International Journal of Hydrological and Environmental for Sustainability
Volume 1, Issue 2, 54-69
e_ISSN: 2828-5050
https://www.journal.foundae.com/index.php/ijhes

Utilization of Industrial Flour Waste as Biobriquette Adhesive: Application on Pyrolysis Biobriquette Sawdust Red Teak Wood

Harini Wahyuni*
Faculty of Technology Industry,
Universitas Muslim Indonesia
INDONESIA

Andi Aladin
Faculty of Technology Industry,
Universitas Muslim Indonesia
INDONESIA

Ruslan Kalla
Faculty of Technology Industry,
Universitas Muslim Indonesia
INDONESIA

Muhammad Nouman
Faculty of Medicine Siriraj Hospital,
Mahidol University
THAILAND

Ardimas
Department of Nanoscience and Technology,
Chulalongkorn University
THAILAND

Md Shahariar Chowdhury
Faculty of Environmental Management,
Prince of Songkla University
THAILAND

***Correspondence: E-mail:** wahyuniharinis@gmail.com

Article Info

Article history:

Received: March 07, 2022
Revised: June 01, 2022
Accepted: June 10, 2022

Keywords:

Biobriquette;
Red teakwood charcoal;
Industrial flour waste;
Compressive strength;
Ignition power.

Abstract

Biobriquette is one of the alternative fuels derived from biomass. The biomass used in this research is red teakwood charcoal. This research purposes to utilize red teakwood charcoal as alternative fuels and then to knows best characters compressive strength, ignition power and caloric value according to Indonesian quality standards (SNI 01-6235-2000). Characteristics of biobriquettes are known by test ash content, moisture content, volatile matter, fix carbon, compressive strength, ignition power and caloric value. The materials used are red teakwood plus industrial flour waste. The process of making biobriquette begins with drying the material, pyrolysis during 150 minutes at a temperature of 400 ^{o}C, sieved with 40 mesh. The briquetting was using a cube-shaped mold with manual pressure which was then dried in an oven to a constant weight and tested its characteristics by the ASTM (American standard Testing and material) method. The results showed that the added adhesive was very take effect in producing the best briquettes. The characteristics of briquettes with the best optimum adhesive composition produce is adhesive 5% charcoal 95% produce ash content 5.49% , moisture content 4.26 %, volatile matter 26.89 %, fix carbon 63.12%, compressive strength 3.64 kgf/cm^2, caloric value 7038 kcal/kg, and ignition power 0.03 gram/minute categorized as passing the specifications for the quality requirements briquettes of SNI 01-6235-2000.

To cite this article: Wahyuni, H., Aladin, A., Kalla, R., Nouman, M., Ardimas. and Salea, A. (2022). Utilization of Industrial Flour Waste as Biobriquette Adhesive: Application on Pyrolysis Biobriquette Sawdust Red Teak Wood. *International Journal of Hydrological and Environmental for Sustainability, 1*(2), 54-69.

INTRODUCTION

The community's need for energy is currently experiencing difficulties. Availability in the earth sooner or later, will be dwindling. Therefore, it is deemed necessary and urgent to seek alternative energy sources. One solution to overcome this problem is to optimize the potential of renewable energy (Adhani et al., 2019). In 2018, the total primary energy production consisting of oil, natural gas, coal and renewable energy reached 411.6 MTOE. 64% or 261.4 MTOE of the total production was exported, mainly coal and LPG. Indonesia's coal production is expected to continue to increase, especially to meet domestic demand (power generation and industry) and foreign demand (export). In terms of the type of energy, the supply of coal, including briquettes, will increase to 298 MTOE or its share of around 32% in 2050. The utilization of coal is directed as a raw material in the process of coal gasification and coal liquifaction as well as DME to increase added value (Suharyati, et al., 2019).

Alternative energy can be produced from simple appropriate technology by utilizing wood charcoal biomass waste. To take advantage of the leftover waste from house wood materials, carving wood and also the remnants of cutting saws that are often abandoned. Indonesian people still have not utilized and developed alternative renewable energy sources (Alfianolita, Y. 2018). Through a technological approach, agricultural waste consisting of various biomass can be further processed into biobriquettes. Biobriquettes can be converted into the latest alternative energy that can be used to reduce or suppress people's dependence, especially kerosene and natural gas (Mandey, L.C., and Tarore, D. 2015).

Biobriquette (**Figure 1**) is a solid fuel with a certain shape and size, which is composed of fine grains of material containing high carbon with a small mixture of adhesive and filler such as clay and tapioca, sawdust or rice husk, which has undergone a compression process with a certain pressure. so that the fuel is easier to handle and generate added value in its utilization (Aladin et al., 2017). The steps needed to make briquettes are by smoothing all the ingredients to a certain size, then mixing them using a mechanical mixer, and then printing them into certain packaging forms to form what are called biobriquettes (Aladin, A and Dea, M., 2011). The demand for briquettes, coal and mineral fuels can be seen in **Table 1**.

Figure 1. Various shapes and sizes of biobriquettes.

According to Aladin, A and Dea, M., (2011) in previous research, biobriquettes have benefits and advantages such as, 1). Can be used as an energy resource that is able to supply in the long term; 2). Substitute for fuel/firewood in households or small industries; 3). Is a place of absorption of work energy which is quite good; 4). Cheap fuel; 5). Provide sources of income to suppliers of briquette raw materials; 6). As a forum for transferring technology and skills for Indonesian workers; 7). Producing coal substitute biobriquettes which are very much needed by the community as a business opportunity.

Generally, some of this sawdust waste is only used as furnace fuel, or simply burned, so that it can cause environmental pollution. Whereas red teak sawdust is a biomass that has not been utilized optimally and has a relatively large calorific value (Ajimotokan et al., 2019). By converting sawdust into biobriquettes, it will increase the economic value of the material, and reduce environmental pollution (Jain et al., 2018). Charcoal biobriquette is a solid fuel that contains carbon, has a high calorific value, and can burn for a long time. Biochar is charcoal obtained by burning dry biomass without air (pyrolysis). Meanwhile, biomass is organic material that comes from living organisms. Biomass can actually be used directly as a source of heat energy for fuel, but it is less efficient. The burning value of biomass is only about 3000 cal, while biochar is capable of producing 5000 cal (Yudanto and Kusumaningrum, 2017).

