 3. Moisture content of Sungkai sawdust biobriquettes

ammount. The higher drying temperature (100 °C) leads a lower moisture content. Based on Energy and Mineral Ministry Regulation Number 47 of 2006 (PERMEN ESDM), all variations in the value of briquette moisture content meet the PERMEN ESDM standards (≤ 15%) and Indonesia National Standard SNI (≤ 8%).

Effect of briquette drying temperature and adhesive volume variation on ash content

The non-combustible component obtained from biomass is ash. Figure 4 shows the ash content result for the briquette samples. The Figure 5 represents that the ash content decreased as the amount of sawdust in the ratio briquette increased (Afsal et al., 2020)

This can be seen in Figure 4. which shows drying biobriquettes at 100° C to produce biobriquettes 1B, 2B, 3B, and 4B with ash content of 1.99%, 1.87%, 1.63% and 1.54% respectively. When compared to briquettes at a drying temperature of 80 °C, it produces briquettes that have a higher ash content of 2.49%, 2.39%, 2.35% and 2.25% for briquettes 1A, 2A, 3A, and 4A. The higher the ash content from the combustion process, the lower the quality of the briquettes, because if the high ash content will reduce the calorific value of the briquettes (Arifah, 2017). The least ash content is resulted in briquettes 4B, which indicates the best quality of briquettes.

The ash content at 80 °C drying temperature decreased with increasing volume of used lubricant oil adhesive. Whereas in bio-briquettes with a drying temperature of 100 °C the ash content was unstable, some went up and some went down. Just like the case with the water content that we have discussed above, this instability is due to the mixing of the tapioca flour adhesive in each sample not using a definite dose, so it is very likely that too much or too little flour adhesive is used. Indonesian National Standard requires a maximum ash content of no more than 8%, whereas according to Energy and Mineral Ministry Regulation Number 047 of 2006 (PERMEN ESDM) wit value maximum of 10%.

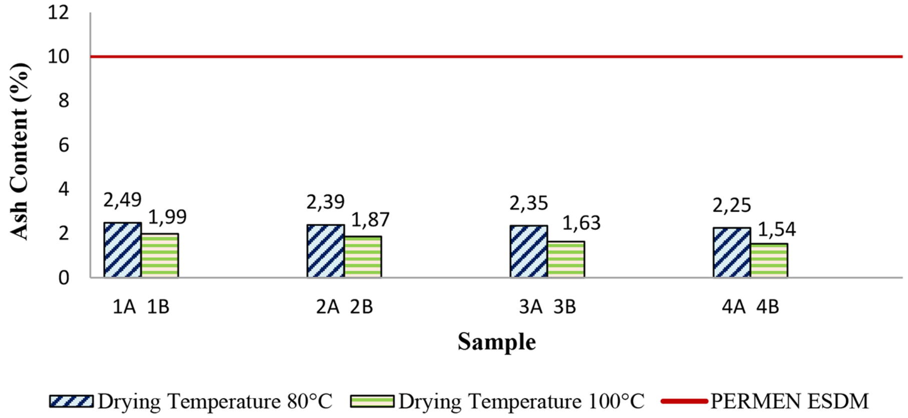

Figure 4. Ash content of wood sawdust biobriquette

Effect of briquette drying temperature and adhesive volume variation on volatile matter

Volatile matter consists of elements such as carbon, hydrogen, and oxygen which are present in the biomass (Ajimotokan, 2019). Furthermore, volatile matter does not contain water that is usually removed by the biomass carbonization process. The result of volatile matter on Sungkai sawdust biobriquettes shows in Figure 5.

