JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 8 No. 2 May 2026

DOI :https://doi.org/10.36378/juatika.v8i2.5187
eissn 2656-1727
pissn 2684-785X
pages : 421 – 428

RESEARCH ARTICLE **Open Access**

Contribution Biopellets as Energy New Renewable from Stalks, Bunches, Waste, Fresh Fruit Bunches, and Shells Coconut (*Cocos nucifera*)

Brefty Meysi Afrilia F[1], Ingrid Ovie Yosephine[1,*], Giyanto[1]

Abstract

Indonesia is the world's largest producer of coconut palm oil, with a total production of 46,986,128 tons in 2023, cultivated over 16,833,985 hectares. This research aims to utilize waste from harvesting fresh fruit bunches (FFB) of coconut palm oil—specifically, bunch stalks and coconut shells—as raw materials for the manufacture of biopellets. Additionally, the study evaluates the influence of varying compositions on the quality characteristics of biopellets, including calorific value, moisture content, ash content, density, and combustion rate. The research employed an experimental method using a Completely Randomized Design (CRD) with a non-factorial arrangement. The treatments consisted of five composition levels of fresh fruit bunches to coconut shell ratios: 100% FFB: 0% shell (K1), 75%: 25% (K2), 50%: 50% (K3), 25%: 75% (K4), and 0%: 100% (K5). Each treatment was replicated three times. The study stages included raw material preparation, chopping, drying of TBS stalks, milling to a particle size of 30 mesh (<0.6 mm), mixing with coconut shell using an adhesive made from gaplek/tapioca flour, pelletizing, drying in an oven at 80°C for 1 hour, and subsequent quality testing according to research parameters. Results indicate that the proportion of coconut shell significantly affects the biopellet characteristics. The highest calorific value was observed in treatment K5 (100% shell) at 3,924.24 cal/g, while the lowest was in K1 (100% FFB) at 3,226.64 cal/g. All treatments met the SNI 8675:2018 standard for moisture content, with the lowest at 5.47% in K5 and the highest at 6.60% in K2. However, ash content across all treatments did not meet the SNI standard, ranging from 22.80% to 36.13%. Biopellet density met the standard, averaging 0.73 g/cm³, and the combustion rate also complied with the standard, averaging 0.00096 g/second. In conclusion, substituting coconut shell for fresh fruit bunch stalks increases the calorific value and improves several quality parameters of biopellets, with the best results observed in treatment K5 for calorific value and moisture content.

Keywords: Biomass, Calorific Value, Coconut Palm Oil, Influence of Composition of Raw Materials, Environmentally Friendly Fuel

1. Introduction

According to BPS (2024), Indonesia is the world's largest palm oil producer, with total palm oil production of 46,986,128 tons in 2023 and a total area of 16,833,985 hectares. However, processing byproducts, such as waste fruit bunch stalks (FFB), remains suboptimal and often ends up as environmental waste. At the Bandar Klippa Plantation of PTPN IV alone, the potential for FFB stalk waste reaches 218,778 tons per year, which has not been economically utilized. Utilizing this waste to produce biopellets (solid biomass fuel) offers a high-value, new, and renewable energy (EBT) solution. FFB stalks have a potential calorific value of 3,500–4,500 cal/g, making them suitable for development as an environmentally friendly alternative energy source.

Biopellets are a new renewable energy source (EBT) in the form of small, solid biomass fuels. with Availability coconut FFB waste palm oil abundant but Not yet utilized maximum, then Accumulation waste dense in the garden area potential cause problem environment, therefore That

*Correspondence: Ingrid_ovie@itsi.ac.id
1) Institut Teknologi Sawit Indonesia - Jl. Williem Iskandar, Kenangan Baru, Kec. Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara 20371, Indonesia

Production material burn congested biomass (biopellets) is not optimal yet side quality characteristics Need energy Still energy dependent fossil so that transition to EBT yet effective Not yet composition the most suitable mix For meet quality parameters biopellets (eg. value heat, content ash, density, rate burning)

The process of making Biopellets can be done in 4 stages: drying raw materials, grinding, molding, and cooling to lower the temperature, producing carbon that can be used to make high-quality Biopellets. This research aims to produce Biopellets from oil palm fruit bunch stalks (FFB). The idea for this research arose from the large amount of solid waste that is not properly utilized, even though it can be a source of new, renewable fuels. (Alamsyah et al., 2025) It is hoped that, using the chosen method and this solid waste, high-quality Biopellets can be produced, given the large volume of solid waste generated. plantation industry in Indonesia that can be utilized effectively (Karlina et al., 2022).

