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Analysis of differences in the characteristics of bio-pellets based on coconut coir, rice husk, and sawdust waste

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Abstract

The increasing energy needs must be balanced with the availability of the right energy, namely by efforts to use new and renewable energy sources (NRE). Bio-pellets are a renewable alternative energy source with great potential in Indonesia. This study made bio-pellets into two compositions with the raw materials used: coconut coir waste, rice husks, and sawdust. The composition of bio-pellet A was made in a ratio of 1:1:1, and the composition of bio-pellet B was made in a ratio of 1:0,5:0,5. This study aimed to determine whether there is a significant difference between the two bio-pellet compositions' calorific value and the raw materials' composition that can produce the best quality bio-pellet. The method used in this study is the hypothesis test of the difference between the two averages. The hypothesis test results indicated a significant difference between bio-pellet composition A's average calorific value and B. Thus, the difference in the ratio of the raw materials composition influences the calorific value of the resulting bio-pellet. The test results showed that the bio-pellets with the best quality are bio-pellet composition A with a density value of 1.51 g/cm3, water content of 9.9%, ash content of 13.65%, a content of volatile matter of 61.625%, fixed carbon content of 14,825%, total Sulphur content of 0.05%, and calorific value of 3458.5 kcal/kg.

Keywords

Bio-pellets, Coconut coir, Rice husk, Sawdust waste

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Introduction

The rapid development and population growth continue to increase, making energy very necessary, especially for industrial, service, transportation, and household activities. Energy use in Indonesia still uses fuel derived from fossil energy such as coal, natural gas, and oil, which means the availability of these fuels will become increasingly scarce. In the 2020 National Energy Balance Review Study Report, it was noted that final energy consumption in 2019 (without biomass) was 132.4 million TOE (Tons of Oil Equivalent) or tons of oil equivalent, consisting of the transportation sector 43.9%, industry 36.6%, household 13.7%, commercial 4.5%, and other sectors 1.2% [1]. Meeting energy needs must be balanced with energy availability in an appropriate, integrated, and sustainable manner to facilitate activities in all energy-using sectors.

One way to improve national energy security long-term is by reducing dependence on non-renewable fossil energy by substituting it with new and renewable energy sources (EBT), especially biofuels (biodiesel, bioethanol, biomass, and biogas). The government has issued various basic policies to increase bioenergy use and encourage the growth of the biofuel industry, including Presidential Decree Number 5 of 2006 concerning National Energy Policy [2]. There is a need for alternative energy as an option to overcome the current energy crisis. Biomass is a renewable alternative energy that has great potential in Indonesia. The potential of this biomass is available in various forms, from plants and agricultural waste to plantation, forest, and livestock waste.

Biomass is a fuel that can be used directly or processed first [3]. Biomass energy produced from organic materials has a minimum carbon footprint compared to fossil fuels, so biomass does not contribute to increasing greenhouse gases [4]. With these advantages, biomass can be a more environmentally friendly alternative fuel. Currently, the utilization of biomass in Indonesia is still very low. Energy needs in Indonesia during 2019 are presented in Figure 1.

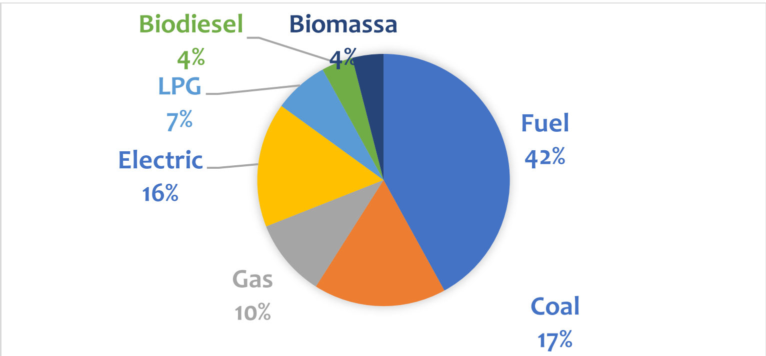

Figure 1. Energy Needs in 2019 [5]

From diagram 1, it can be seen that the most prominent energy demand in Indonesia is BBM (Fuel Oil), amounting to 42% of the total energy demand in 2019, amounting to 989.9 million BOE (Barrel Oil Equivalent), and the second position is coal amounting to 17% while the utilization or the need for biomass is still minimal, namely only around 4% of total energy needs [5]. One form of biomass often found is bio-pellets (wood pellets). Bio-pellets (wood pellets) are a type of solid fuel based on biomass waste with a smaller size and cylindrical shape, as seen in Figure 2 [6].