Based on figure 5, the volatile matter content contained in biobriquettes with variations in biobriquette drying temperature and variations in adhesive volume does not meet Energy and Mineral Ministry Regulation Number 47 of 2006 (PERMEN ESDM), namely ≤ 15%. Factors that influence this occasion can occur because the type of raw material used has a high lignin content. The higher the lignin content in the raw material, the higher the volatile matter content produced in the biobriquettes. The lignin content contained in Sungkai wood ranges from 18% to 33%. High lignin content requires a perfect carbonization process. The perfect carbonization stage will release volatile substances in the form of CO, CO_2, CH_4 and H_2 gas through the decomposition of cellulose and lignin (Yuniarti et al., 2011). The high volatile matter content is also influenced by one of the adhesives used, namely tapioca flour. Tapioca flour contains carbohydrates (amylose and protein) which are not burnt in the combustion process so that this material also causes an increase in volatile matter levels (Tanui et al.,2018). This implies that low volatile matter is required for good-quality briquette. also indicated that low volatile matter briquettes might not be easy to ignite, but once ignited, they burn smoothly (Onchieku et al., 2014). The study of Onchieku indicated that high volatile matter results in high combustibility at low ash content.

The result reveals that sungkai sawdust increment in the agglomerated biomass resulted in the volatile matter percentage increment of the briquettes in the range 59.44–68.13%. High volatile matter content is an indication of the readiness of fuel samples to ignite. In terms of quality of the briquette, the high volatile matter implied that the briquette would readily ignite with a high proportionate flame during combustion (Loo et al., 2008).

Effect of briquette drying temperature and adhesive volume variation on fixed carbon content

The fixed carbon of a fuel is the percentage of carbon available for combustion (Achebe et al., 2018). The highest percentage of fixed carbon content of sawdust briquette might be a good bondage and uniformity of particles size helpful to increase the fixed carbon content and heating value of producing briquette. The result of fixed carbon content of Sungkai sawdust biobriquettes is represented on Figure 6.

Based on Figure 6, the data obtained from the test results for the fixed carbon content of biobriquettes with variations in briquette drying temperature and variations in adhesive volume, around 23.31% to 31.57%. All results of fixed carbon content do not meet the Energy and Mineral Ministry Regulation Number 47 of 2006, namely ≥ 77%. Inadequate bound carbon levels are affected by too high levels of volatile matter. The amount of carbon bonded in briquettes depends on the results of the moisture content, ash content and volatile matter content. The lower the results of the moisture content, ash content and volatile matter content, the greater