Table 1. Demand for Briquettes, Coal, and Mineral Fuel in 2014

Country	Quantity	Value (US$)
Japan	94 489 000	32 266 880
Ireland	68 002 011	14 599 534
French	43 513 246	9 803 737
China	37 528 737	3 571 670
Czech Republic	27 230 478	3 716 504
English	14 381 913	3 249 494
Poland	13 379 830	1 702 620
North Africa	10 258 822	1 218 759
Slovakia	7 851 364	1 516 355
Other Countries	18 114 120	8 340 998
Total	334 749 521	79. 986 551

(**Source :** Haryanto et al., 2021)

Red teak is used as a raw material in the manufacture of biobriquettes and is superior to burning raw biomass because in addition to being smokeless, excessive emissions are also due to its higher heating value, available in large quantities (Salim, R., 2016). Good quality biobriquettes have properties such as smooth texture, not easy to break, hard, safe for humans and the environment, good ignition properties. The characteristics of this ignition are easy to ignite, the flame time is long enough, does not cause symptoms, smoke is little and disappears quickly and has a high calorific value (Handoko, et al., 2019).

One of the materials that can be used as an adhesive in briquettes is industrial flour. Made from semolina, a by-product of milling wheat into flour. This flour contains as much as 50% starch so it is widely used by the plywood adhesive industry and as a mixture in the manufacture of fish feed. Industrial flour is a by-product of wheat flour that can be recycled but cannot be consumed (Anizar et al., 2020). Adhesive material greatly determines the quality of biobriquettes, the adhesive used must have characteristics such as high adhesion and can increase the calorific value, resulting in smokeless and durable briquettes. The use of adhesive materials is intended to attract water and form a dense texture or bind the two substrates to be glued, so the arrangement of the particles will be better and more regular (Anggoro et al., 2017).

A related study conducted by Ningsih et al (2016) entitled the effect of the type of adhesive on briquettes from Bintaro fruit peel on the burning time with variations of adhesive 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35 % and 40%. The best type of adhesive is tapioca flour with a 20% adhesive composition that meets SNI, namely water content of 1.91%, ash content of 7.35%, volatile matter content of 15.34, burning time of 72 minutes and calorific value of 6000.46 calories/gram (Ningsih, et al., 2016).

The manufacture of biobriquettes has been done by many previous researchers, to develop it requires a more in-depth discussion. Based on the reasons mentioned above, the purpose of this research is to optimize the waste that has the potential to be used as raw material in the manufacture of biobriquettes by using industrial flour waste adhesive from each biobriquette. The development of biobriquettes with adhesives from industrial flour waste needs to be carried out with the aim of knowing the optimum composition of the adhesive so that the best compressive strength, combustion rate and calorific value are produced.

METHOD

The method in this research is using an experimental method in a laboratory with a pyrolysis process, making and testing samples. The stages before the research are literature study, collecting materials and preparing tools. The research time will be carried out for approximately one month which takes place in the 4th week of September - 4th week of October 2021. The location of research activities will be carried out in the Chemical Engineering Operations laboratory, Faculty of Industrial Technology, Universitas Muslim Indonesia, PT. Sucofindo Makassar and Makassar Plantation Product Industry Center, Indonesia.

Research Tools and Materials

The equipment used in this research is the main tool, namely a set of pyrolysis tools, supporting tools in the form of a briquette printer, sieve, analytical balance, oven, furnace, desiccator, spoon, tray, and instruments in the form of a bomb calorimeter, and briquette compressive strength test equipment as **Figure 2** is a set of pyrolysis tools with Informations: 1). Pyrolysis reactor, 2). Condenser, 3). Water reservoir , 4). Gas cylinder, 5). Water pump, 6. Condensation reservoir.

The materials used in this research are red teak sawdust waste and industrial flour waste. Red teak sawdust obtained from sawdust processed by the phinisi shipbuilding in Bulukumba which is no longer needed will accumulate as waste, while industrial flour waste is obtained from PT. Eastern Pearl Flour Mills Makassar.

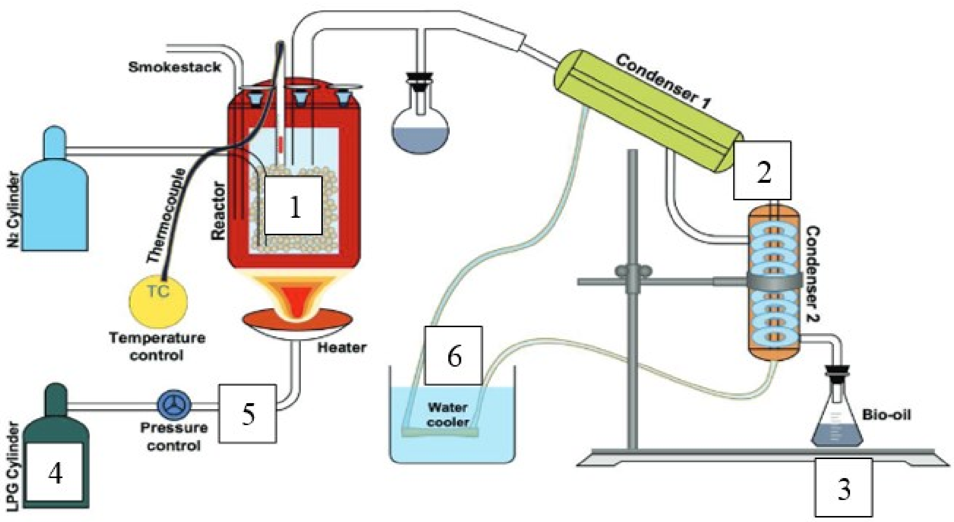

Figure 2. A set of pyrolysis tools

Dependent variable

The dependent variables in this study are temperature and operating time where the temperature in the pyrolysis process used is 400 oC and the pyrolysis time is 150 minutes, charcoal granules are 40 mesh, briquette weight is 30 grams.

Independent Variable

The independent variables in this study were the composition of the raw material for charcoal biobriquette, sawdust, red teak wood, namely 95%, 90%, 85%, 80%, 75% and the composition of the adhesive material, namely industrial flour waste, respectively 5%, 10%, 15%. , 20%, 25% of the total weight of briquettes.

Biobriquette Manufacturing Process

The biobriquette manufacturing process can be see in **Figure 3**. Before making briquettes, first prepare raw materials in the form of red teak sawdust waste and industrial flour waste. The sawdust is dried in the sun for 3 days. The drying process of raw materials aims to remove the water content in the material because if the material still contains water, the pyrolysis process will not be optimal. The process after drying the raw materials is the burning of the sample which is done by pyrolysis. This process aims to obtain charcoal from raw materials. Red teak sawdust waste is pyrolysis with the takes place at a temperature of 400 ^{o}C within 150 minutes.

Next is the process of grinding the material, the red teak charcoal that has been pyrolyzed is then ground and then sieved with a size of 40 mesh. According to Arake, S.R. (2017), the optimal size is between 30-50 mesh, this is because the particle size of the biomass should not be too large because it will cause voids in the porosity of the briquettes (Ansar et al., 2020). Then the process of mixing the raw material of red teak charcoal with industrial flour waste adhesive.