The raw material for bio-pellets (wood pellets) is very abundant in Indonesia, and much research has been carried out on bio-pellets, including the use of eucalyptus and Gondorukem solid waste with a particle size of 40 mesh and a moulding temperature of 230°C, obtaining a calorific value of 5097.5 kcal/kg [7]. Then, the use of candlenut shell waste with the addition of 10% of the total weight of the mixture of sago bark waste biomass and sawdust obtained test results, namely water content of 9.96%, density of 0.31 g/cm3, the calorific value of 4.182 cal/g, ash content of 11.30% and the volatile matter content is 73.69% [8]. In other research, a mixture of flamboyant sawdust waste (*Delonix regia*) and Trembesi wood (*Samanea saman*) has potential as a raw material for bio-pellets with a calorific value of 4,350.83-4,431.47 cal/g [9].

Figure 2. Wood pellet

Based on the description above, several other materials have the potential to be used as raw materials for making bio-pellets (wood pellets), such as coconut fiber, rice husks, and sawdust. Coconut fiber waste can be used as raw material for making bio-pellets. Coconut plants are one of the largest plantation commodities in Indonesia. Based on national plantation statistical data, it was recorded that coconut production in 2019 reached 2,839,852 tons with a total area of 3.4 million Ha [10]. Coconut fiber is a by-product and is the most significant part of the coconut, which is around 35% of the weight of the coconut [11]. Thus, around 993 thousand tons of coconut fiber waste is produced and not yet utilized.

One of the reasons why coconut fiber waste has not been utilized is that community plantations are still traditional and have not been supported by adequate technological innovation, with industrial capacity still being very small compared to the available potential [10]. This means that by-products from coconuts, such as coconut water, shells, and coconut husks, are not widely used, and most of them just become waste. According to research by Shinta Rismayanani, coconut fiber waste has a relatively high calorific value, 3950 kcal/kg [12]. Therefore, coconut fiber waste has the potential to be used as an ingredient in making alternative fuels such as bio-pellets (wood pellets).

Rice husks are one of the wastes produced by the agricultural industry. So far, rice husks have been left to rot or be burned, which can endanger health and the environment. Rice husks are used only for animal feed, fertilizer, and mushroom media. Research results from the Agricultural Research and Development Agency (Balitbang) show that the calorific value contained in the calorific value of 1 kg of rice husk is 3300 kcal/kg [13]. Seeing the potential of rice husks in producing heat, rice husks can be used as an ingredient in making alternative fuels such as bio-pellets (wood pellets).

Wood sawdust is waste obtained from sawing wood using either machines or manually [14]. Sawdust is only used as a planting medium, while the utilization and handling of waste are still very poor. So, untreated waste can increase the amount of carbon gas, which can damage the earth's atmosphere and, of course, negatively impact the environment. Andri Prawoto's research showed that the calorific value contained in Keruing and Acacia wood powder was 4,318.58-4,594.66 cal/g [15]. With this calorific value, wood powder has the potential to be used as raw material for making bio-pellets (wood pellets).

By looking at the background above, in this research, bio-pellets will be made using materials from coconut fiber waste, rice husks, and sawdust as an alternative fuel. Bio-pellets are made with two different composition ratios, bio-pellet (wood pellets) A with a composition ratio of coconut fiber waste, rice husks and sawdust, namely 1:1:1 and bio-pellet (wood pellets), B with a composition ratio of coconut fiber waste, husks rice, and sawdust, namely 1:0.5:0.5. Next, the characteristics of the two bio-pellets will be tested on a laboratory scale. The characteristics of the bio-pellets produced will be analyzed against the quality standards of bio-pellets (wood pellets) following the applicable SNI (Indonesian National Standards), and a hypothesis test analysis of the difference between the two averages will also be carried out to find out whether there is a natural (significant) difference between the average values. There are two heat of bio-pellets of composition A with composition B. In this research, it is hoped that the author will be able to determine the potential of bio-pellets made from coconut fiber, rice husks, and sawdust to be used as renewable alternative fuels. In this research, two bio-pellet compositions will be tested: bio-pellets (wood pellets) A with a composition ratio of coconut fiber waste, rice husks, and sawdust, namely 1:1:1, and bio-pellets (wood pellets) B with a composition ratio of coconut fiber waste, rice husks, and sawdust, namely 1:0.5:0.5. The composition that provides the best quality will be used as a proposal for making bio-pellets as an alternative fuel.