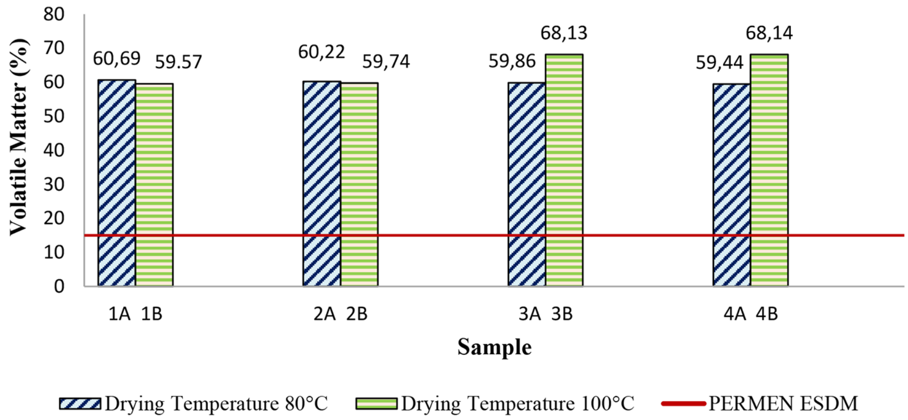

Figure 5. Concentration of volatile matter in Sungkai sawdust biobriquettes

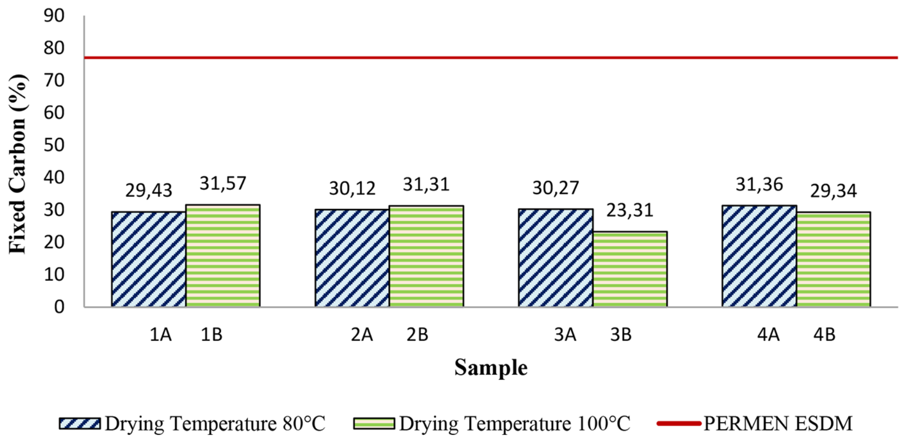

Figure 6. Carbon content of Sungkai sawdust biobriquettes

the bound carbon content. Vice versa, the greater the results of the water content, ash content and volatile matter content, the lower the carbon content (Sari and Aminah, 2020). Fixed carbon content close to the Energy and Mineral Ministry Regulation Number 47 of 2006 (PERMEN ESDM) is biobriquette 1B of 31.57% with 8.70 gr raw material and 4.35 gr adhesive at a drying temperature of 100 °C.

In addition, this briquette generated a small amount of ash compared to other tested fuels of biomass. Kebede et al (2022) mentioned that it indicates that this fuel was highly reactive and has a high carbon conversion efficiency.

Effect of briquette drying temperature and adhesive volume variation on calorific value

The results on the effect of drying temperature briquettes on the calorific value are shown in Figure 7. Low calorific values (2903 cal/g) at high moisture contents (7.39%) could be attributed to the presence of more water which might have absorbed heat liberated during combustion which is in line with Dermibas statement (2007).

The highest calorific value of sawdust briquette might be the type of biomass waste, low moisture content, and high fixed carbon present in the produced sample (Sisay et al., 2020). From the test results using a bomb calorimeter, the calorific values obtained varied from 2903.30 to 4373.89 cal/gr. The highest calorific value was found in biobriquette 4B and the lowest calorific value was found in biobriquette 1A. The highest calorific value can be affected by the adhesive ratio of the used lubricant oil used and the longer drying temperature. The higher the used lubricant oil composition in the biobriquettes, the higher the calorific value of the biobriquettes (Utomo, 2015). The used lubricant oil adhesive used in biobriquette 4B was 17.4 gr with a drying temperature of 80 °C, while in biobriquette 1A only used 4.35 gr of used lubricant oil with a drying temperature of 100 °C. Based on tests with a