After mixing, the next process is printing, the briquettes are printed on a biobriquette printer. The same process was carried out with a comparison of red teak sawdust charcoal, namely 95%, 90%, 85%, 80% and 75% with an adhesive composition of 5%, 10%, 15%, 20% and 25% of the total weight of the briquettes. The next process is oven at a temperature of 40 °C for 20 minutes with the aim of drying the briquettes. After that enter the stage of testing wood charcoal.

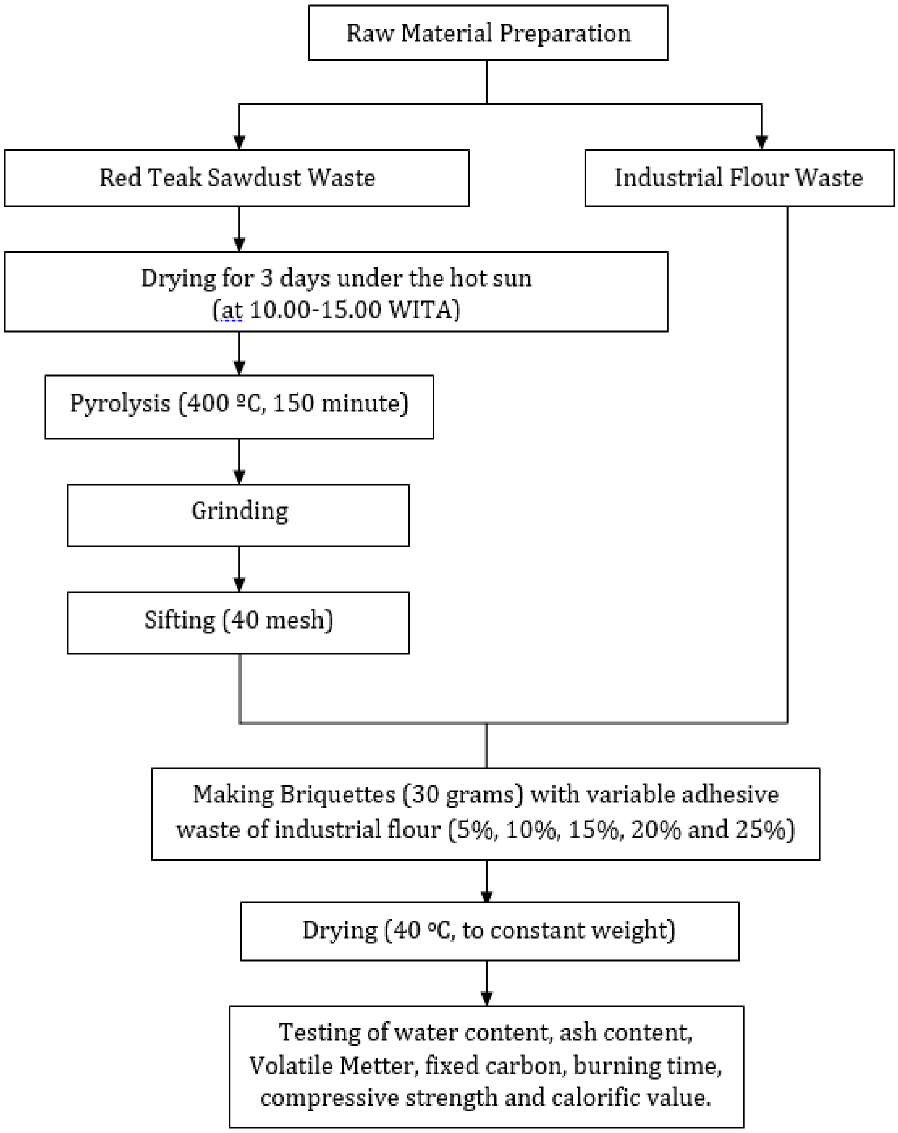

Figure 3. Research flow chart

Sample Test

The next stage is testing, the biobriquettes are tested by testing water content, ash content, volatile meter content, fixed carbon, burning time, heating value and compressive strength of biobriquettes. Next is the data analysis stage. The data analysis method used is quantitative analysis, where the test results obtained are processed and then compared with the biobriquette quality standard according to the Indonesian National Standard and compares the results of previous studies.

Compressive Strength Value

Testing the quality and quality of biobriquettes refers to SNI 01–6235–2000. This activity is intended to test its feasibility when applied to partners. The test is carried out by placing the test object on the press machine centrically (**Figure 4**). Then run the press machine with constant load increments ranging from 2 to 4 kg/cm^2 per second. Carry out the loading of the test sample to crush and record the maximum load that occurs during the examination of the test object. Calculate the compressive strength (Kgf/cm^2) using the equation:

$$\text{Compressive Strength} = B/A \quad (1)$$

where:

A : Area of compression (cm^2)

B : Compressive Load (KgF)

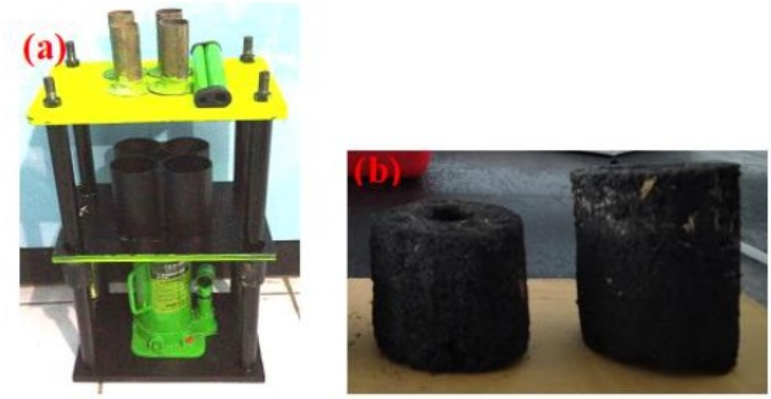

Figure 4. (a) Design of biobriquette printing equipment and (b) red teak sawdust charcoal biobriquette.