Based on the previous description, this research aims to find out the results of the analysis of the calorific value of bio-pellets to see the real difference between the two bio-pellet processes made by conducting a hypothesis test of the difference between the two averages and to find out the composition of bio-pellets which can be used as a proposal for alternative fuel.

Methods

Preliminary studies

A preliminary study was carried out to determine the potential of designing the composition of bio-pellets (wood pellets) using coconut fiber waste, rice husks, and sawdust as raw materials in determining the characteristics of the bio-pellets (wood pellets) and the process of making bio-pellets (wood pellets) with a comparison of the composition of the raw materials used differently.

Object of research

The object of this research is the characteristics of bio-pellets (wood pellets) produced from two different comparisons of raw material composition. Bio-pellet (wood pellets) A with a composition ratio of coconut fiber waste, rice husks, and sawdust, namely 1:1:1, and bio-pellet (wood pellets) B with a composition ratio of coconut fiber waste, rice husks, and sawdust, namely 1:0, 5:0.5. The characteristics of bio-pellets (wood pellets) are obtained from laboratory test results which include several test parameters such as water content, ash content, volatile matter content, fixed carbon content, total sulphur content, density, and heating value. From the results of the calorific value of the object, a hypothesis test will be carried out, namely a test to find out whether there is a real difference in the value of the two bio-pellet compositions on the calorific value of the bio-pellet produced.

Data source

The data sources that will be used for processing and analysis consist of:

1. Data on the composition of the raw materials for the bio-pellets (wood pellets) made.
2. Process of making bio-pellets (wood pellets).
3. The quality requirements for bio-pellets (wood pellets) using SNI 8951:2020
4. Laboratory test results on two bio-pellet (wood pellet) processes using different raw material composition ratios.

Wood pellet-making process

Wood pellets in this research used materials such as rice husk waste, young coconut fiber, and sawdust. The process of making wood pellets consists of several stages, illustrated in Figure 3.

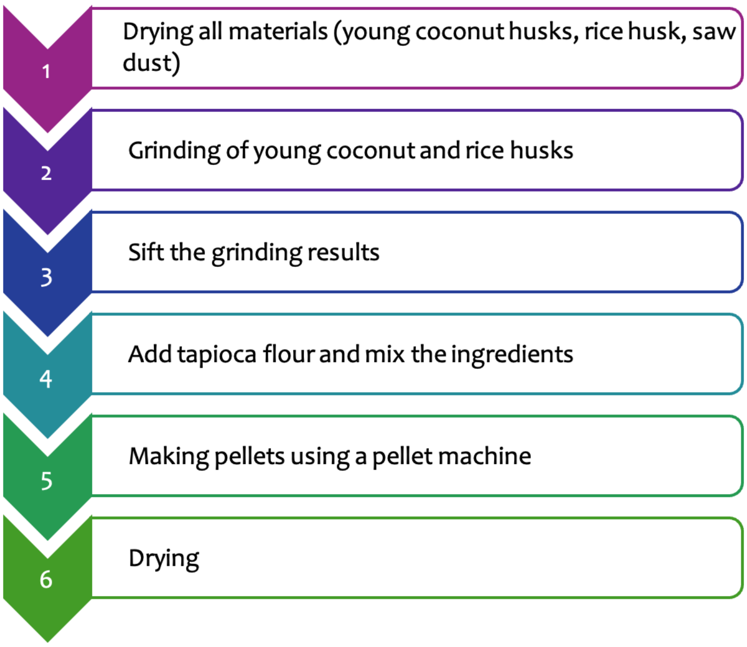

Figure 3. Wood Pellet making process

Bio pellet standard specifications

Quantitative testing of bio-pellet characteristics was carried out by referring to the standard, SNI 8951:2020, concerning Biomass Pellets for power plants presented in Table 1. Bio-pellet characteristics (wood pellets) were tested at the Testing and Analysis Laboratory of PT Sucofindo Bekasi-West Java.