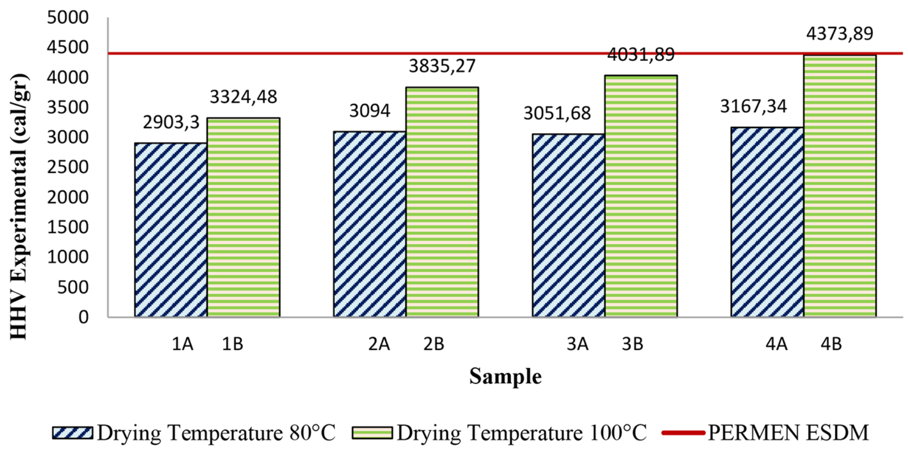

Figure 7. Experimental calorific value of Sungkai sawdust biobriquette

bomb calorimeter, the calorific value contained in biobriquettes with variations in drying temperature and variations in adhesive volume does not meet Energy and Mineral Ministry Regulation Number 47 of 2006 (PERMEN ESDM) which is 4400 cal/gr. To determine the level of accuracy and deviation (deviation) of the calorific value by experimental HHV testing, HHV testing was also carried out with the calculation equation HHV = 0.196 (FC) + 14.119. The equation is obtained from Demirbas (1997). The results of calculating the calorific value can be seen in Figure 8. The results in this study indicate the calorific value of sungkai sawdust briquette (4512–4749 cal/g) might be used as alternative fuel due to adequate energy, reducing deforestation and solid waste.

Based on Figure 8, the calorific value of biobriquettes with variations in adhesive volume and drying temperature variations is 4749 cal/gr, 4850 cal/gr, 4782 cal/gr, 4837 cal/gr, 4789 cal/gr, 4512 cal/gr, 4840 cal/gr, and 4696 cal/gr. Biobriquette 1B has the highest calorific value, while biobriquette 3B has the lowest calorific value. According to Energy and Mineral Ministry Regulation Number 47 of 2006 the calorific value that meets the standards is 4400 cal/gr. If seen from the results of calorific value calculations, all biobriquettes comply with Energy and Mineral Ministry Regulation Number 47 of 2006.

Effect of briquette drying temperature and adhesive volume variation on ignition time

One of the parameters analyzed in this study is the ignition time. The ignition time of biobriquettes refers to the time required to start the combustion process when the briquettes are exposed to fire. This is related to the ability of briquettes to produce a flame and start a combustion reaction quickly. The faster the burning time, the better the briquettes as fuel. Used lubricant oil added in biobriquettes can speed up the time to start burning (ignition). The mean ignition time of briquettes produced from biomass wastes and binders was significantly varied on Table 2.

The results of the analysis obtained from burning briquettes using a lighter or igniter showed that the longest flame time was obtained in treatment 4A which was 17.9 seconds, then the fastest ignition time was obtained in treatment 3B (Figure 9). The higher the volatile matter leads the faster the ignition process. The lower the volatile matter brings the slower the briquette ignition process will be until a fire occurs. Water content can also determine the quality of biobriquettes. The rapid ignition of the briquettes is due to the low water content in the briquettes. It is in line with Faizal (2017) statement that the high water content causes the briquettes to burn for longer time. Besides, the lowest ignition time of briquette might be accredited due to relatively low particle size, low porosity, and high bonding force of briquette (Davies et al, 2013).

Effect of drying temperature and adhesive volume variation on combustion time

The good quality of briquettes can be seen from the longer the briquettes can last in the ignition process. Figure 10 shows the result of combustion time of sungkai sawdust biobriquettes.

The fastest burning time for sawdust charcoal briquettes was used up in sample 3B with a time of 19.83 minutes and the longest in sample 4A with a time of 38.95 minutes. The adhesive content in the briquettes affects the calorific