Calorific Value (ASTM-1205-04)

The calorific value test is carried out by weighing a sample of 0.5 grams and placing it in a platinum cup and placing it at the end of the igniter rod that has been installed with the igniter wire. Then put it in the bomb tube and close it tightly. Oxygen is filled into a tube with a pressure of 30 bar and put into a calorimeter tube that has been filled with 1250 ml of cooling water. The calorimeter is closed and the thermometer is attached to the calorimeter cover. The cooling water stirrer was turned on for 5 minutes and the temperature indicated on the thermometer was recorded. The ignition was carried out and the cooling water was continuously stirred for 5 minutes, then the temperature increase was recorded on the thermometer. The calorific value (Kcal/kg) is calculated by the equation:

$$Q_{vad}(\text{gross}) = \frac{[(\text{txEe}) - e1 - e2 - e3 - e4](\text{Kcal})}{m\ (kg)} \quad (2)$$

where:

Q_{vad}(gross) : Gross calorific value at constant volume (cal/g)

Ee : Calorimeter heat capacity (cal/ ºC)

t : Temperature (ºC)

e1 : Acid correction (cal)

e2 : Dry correction (cal)

e3 : Correction of sulfur (cal)

e4 : Correction of acid burning (cal/g)

m : Weight of sample (gram)

Combustion Rate

Testing the rate of combustion is done manually using a briquette furnace. Where the flame of each briquette mixture is judged which one is more durable for the flame. Before testing the mass of each sample is weighed, then each sample is burned to ashes, the combustion time is calculated using a stopwatch and the mass of ash is weighed again to determine the difference in the initial mass. This combustion rate test is intended to determine the level of briquette fuel efficiency. Calculate the burning rate (grams/minute) using the equation:

$$\text{Briquette Combustion Rate} = (W)/t \quad (3)$$

where:

W : Weight of sample(grams)

T : Burning time(minutes)

Ash Content (ASTM D3174-2004)

Calculation of ash content was carried out using a porcelain dish that had been cleaned in a dry position and weighed first. Then 1 gram of the sample was weighed into a porcelain cup. Next, put the sample into the furnace at a temperature of 600-800oC for 4 hours so that all the carbon is lost. Then cool the cup and its contents into a desiccator and then weighed to get the weight of the ash. Calculate the ash content (%) using the equation:

$$\text{Ash content} = (w_2-w_0)/w_1 \times 100\% \quad (4)$$

where:
w_0 : Weight of empty crucible (grams)
w_1 : Sample weight (grams)
w_2 : Weight of crucible + sample after igniting (grams)

Moisture Content (ASTM D3175)

Not only the ash content, the moisture content was also calculated by the first step of providing a cleaned cup that was dried in an oven at 105 °C for 1 hour. Then cool in a desiccator for a while, then weighed. Next, weigh each mass of the cup and 1 gram of the sample. After that, the samples were dried using an oven at 105 °C for approximately 3 hours. The sample was cooled for 1 hour and then weighed. Weighing and drying repeatedly to reach a constant weight. Calculate the water content (%) with the equation:

$$\text{Moisture Content} = (w_0-w_2)/w_1 \times 100\% \quad (5)$$

Where:
w_0 : Weight of weighing bottle + sample before drying (grams)
w_1 : Sample weight (grams)
w_2 : Weight of weighing bottle + sample after drying (grams)

Volatile Meter (ASTM-3175)

The process of calculating the volatile meter is carried out using a porcelain cup whose mass is first weighed. Next, the porcelain cup is filled with a sample of 1 gram, then weighed. Then heated using a furnace with a temperature of 750°C for 7 minutes. The final step is to cool it in a desiccator for 30 minutes and then weigh it. Calculate the ash content (%) with the equation:

$$\text{VM (Loss-Moisture)} = (w_2-w_1)/(w_1-w) \times 100\% \quad (6)$$

where:
w : Weight of empty cup (grams)
w_1 : Weight of cup + sample(grams)
w_2 : Weight of the cup + sample after being ignited (grams)

RESULTS AND DISCUSSION

Based on the test results using the pyrolysis method, it can be seen the results before and after the raw material of red teak sawdust into charcoal in **Table 2** which is used as raw material for making biobriquettes.

Table 2. Results of pyrolysis of red teak sawdust

No	Before pyrolysis (gram)	After pyrolysis (gram)	Yield (%)
1	1700	557	32.76
2	1500	390	26.0
3	1500	453	30.2
4	1500	485	32.33
x	1550	471.25	30.32

(**Source :** Data of this study)

The charcoal used for briquetting is the result of pyrolysis where the process is that the raw materials are weighed first 1500 grams and then put into the reactor tool. The pyrolysis equipment is then assembled and confirmed to be in good condition (Ayuningtyas, E and Aridito, M.N. 2019; Faui., 2020; Febrianti et al., 2020). The temperature of the instrument is set at 400 ^oC. After the pyrolysis temperature is reached, the pyrolysis process is carried out for 150 minutes. The pyrolysis process was stopped and cooled at room temperature. The carbonized charcoal is then removed, ground and sieved 40 mesh to obtain the size of charcoal to be printed as biobriquettes.

Making biobriquettes by characterizing the raw materials used for red teak sawdust charcoal, to determine the quality of the raw materials, proximate testing (moisture content, ash content, volatile meter content and fixed carbon content) and ultimate (heat content) of powder and charcoal can be seen in **Table 3** refers to SNI 01-6235-2000.

Table 3. Test results of red teak sawdust and charcoal (ASTM D-3173-03)

Test Type	Powder	Charcoal
Water content (%)	13.32	4.32
Ash Content (%)	1.57	6.48
Volatile Meter (%)	76.63	32.58
Fixed Carbon (%)	8.24	56.33
Calorific Value (%)	4349	7041

(**Source :** Data of this study)

In **Table 3** shows that pyrolysis can reduce the water content due to the evaporation of water in the pyrolysis process which is included in the liquid smoke, the ash content increases due to the final residue of the combustion process of mineral substances that are not lost during the combustion process (Kaulan, 2010; Kasman et al., 2021; Kumar et al., 2016). High ash content reduces the fixed carbon and high water content increases the volatile meter and which increases the calorific value because the fix carbon is quite high. Making biobriquettes by characterizing the raw materials used in industrial flour waste adhesives, to determine the quality of the raw materials, proximate and ultimate tests were carried out in **Table 4** referring to the International Association For Cereal Chemistry ICC-Standart No. 110&10.

Table 4. Industrial flour waste test results data (International Association For Cereal Chemistry ICC-Standart No. 110&105)

Test Type	Test result
Water content (%)	11.90
Ash Content (%)	2.03
Calorific Value (%)	4241
Starch (%)	59.90
Proteins (%)	22.62

(**Source :** Data of this study)

In **Table 4**, the test results show that industrial flour waste is a high quality adhesive because it has low ash and water content and a very high starch content so that it can increase the calorific value and is widely used by the plywood industry as an adhesive because it has a high starch content. which can increase the adhesive value.

Based on the characterization of red teak charcoal and industrial flour waste adhesive, the compressive strength, combustion rate and calorific value were tested for 5 variations of adhesive concentration, namely 5%, 10%, 15%, 20% and 25% of the five concentrations, the best concentration will be taken. Based on the optimum composition of the adhesive, the results of the compressive test were obtained as shown in **Table 5**.