Table 1. Bio pellet Requirements According to SNI 8951:2020

Parameter	Unit	Requirements
Density	g/cm3	Min. 0,5
Water content	%	Max.10
Ash content	%	Max. 3
Volatile matter	%	Max. 71
Fix Carbon	%	Min. 16
Total sulfur	%	Max. 0,05
Caloric valur	kcal/kg	Min. 4300

Data analysis

The characteristics of bio-pellets obtained from laboratory test results are the results of tests for water content, ash content, density, volatile matter content, fixed carbon content, and heating value. The calorific value of the two bio-pellet samples will be analyzed and data processed using hypothesis testing, namely the two variance tests and the difference between two average tests to prove whether or not there is a significant difference between the average calorific value of bio-pellet pellet composition A and composition B. The two bio pellet processes are independent samples, and the two processes' variance is unknown. Then, because in this study, the number of samples was n = 4, a two-average hypothesis test analysis was used for small samples (n ≤ 30), namely the t-test. Before carrying out a difference test between two means, a test of two variances is first carried out on the characteristics of the two bio-pellets.

1. Two variants test

The two-variance test was conducted to determine whether the two bio-pellet processes had the same variance. The procedure in testing two variances can use the equation in testing two variances with the following steps [16]:

a. Statement of the null hypothesis and alternative hypothesis. In this study, the hypothesis test used was a two-sided test with an explanation of the research hypothesis as follows:

$$H_0 : \sigma_1^2 = \sigma_2^2$$

$$H_a : \sigma_1^2 \neq \sigma_2^2$$

b. Selecting the level of importance (level of significance) α = 0.5.
c. Determination of the test distribution used. In these two variance tests, the F distribution is used with the F table values being Fα, df1, df2.
d. Defining rejection or critical areas.
e. The decision rule statement is the calculation of the test ratio (RU) using the F Test in the Two Variant Test with equation 1:

$$RU_F = F_{test} = \frac{s_1^2}{s_2^2} \quad (1)$$

f. Statistical decision making. If the test ratio value is in the acceptance area, then the null hypothesis is accepted, whereas if it is in the rejection area, the null hypothesis is rejected.

2. Testing the hypothesis of the difference between two averages

After carrying out the two variant tests, the results will be obtained whether or not the two characteristic variants of the two wood pellet processes have the same variant. Then, the hypothesis of the difference between the two averages is tested. Hypothesis testing about the difference between two average parameters aims to study the difference in the average of a criterion variable from two groups or which can be classified into two groups. If the results of the test for two variants (F test) state that the two variants are the same, then the formula for the hypothesis test equation of two means (same variance) can be used with the following data processing steps [16]:

a. Determination of hypothesis formulation.

$$H0 : \mu 1 = \mu 2$$
$$Ha : \mu 1 \neq \mu 2$$

b. Determining the level of significance or α value. The level of significance used is 5% or α = 0.05.
c. Determination of testing criteria/rejection areas. Because the hypothesis used is H0 : μ1 = μ2 and Ha : μ1 ≠ μ2, then for the rejection area H0 is accepted if -tα/2 ≤ t0 ≤ tα/2 and H0 is rejected if t0 > tα/2 or t0 < - tα/ 2.
d. The t0 statistical test (equal variance) uses equation 2:

$$t_0 = \frac{(\underline{x}_1 - \underline{x}_2) - \mu_0}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad (1)$$

With the value S_p^2 using equation 3:

$$S_p^2 = \frac{(n_1 - 1)\, S_1^2 + (n_2 - 1)\, S_2^2}{n_1 + n_2 - 2} \qquad (2)$$

e. The test conclusion is acceptance or rejection. If H0 is accepted, then Ha is rejected, and vice versa

Results and Discussion

Wood pellet characteristics test results

Bio pellet characteristics testing is intended to test the characteristics contained in the bio-pellet that has been made. This test is carried out on a laboratory scale with the parameters tested: water content, ash content, volatile matter content, fixed carbon content, total Sulphur content, density test, and heating value. Four samples tested each bio-pellet composition for each parameter tested. The results of the bio-pellet characteristics test for processes A and B are shown in Table 2.