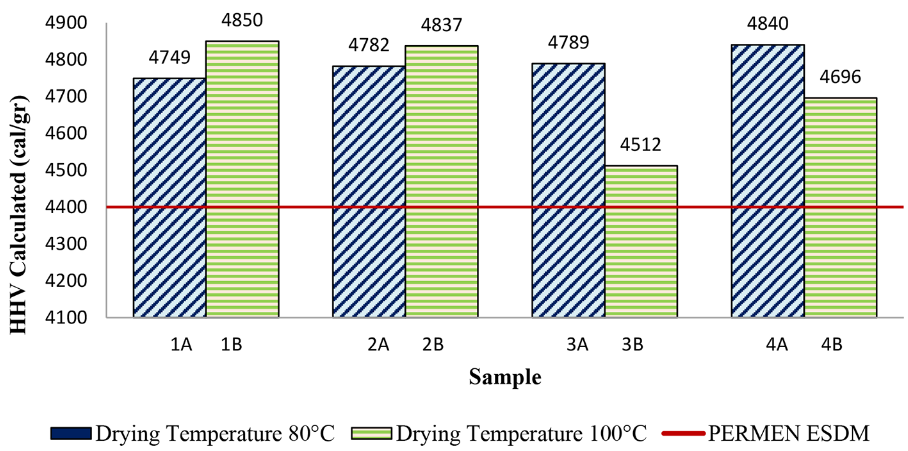

Figure 8. Calculated calorific value of Sungkai sawdust biobriquette

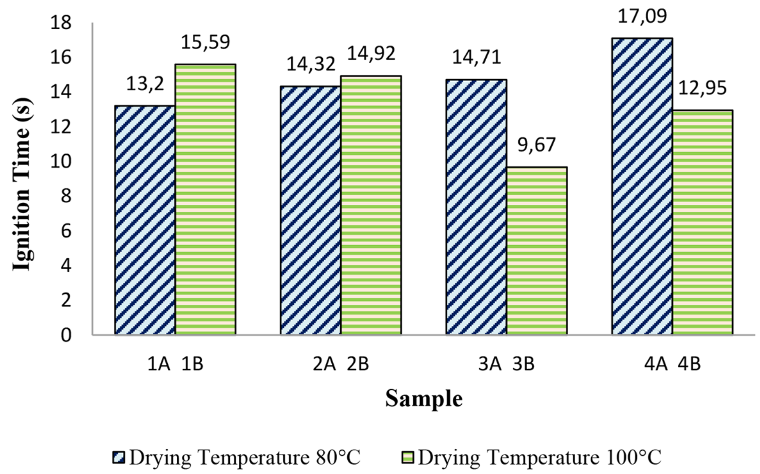

Figure 9. Ignition time of Sungkai sawdust biobriquette

value, ash content and volatile matter in the briquettes, the higher the adhesive content given to the briquettes, the slower the reduction in briquette mass that occurs when combustion. The higher the volatile matter content, the faster the briquettes will burn and the shorter the burning time. As a result, briquettes with a high volatile matter content tend to burn faster than the biobriquette with a lower volatile matter content. Burning time is also influenced by other factors including moisture and fixed carbon.

Biobriquettes that are wet or have high humidity can reduce combustion efficiency. The water in the briquettes will inhibit the combustion process by consuming some of the heat energy to vaporize the water before actual combustion takes place. The amount of bound carbon in biobriquettes from Sungkai sawdust basically comes from the carbon content in the wood before it is converted into briquettes. The higher the carbon content in Sungkai wood, the more carbon contained in the biobriquettes. The high content of fixed carbon can sustain the burning time to be longer.

Effect of briquette drying temperature and adhesive volume variation on the ability of briquettes to boil water

To determine the ability of Sungkai sawdust biobriquettes, a performance test was carried out in boiling water as much as 100 ml of biobriquettes. The biobriquette performance test was carried out by burning the biobriquette on the stove. The biobriquettes used for testing were as much as 10 grams of each treatment. The duration of burning starts when the bio-briquettes become coals until the biobriquettes coals die and turn to ashes, calculated based on the time unit of minutes and seconds. Combustion temperature is calculated using a thermo gun while the coals are burning. The test results data are available in Table 4.