Table 5. Compressive strength of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Compressive Strength (Kgf/cm^2)
0	100	0
5	95	3.64
10	90	3.00
15	85	2.89
20	80	4.64
25	75	3.34

(**Source :** Data of this study)

Seen in **Table 5**, the highest compressive strength is found at a concentration of 5% adhesive, which is 4.64 Kgf/cm^2 and the lowest is at 20% adhesive, which is 2.89 Kgf/cm^2, in **Figure 5** of the five variations, one of the adhesive concentrations with the best compressive strength is selected. concentration of 5% adhesive with a compressive strength of 3.64 Kgf/cm^2 because the compressive strength produces a very high heating value **(Table 6)** and a fast burning rate **(Table 7)**.

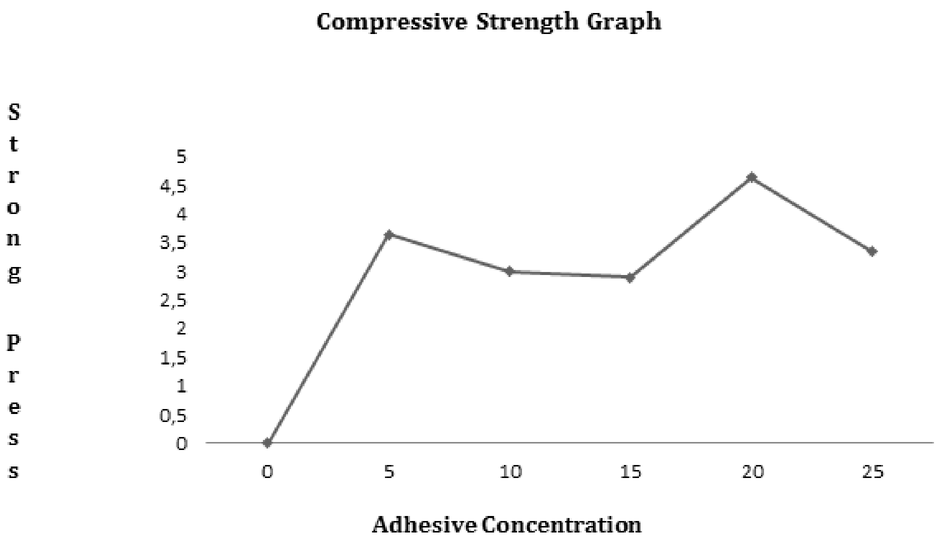

Figure 5. Graph of the relationship between adhesive concentration and compressive strength

Indonesian National Standard No. 01-6235-2000 does not require the hardness value of a briquette (Sulistyaningkarti, L and Utami, B. 2017; Muhlis et al., 2019; Nuhardin, I. 2018). However, the value of hardness can be anticipated to prevent damage in packing during the transportation and storage process in the long term (Ansar, et al., 2020). The quality of the briquettes is also determined from the physical analysis of the briquettes, one of which is the compressive strength given to the surface of the briquettes. However, according to Parinduri, L and Parinduri, T. (2020), the higher the amount of adhesive used in making briquettes, the higher the density of briquettes tends to be. This result is in accordance with research (Anizar, et al., 2020; Putri, R. E and Andasuryani. 2017) with an adhesive concentration of 20% producing a compressive strength of 0.57 g/cm3 and an adhesive concentration of 30% producing a compressive strength of 0.60 g/cm^3.

Calorific Value

The test results show **Table 6** that the calorific value of the briquettes in this study showed the highest concentration of 5% adhesive, which was 7038 Kcal/Kg and the lowest was at 20% adhesive, which was 6279 Kcal/Kg. So the best calorific value according to the optimum composition in **Figure 6** is the calorific value at a concentration of 5% adhesive and 95% charcoal, which is 7038 Kcal/Kg.

Table 6. The calorific value of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Calorific Value (Kcal/Kg)
0	100	0
5	95	7038
10	90	6951
15	85	6894
20	80	6279
25	75	6555

(**Source :** Data of this study)

This agrees with Qistina, I., Sukandar, D and Trilaksono. (2016) which states that the greater the percentage of adhesive, the lower the calorific value produced. The results of Qistina, I., Sukandar, D and Trilaksono. (2016) show that with 5% adhesive the calorific value produced is 3,347 cal/g, while briquettes with 12.5% adhesive concentration produce a calorific value of 3,061 cal/g. The calorific value of briquettes is a very important parameter to know because it will determine the quality of the briquettes produced whether it is feasible or not to be used.

The higher the heating value of the briquettes, the higher the quality of the briquettes. The calorific value of briquettes depends on the composition of the ingredients. However, the carbonization temperature also cannot be too high, meaning that it is only at the optimum limit of the carbonization temperature, so that charcoal briquettes are of high quality and efficiency in saving a fuel (Usman, 2020). The calorific value in this study as a whole meets the quality standard of SNI No. 01-6235-2000 ie > 5000 kcal/kg.

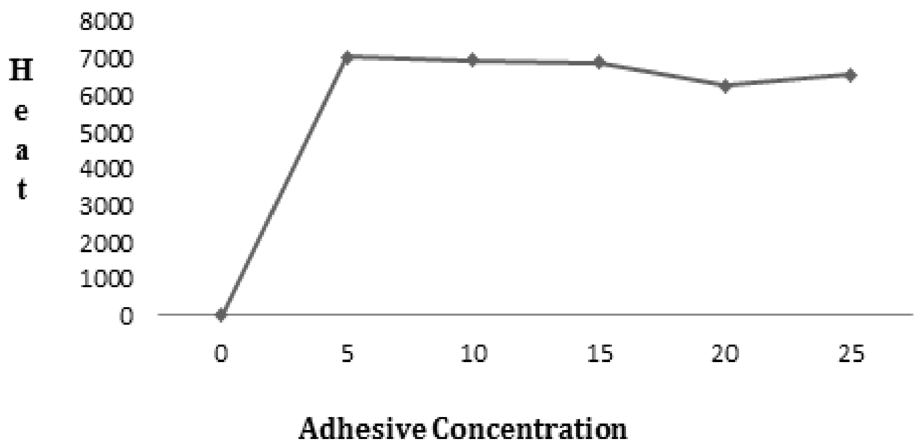

Figure 6. Graph of the relationship between adhesive concentration and calorific value

Combustion Rate

The test results show in **Table 7** that the briquette burning rate in this study showed the highest concentration of 5% adhesive, 0.03 gram/minute and the lowest 10% adhesive, 0.02 gram/minute. So the combustion rate according to the optimum composition in **Figure 7** is the best calorific value at a concentration of 5% adhesive and 95% charcoal, which is 0.03 gram/minute because it is also considered from the calorific value and high compressive strength.