Compared with SNI 8951: 2020, the average value of bio-pellet A water content is included in the SNI value. High water content in bio-pellets can reduce their calorific value and combustion efficiency, complicating the ignition process during combustion and making combustion less efficient [17]. This water content can be caused by several factors, such as the drying process of raw materials, which is less than optimal, the addition of water when mixing the materials, and the process of moulding bio-pellet, which is still manual.

Table 2. Wood Pellet Characteristics Test Results

No	Parameter	Unit	Composition A		Composition B	
			Mean	Std Dev	Mean	Std Dev
1	Water content	%	9,9	0,158	10,05	0,15
2	Ash content	%	13,65	0,05	12,75	0,09
3	Volatile matter	%	61,63	0,11	61,18	0,55
4	Fix Carbon	%	14,83	0,11	16,03	0,46
5	Total Sulfur	%	0,05	0,00	0,07	0,01
6	Density	g/cm3	1,51	0,00	1,50	0.01
7	Caloric value	Kkal/kg, ar	3459	28,03	3228	56,49

Ash content is a residual material from the combustion process that does not have carbon elements or calorific value. Compared with SNI 8951: 2020, both bio-pellet compositions have ash content values that exceed SNI standards. The high ash content in bio-pellets will reduce their quality. This ash content can cause the heat produced to be lower due to the buildup of unburned ash [17]. The ash produced depends on the type of bio-pellet material used and its composition. One is silica, where rice husks contain pretty high levels of silica, namely 16.98% [13]—adding rice husks to bio-pellet A influences the ash content produced. The higher the silica content in the bio-pellet material, the more ash will be produced during the combustion process [18].

The average value of volatile matter content in bio-pellet compositions A and B is smaller than SNI 8951: 2020, so both bio pellet compositions meet SNI standards. The content of organic and inorganic substances in each raw material causes the differences in the volatile substances in each bio-pellet. When heated, organic and inorganic substances are released from the material as volatile components [6]. The high levels of these volatile substances provide advantages and disadvantages for bio-pellet. The advantage of a high volatile matter content is that ignition and combustion are more accessible, but on the other hand, a high volatile matter content has the disadvantage of a low fixed carbon content and produces smoke that ignites more [19]. The content of volatile substances in the fuel determines the combustion time, combustion rate, and the amount of smoke produced during combustion. The higher the content of volatile substances, the less efficiently the material burns and the more smoke is produced [20].

Only wood pellet B meets SNI 8951: 2020 for the average value of fixed carbon content. Testing for fixed carbon content aims to show the amount of solid material that can burn after volatile substances have been removed from the material. The fixed carbon content value results from reducing the total weight (100%) with the content of water, ash, and volatile substances [21]. So, when determining carbon content, water, ash, and volatile matter content must be considered. Carbon content remains one of the fuel quality parameters that can influence the size of the calorific value. The higher the fixed carbon content in a wood pellet, the higher the calorific value, so the quality of the wood pellet is better [17].

The Sulphur content test aims to determine the amount of Sulphur gas emissions produced during the wood pellet combustion process. During the combustion process, SOx gas emissions can be produced from the Sulphur content contained in the material and can irritate the respiratory tract [22]. Wood pellets naturally contain deficient levels of Sulphur. However, it can be higher due to additional materials such as adhesives [23]. From the test results, wood pellet composition A meets SNI 8951: 2020.

The density test results show that bio-pellet compositions A and B meet SNI 8951: 2020. The higher the adhesive concentration, the stronger the binding force between the particles, so the bio-pellet's density will be higher, and the voids between the particles will be smaller. Apart from that, the material's specific gravity can affect the bio-pellet's density value [20]. The specific gravity of a material is influenced by its particle size, where the coarser or larger the particle size of the material, the smaller the specific gravity, resulting in a smaller density [24].

Testing the calorific value resulted in bio-pellet compositions A and B not meeting SNI 8951: 2020. The low calorific value of the two bio-pellets can be caused by several factors, such as the water content, which is still relatively high, where the higher the water content, the lower the heat produced. The calorific value is also influenced by the fixed carbon content, the value of which is directly proportional to the calorific value produced. Ash content that is too high also affects the calorific value of bio-pellet. This is because many of the minerals in bio-pellets are still left behind and cannot be burned completely [25], causing the resulting calorific value to remain low.