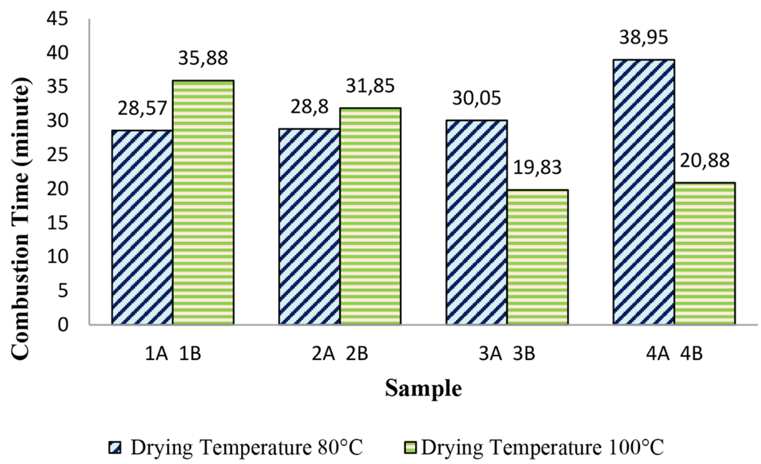

Figure 10. Combustion time of Sungkai sawdust biobriquettes

Table 4. The ability of Sungkai sawdust biobriquettes in boiling water

No.	Sample	Combustion temperature (°C)	Ability to boil water (min)	Burning rate (g/min)
1.	1 A	225.0	10.15	0.3325
2.	2 A	274.7	9.04	0.3263
3.	3 A	276.6	8.55	0.3128
4.	4 A	296.0	6.35	0.2413
5.	1 B	302.5	6.39	0.2619
6.	2 B	348.6	4.42	0.2982
7.	3 B	413.0	3.56	0.4740
8.	4 B	462.3	2.29	0.4501

Based on the test results, it can be seen that the higher the combustion temperature, the faster the water boils. The combustion temperature will increase as the volume of used lubricant oil adhesive increases and the drying temperature increases. The combustion temperature is closely related to the calorific value, a high combustion temperature comes from a high calorific value resulting in greater heat energy which makes water boil faster. This is in line with the statement of Kurniawan and Syukron (2019) that the higher the calorific value, the higher the heat energy produced. The biobriquette that had the best performance in the 100 ml water boiling test was biobriquette 4B with a burning temperature of 462.3 °C, a burning rate of 0.4501 and a boiling time of 2.48 minutes. Biobriquettes which had poor performance in the combustion test boiling 100 ml of water were 1A biobriquettes with a combustion temperature of 225.0, a burning rate of 0.3325 and a time of boiling water for 10.15 minutes. This case is because the calorific value of the 1A biobriquette is low in the HHV experimental so that the 1A biobriquette has a low temperature which makes the water boil for a long time. This study is supported by Sengar et al (2012) that mentioned about the increase of biomass concentration leads the cooking efficiency and burning rate.

CONCLUSIONS

The results of this research show that the greater the volume of used lubricant oil leads the greater the calorific value. Biobriquette 4B has the highest calorific value with experimental tests of 4373.89 cal/gr. Based on the calculation equation, the highest calorific value is found in biobriquette 1B, namely 4850 cal/gr. The more used lubricant oil used, the higher the calorific value of the biobriquettes, which makes the combustion temperature of the biobriquettes also higher, namely 462.3 °C which is achieved in 4B briquettes with a used lubricant oil of 17.4 g and a drying temperature of 100 °C. Used lubricant oil is flammable and has a high volatile content so it can help speed up the ignition process or ignition time. The higher the drying temperature, the faster the water evaporates which produces biobriquettes with lower water content. Biobriquette 3B has the lowest water content, namely 5.98%. High drying temperatures reduce the ash content in the resulting biobriquettes. The higher the drying temperature, the greater the volatile matter content in the biobriquettes. The higher the drying temperature leads the lower the water content so that the briquettes ignite more easily and the briquettes boil water faster. The lowest ash content of 1.54 % was found in 4B briquettes. The higher the volatile matter content leads the faster the biobriquettes will ignite, but the faster the biobriquettes will burn out.

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