Table 7. Combustion rate of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Combustion Rate (grams/minute)
0	100	0
5	95	0.03
10	90	0.02
15	85	0.04
20	80	0.03
25	75	0.04

(**Source :** Data of this study)

Combustion rate is a description of the loss of weight per unit time during combustion. The adhesive will slow down the burning rate. Good quality briquettes are briquettes that are flammable and have a high combustion rate. This is evidenced by the results of research by Ristianingsih, et al (2015), namely briquettes with an adhesive concentration of 5% produced a burning rate of 7.88 g/minute while briquettes with an adhesive concentration of 10% produced a burning rate of 13.31 g/minute regarding the standardization of the rate of burning of briquettes.

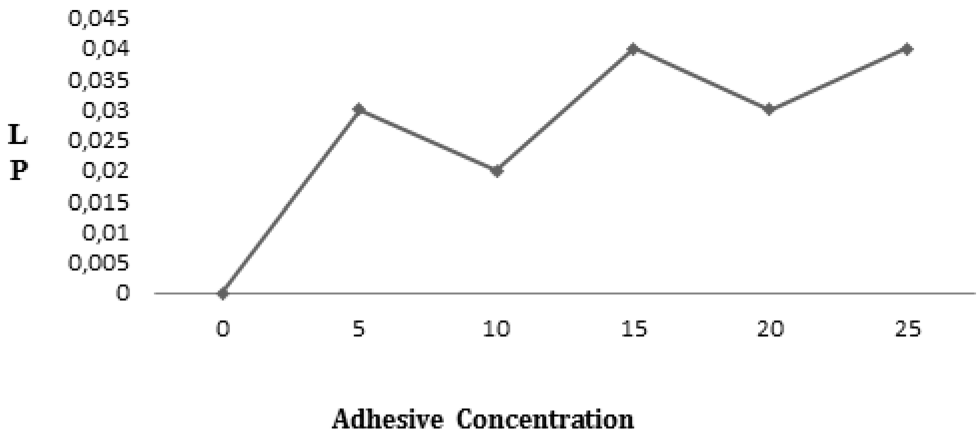

Figure 7. Graph of the relationship between adhesive concentration and burning rate

Ash Content

The test results show **Table 8** that the ash content of the briquettes in this study showed the highest concentration of 5% adhesive, namely 5.49% and the lowest at 25% adhesive, namely 4.79%. So the best ash content according to the optimum composition is at a concentration of 5% adhesive and 95% charcoal, which is 5.49% because it refers to the value of compressive strength, calorific value and the best combustion rate of 5 variations of adhesive concentration. The decrease in ash content was caused by the decreasing percentage of charcoal. In accordance with Triono's (2016) which states that the addition of charcoal concentration will cause an increase in the briquette ash content value and a decrease in charcoal concentration will decrease the briquette ash content value (Rahmadani et al., 2017). The decrease in the concentration of charcoal used causes the ash content to decrease, because it is the inorganic substance contained in the charcoal that produces ash, so that when the concentration of charcoal used is small, the ash content in the briquettes will also be small. Then (Western, C, M., 2021) in his research showed that the ash content of palm stem briquettes increased with increasing concentration of tapioca adhesive 0%, 10%, 20% and 30% at a constant lime concentration. The ash content in this study as a whole meets the quality standard of SNI No. 01-6235-2000 that is <8%.

Table 8. Ash content of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Ash Content (%)
0	100	5.49
5	95	5.44
10	90	5.06
15	85	5.08
20	80	4.79
25	75	5.49

(**Source :** Data of this study)

Moisture Content

The test results show **Table 9** that the moisture content of the briquettes in this study showed the highest concentration of 25% adhesive, 5.13% and the lowest 10% adhesive, 4.17%. So the best moisture content according to the optimum composition is at a concentration of 5% adhesive and

95% charcoal, which is 4.26% because it refers to the value of compressive strength, calorific value and the best combustion rate of 5 variations of adhesive concentration.

The moisture content of briquettes greatly affects the calorific value. The smaller the value of the moisture content, the better the calorific value. Charcoal briquettes have high hygroscopic properties, so the calculation of moisture content aims to determine the hygroscopic properties of charcoal briquettes as a result of research (Handoko, et al., 2019). At 10% and 20% adhesive concentrations, the moisture content decreased due to the unevenness of the adhesive mixture, resulting in different water absorption and incomplete drying of raw materials (Ansar et al., 2020). The moisture content of briquettes comes from the type of adhesive so that the adhesive greatly determines the results of the water content (Ningsih, et al., 2016). This is in accordance with the results of research (Anizar, et al., 2020) with 20% adhesive producing a moisture content of 8.11% and 30% adhesive yielding a moisture content of 8.7%. From the overall results of the average water content referring to the SNI standard for Wood Charcoal Briquettes 01-6235-2000, it can be categorized as passing the specifications for briquette quality requirements, where the maximum moisture content of briquettes quality requirements is 8%.

Table 9. Moisture Content of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Moisture Content (%)
0	100	5.49
5	95	5.44
10	90	5.06
15	85	5.08
20	80	4.79
25	75	5.49

(**Source :** Data of this study)

Volatile Matter Analysis

The test results show **Table 10** that the Volatile Metter briquette content in this study showed the highest concentration of 20% adhesive, which was 29.32% and the lowest was at 5% adhesive, which was 26.89%. So the Volatile Metter content according to the optimum composition is best at a concentration of 5% adhesive and 95% charcoal, which is 26.89% because it refers to the compressive strength, calorific value and the best combustion rate of 5 variations of adhesive concentration.

Volatile Matter content is a substance that can evaporate as a decomposition of compounds that are still present in the charcoal other than water. The content of high volatile substances in charcoal briquettes will cause more smoke when ignited, if the CO is of high value this is not good for health and the surrounding environment. Information was also obtained that high levels of volatile matter are influenced by the chemical components of charcoal such as the presence of impurities from charcoal raw materials (Usman, 2007). The inhomogeneous drying process of mangroves also affects. The volatile matter content of charcoal briquettes increases with the increase in the percentage of adhesive, this is in accordance with the results of research (Anizar, et al., 2020) with 20% adhesive producing 61.94% volatile metter levels and 30% adhesive yielding 75.45% volatile metter levels . This red teak briquette has met the volatile meter levels of SNI No. 01-6235-2000 because >30%.

Table 10. Volatile Metter content of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Volatile Matter Content (%)
0	100	26.89
5	95	27.25
10	90	29.80
15	85	29.32
20	80	33.15
25	75	26.89

(**Source :** Data of this study)

Fixed Carbon

The test results show **Table 11** that the levels of Fixed Carbon briquettes in this study showed the highest concentration of 5% adhesive, 63.12% and the lowest 25% adhesive, 56.68%. So the fixed carbon content according to the optimum composition is best at a concentration of 5% adhesive and 95% charcoal, which is 63.12% because it refers to the value of compressive strength, calorific value and the best combustion rate of 5 variations of adhesive concentration.