Two variant hypothesis testing

A two-variant hypothesis test was carried out on the results of the calorific values of the two wood pellet compositions to compare the variances of the two populations and whether there was a difference between the two population variances or not. With a value of α = 5%, df1 = 3 and df2 = 3, the values obtained are F0.025;3;3 = 15.44, and F0.95;3;3 = 0.065. Testing the two variance hypotheses using Formula 1 obtained a F_{test} value = 4.06. The critical area in the two-variant hypothesis test is to reject H0 if the F_{test} > 15.44 and the F_{test} < 0.065. Thus, H0 is accepted, which means that there is no significant difference in the variability of the calorific value results of the two wood pellet processes ($H_0 : \sigma_1^2 \ = \ \sigma_2^2$).

Testing the hypothesis of the difference in two means

Hypothesis testing of the difference between the two means was carried out to determine whether or not there was a significant difference between the average calorific value of bio-pellet composition A and B. With α = 5% and df = 6, the value "t" _" 0.025;6" = 2.447 was obtained. By using formula 2, the value "t" _"0" " = 7.3178" is obtained. The critical area in the two-average hypothesis test is that H0 is accepted if -2.447 ≤ to ≤ 2.447. Thus H0 : µ1 = µ2 is rejected. This shows a significant difference between the average calorific value of bio-pellet compositions A and B. So, the difference in the composition ratio of the raw materials used (coconut fiber waste, rice husks, and sawdust) influences the calorific value of bio-pellets (Wood Pellets) generated.

From the results of the hypothesis test of the difference between the two averages, there is a significant difference between the average calorific value of bio-pellet composition A and B. This is indicated by the calorific value of composition A being more significant than the calorific value of composition B. Even though the calorific value of composition A is more excellent, it will, but the calorific value of composition A is still not following SNI 8951:2020. The heating value is influenced by high levels of fixed carbon and low levels of water, ash, and volatile substances [26].

The reasonably high-water content in the composition of A bio-pellet can be influenced by the drying process of the material, which is still less than optimal. As is known, bio-pellet production in this research is still natural, namely using solar energy for the drying process. This natural drying has several disadvantages: unstable heat due to uncertain weather. This causes the drying process to be less than optimal and results in high water content. Apart from the drying process, the high-water content can be influenced by the manual compression process and the addition of water when dissolving the adhesive during the raw material mixing process.

Another factor that influences the calorific value of composition A is the ash content of composition A, which is still high. High ash content risks the formation of mineral deposits/scales during combustion, which can reduce the calorific value and combustion rate, thereby causing a decrease in the quality of bio-pellets [27]. The lower the ash content, the better the bio-pellets' quality.

Low levels of fixed carbon also affect the heating value. The carbon content value remains directly proportional to the heating value. Bio-pellets with high fixed carbon content tend to have a higher calorific value. The more solid material can be burned, the greater the calorific value produced [26].

Suspendisse From the process of the research about design oximeter based on MySQL and Telegram, there are some results that can be concluded. One of them is the average reading error from all volunteers for BPM and SpO_2 which are 0.85% and 0.89%. For the data transfer, there are only three data that failed to be sent to Telegram because of the disturbance of internet connection. The last result from this research is no anomaly heartbeat and hypoxemia to be found in ten volunteers. All the results show that the designed oximeter is good enough to be used. Hopefully, this research can be one of the foundations to improvise or develop better oximeter system.

Conclusion

The results of the hypothesis test analysis of the difference between the two means show a significant difference between the average calorific value of bio-pellet composition A and B. The difference in the composition ratio of the raw materials (coconut fiber waste, rice husks, and sawdust) influences the calorific value produced by wood pellets. The better composition formulation between compositions A and B, namely that of the seven characteristics of bio-pellet tested on a laboratory scale, still has several characteristics that do not follow SNI 8951:2020. In composition, A bio-pellet, the values for ash content, fixed carbon content, and heating value are still not following SNI, while for composition B, the values that are not following SNI 8951:2020 are the values for water content, ash content, total Sulphur content and heating value. Composition B has more characteristics that do not meet the wood pellet standard, namely SNI 8951:2020. Judging from the calorific value of composition A (3458.5 kcal/kg), it is greater than the calorific value of composition B (3227.8 kcal/kg). Based on these results, it can be obtained that the bio pellet formula for composition A is better than composition B with a composition ratio of coconut fiber waste, rice husks, and sawdust, namely 1:1:1.

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