The bonded carbon content of charcoal briquettes at each addition of the adhesive concentration decreased in the adhesive concentration, this is in accordance with the results of research (Anizar, et al., 2020) with 20% adhesive producing 18.76% fixed carbon content and 30% fixed carbon content in the adhesive. 19.37%. The decrease in the level of bound carbon is due to the decrease in the concentration of charcoal, so the lower the concentration of charcoal will reduce the level of bound carbon contained in the briquettes.

The average content of fixed carbon is 60.78%, it does not meet SNI 01-6235-2000 which requires a bonded carbon value of at least 77% due to the possibility of the drying process of the material being less than optimal and the presence of impurities in the raw material.

Table 11. Fixed carbon content of red teak charcoal biobriquettes

Adhesive Concentration (%)	Charcoal Concentration (%)	Fixed Carbon Content (%)
0	100	63.12
5	95	62.90
10	90	60.36
15	85	60.83
20	80	56.68
25	75	63.12

(**Source :** Data of this study)

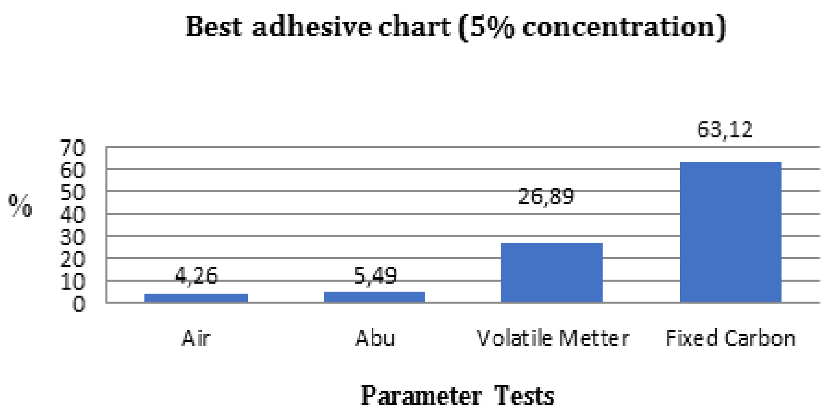

Figure 8. Graph of the relationship between adhesive concentration and the best variation

Graph of the relationship can be seen in **Figure 8**, the best adhesive concentration is at a concentration of 5% adhesive 95% charcoal. Where the results of water content 4.26%, ash content 5.49%, volatile meter 26.89% and fixed carbon 63.12%, by using a small concentration of adhesive (5%) high quality biobriquettes can be produced and referring to the SNI standard for Wood Charcoal Briquettes 01- 6235-2000 can categorized as passing the specifications for briquette quality requirements. Low ash content means that the resulting briquette combustion is good (Anizar, et al., 2020). This is because the carbon content is influenced by the volatile matter content and ash content. According to Usman, (2017), that the higher the volatile matter content, the lower the bound carbon content and vice versa. Likewise, if the ash content is high, the carbon content will be lower (Ristianingsih, et al., 2015). Based on the research results, biobriquettes using red teak sawdust briquette have the characteristics of Density of 1.48 g/cm^3, Briquette Shape: hollow cylinder, Cylinder diameter: 5 cm, Height/Thickness: 2.5 cm, Calorific value: 5443 kcal/kg, Moisture content:

10-12%, Ash Content : 10-15%, NO_x Gas Emission : 115 ppm, SO_2 Gas Emission : 247 ppm, CO_2 Gas Emission : 0.4%, CO_2 Gas Emission : not detected.

CONCLUSION

Based on the results of the research conducted, it can be concluded that the optimum composition of industrial flour waste adhesive so that the maximum compressive strength is produced is in treatment 1 which is 3.64 kgf/cm^2 with a concentration of 5% industrial flour waste adhesive and 95% sawdust charcoal. In addition, the characteristics of biobriquettes based on the optimum calorific value conditions were the treatment in treatment 1, which was 7041 kcal/kg with a concentration of 5% adhesive waste from industrial flour and 95% sawdust charcoal. While the optimum composition of industrial flour waste adhesive so that the maximum ignition rate is produced is in treatment 1, which is 0.03 gram/minute with a concentration of 5% industrial flour waste adhesive and 95% sawdust charcoal. For continuous research, the use of fuel for cooking that is efficient, environmentally friendly, renewable and inexpensive needs to be sought in order to maintain environmental balance and is easy to use and obtain by the wider community. In addition, further research is needed to produce better quality red teak sawdust briquettes and use them directly on the briquette stove. In addition, to find out other benefits of waste, we can use it to meet our needs, so that we can reduce dependence on LPG gas.

ACKNOWLEDGMENT

The authors are grateful to PT. Sucofindo Makassar and Makassar Plantation Product Industry Center for providing the opportunity to conduct research and provide direction and guidance during the research.

CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

REFERENCES

Adhani, L., Masrya. M.A., Octavia, S.I and Sindiany, I.I. (2019), Analisis Bahan Bakar Alternatif Komposit Biobriket dari Enceng Gondok dengan Perekat Kotoran Sapi, *Jurnal Al-Kimiya*, 6(2): 81-86.

Ajimotokan, H.A., Ehindero, A.O., Ajao, K.A., Adeleke, A.A., Ikubanni, P.P and Babata, S.Y.L. (2019). Combustion Characteristics of Fuel Briquettes Made from Charcoal Particles and Sawdust Agglomerates, Science Direct, E00202.

Aladin, A and Dea, M. (2011). Sumber Daya Alam BatuBara, CV. Lubuk Agung: Bandung.

Aladin, A., Alwi, R.S and Syarif T. (2017). Design of Pyrolysis Reactor For Production of Bio-Oil And Bio-Char Simultaneously, International Seminar On Fundamental And Application Of Chemical Engineering, *AIP Conf. Proc*. 1840, 110010-1–110010-4.

Alfianolita, Y. (2018). Perbadingan Variasi Perekat pada Pembuatan Briket Tempurung Kelapa (Studi Kasus: Kecamatan Sutera Kabupaten Pesisir Selatan), Sekolah Tinggi Teknologi Industri (STTIND) Padang.

Anggoro, D.D., Hanif, M.D.W and Fathoni, M.Z., (2017). Pembuatan Briket Arang dari Campuran Tempurung Kelapa dan Serbuk Gergaji Kayu Sengon, *Jurnal Teknik*, 38(2): 1-5.

Anizar, H., Sribudiani, E and Somadona, S. (2020). Pengaruh Bahan Perekat Tapioka Dan Sagu Terhadap Kualitas Briket Arang Kulit Buah Nipah, *Jurnal Perennial*, 16(1): 11-17.

Ansar, Setiawati, D.A., Murad and Mliani, B.S. (2020). Karakteristik Fisik Briket Tempurung Kelapa menggunakan Perekat Tepung Tapioka, *Jurnal Teknologi Pertanian*, 13(1): 1-7.

Arake, S.R. (2017). Uji Kalor Briket Limbah Tongkol Jagung dan Sekam Padi dengan Proses Karbonisasi. Universitas Hasanuddin.

Ayuningtyas, E and Aridito, M.N. (2019). Studi Karakteristik Proses Pirolisis dan Arang dari Briket Serbuk Kayu dengan Variasi Laju Pemanasan Menggunakan Metode Pirolisis Single Rocket Stove, *Jurnal Rekayasa Lingkungan*, 19(1):1-14.

Faui, M.A., Mahfudz., Pudjiono, S., Hamdan, A.A., Hasna, T.M., Wibowo, A., Setiadi D and Rimbawanto, A. (2020). Beberapa Jenis Jati (Tectona sp.) Variasi dan Potensi Pemuliaannya, Badan Litbang dan Inovasi Lingkungan Hidup dan Kehutanan, Yogyakarta.

Febrianti, N., Filiana, F and Hasana P. (2020). Potensi Sumber Energi Terbarukan dari Biomassa yang Berasal dari Sumber Daya Alam di Balikpapan, *Jurnal Presipitasi*, 17(3): 316-323).

Handoko, R., Fadelan., and Malyadi, M. (2019). Analisa Kalor Bakar Briket, Berbahan Arang Kayu Jati, Kayu Asam, Kayu Johar, Tempurung Kelapa, dan Campuran, *Jurnal Ilmiah Mahasiswa Komputek*, *3*(1), 14-21.

Haryanto, A., Hidayat, W., Hasanudin, U., Iryani, D.A., Kim, S., Lee, S., Yoo, J. (2021). Valorization of Indonesian Wood Wastes through Pyrolysis: A Review. *Energies 2021*, 14, 1407.

Jain, H., Vijayalakshmi, Y and Neeraja, T. (2018). Preparation of Biobriquettes Using Biomass Combinations and Estimation of its Caloric Value, *International Journal of Sciences and Research (IJSR)*, 4(3): 322-324.

Kasman, Sudirman, I and Ulum, M.S. (2021). Karakterisasi Sifat Fisik Biobriket Campuran Batubara Buol., Arang Tempurung Kelapa dan Tongkol Jagung, *Jurnal Gravitasi*, 15(1): 1-9.

Kaulan, (2010). Proses Pengolahan dan Kontrol Proses Pengolahan Tepung Terigu Spesial, https://digilib.uns.ac.id/dokumen/download/15110/MzAwMDk=/Laporan-magang-di-PT-Indofood-Sukses-Makmur-Bogasari-flour-mills, accessed on July 31, 2021 at 21.30.

Kumar, G.S., Rao, C.J and Madhavi,S.K. (2016). Evaluation of Caloric Value of Bio-Briquette, *International Journal of Research in Engineering and Technology, 5*(9), 123-128.

Mandey, L.C., and Tarore, D. (2015). Pengembangan Produksi Biobriket dari Limbah Hasil Pertanian Sebagai Bahan Bakar Pengganti Minyak Tanah dan Gas, *Jurnal Ilmu dan Teknologi Pakan*, 3(2): 1-7.

Muhlis, A.M., Sahara and Fuadi, N. (2019). Uji Kualitas Biobriket Campuran Tempurung Kelapa, Tongkol Jagung dan Sekam Padi dengan Tepung Sagu sebagai Perekat, JFT, 6(1): 16–25.

Ningsih, E., Mirzayanti, Y.W., Himawan, H.S and Indriani, H.M. (2016). Pengaruh Jenis Perekat pada briket dari kulit Bintaro Terhadap Waktu Bakar, *Prosidising Seminar Nasional Teknik Kimia "Kejuangan"*, ISSN 1693-4393.

Nuhardin, I. (2018). Kualitas Limbah Serbuk Gergaji untuk Arang yang Diperoleh dengan Metode Pirolisi Lambat, Jurnal Tek. Mesin Univ. *Muhammadiyah Metro*, 2(2):166-173.

Parinduri, L and Parinduri, T. (2020). Konversi Biomassa Sebagai Sumber Energi Terbarukan, *Journal of Electrial Technology*, 5(2): 88-92.

Putri, R. E and Andasuryani. (2017). Studi mutu briket arang baku limbah biomassa, *Jurnal teknologi pertanian andalas, 21*(2): 143-151.

Qistina, I., Sukandar, D and Trilaksono. (2016). Kajian Kualitas Briket Biomassa dari Sekam Padi dan Tempurung Kelapa, *Jurnal Kimia Valensi*, 2: 136–142.

Rahmadani., Faizah, H., Farida, H, and Hamzah. (2017). Pembuatan Briket Arang Daun Kelapa Sawit (Elaeis guineensis Jacq.) Dengan Perekat Pati Sagu (Metroxylon sago Rott.), *Jom Faperta*, 4(1): 1-11.

Ristianingsih, Y., Ulfa, A and Syafitri, R.KS. (2017). Pengaruh suhu dan konsentrasi perekat terhadap karakteristik briket bioarang berbahan baku tandan kosong kelapa sawit dengan proses pirolisis, *Jurnal konversi*, 4(2): 16-22.

Salim Rais. (2016). Karakteristik dan Mutu Arang Kayu jati (Tectona grandis) dengan Sistem Pengarangan Campuran pada Metode Tungku Drum, *Jurnal Riset Industri Hasil Hutan*, 8(2):53-64.

Suharyati., Sadmoko, H.P., Jamaluddin, L.W and Nurian, I.P. (2019). Outlook Energi Indonesia, Sekretariat Jendral Dewan Energi Nasional, ISSN: 2527 3000.

Sulistyaningkarti, L and Utami, B. (2017). Pembuatan Briket Arang dari Limbah Organik Tongkol Jagung dengan Menggunakan Variasi Jenis dan Persentase Perekat, *Jurnal Kimia dan Pendidikan Kimia, 2*(1): 43-53.

Triantoro, A., Mustofa,A. and Daniah, M.H. (2020). Studi Karakteristik dan Kualitas Biobriket Campuran Bottom Ash Batubara dengan Arang Tempurung Kelapa, *GEOSAPTA, 6*(1): 13–17.

Usman, N.M. (2020). Mutu Briket Arang Kulit Buah Kakao Dengan Menggunakan Kanji Sebagai Perekat, *Jurnal Perennial*, 3(2): 55-58.

Western Cape Milling. (2021). Industrial Flour, http://wcmilling.co.za/product/industrial-flour/, accessed on August 01, 2021 at 17.00.

Yudanto and Kusumaningrum. (2017). Pembuatan Briket Bioarang dari Arang Serbuk Gergaji Kayu Jati, Repisotory Jurusan Teknik Kimia, Fakultas Teknik, Universitas Dipanegoro.