This research is urgently needed to optimize the conversion of fresh fruit bunch (FFB) stalk waste into biopellets by varying the composition of the raw material mixture, thereby developing an efficient renewable energy production process. Unlike previous studies that used different types of biomass mixtures, this study focuses specifically on utilizing waste from coconut palm FFB stalks and coconut shells, with varying compositions.

The research findings are expected to offer practical solutions for managing plantation waste, reducing environmental pollution, and providing a valuable alternative fuel. The primary objective of this study is to utilize waste from fresh fruit bunch (FFB) stalks as a raw material for biopellets, thereby supporting the transition from biomass to alternative energy sources and reducing reliance on fossil fuels.

2. Material and Methods

This research will be conducted at the Bandar Klippa Plantation of PTPN IV for the collection of Raw Materials, the Chemistry and Physics Laboratory of the Indonesian Palm Oil Technology Institute (ITSI) for the biopellet manufacturing process, and for the next process, quality analysis will be carried out at the Integrated Laboratory of the Faculty of Engineering, Gadjah Mada University, located on Jl. Kaliurang Km 4 Sekip Utara, Yogyakarta, Indonesia 55281 (-7.77004224834925, 110.37621159999998). This research will be conducted for 12 months, starting in March 2025 and ending in February 2026.

This research uses an experimental method to determine which composition produces the highest-quality manufacturing results. Biopellets using FFB bunch stalks and coconut shells. The design used was a Non-Factorial Completely Randomized Design (CRD) with 5 treatment levels and 3 replications (Ezward et al., 2025).

Table 1. Design Study

Sample	Material Baku	
	Fresh Fruit Bunch Stalk	Shell coconut
K 1	100%	0%
K 2	75%	25%
K 3	50%	50%
K 4	25%	75%
K 5	0%	100%

2.1. Materials and tools

The ingredients used in the study include, among others, fresh fruit bunch stalks, coconut shells, cassava flour adhesive, and clean water. And other tools: The tools used include grinders/crushers (choppers), digital scales, porcelain cups, desiccators, machetes, pellet machines (meat Mixer), 30 Mesh Sieve, e2k Oxygen Bomb Calorimeter, Furnace, and Oven.

2.2. Stages Study

The process of making biopellets from fresh fruit bunch stalk and shell harvest waste consists of several steps, namely:

2.2.1. Raw Material Preparation

The raw materials used in this study were waste from the FFB harvest stalks obtained from PTPN IV Bandar Klippa Plantation, Sidodadi Village, Batang Kuis District, Deli Serdang Regency, and coconut shells obtained from the MMTC Main Market, Medan. The adhesive used was tapioca flour. Preparation of raw materials began with cleaning the FFB harvest stalk waste, chopping it into smaller pieces, and then drying it. Small-scale drying of FFB stalks using solar heat for 2-3 days aims to produce air-dried FFB stalks. The next stage is milling.

2.2.2. Milling

The dried FFB stalk waste is then ground using a chopper. Then, it is sieved through a 30-mesh sieve, with particles <0.6 mm used as raw material for biopellet production.

2.2.3. Biopellet Printing

Before printing Biopellets, the waste powder from TBS stalks, coconut shells, and tapioca flour adhesive is stirred to mix, depending on the sample being made. After mixing, the mixture will be printed on a pellet-printing machine (Meat Mixer).

2.2.4. Biopellet Drying

After the Biopellet is successfully printed, it is dried to harden it and reduce its water content. reduced. Biopellets are dried in an oven at 80°C for 1 hour. For reaching the maximum water content according to SNI 8021:2014, namely 12%.

2.2.5. Quality Testing

The processed biopellets will be tested for quality. Some of the parameters tested include ash content, moisture content, calorific value, density, and combustion rate.

2.3. Observation Parameters

2.3.1. Water content

Water content is an important factor that can affect the quality of Biopellet. The lower the water content, the higher the calorific value, resulting in pellets that burn easily. The method used to test the water content is to weigh the sample (M1), then dry it in an oven at 105°C for 1 hour, and reweigh the Biopellet sample after drying (M2). According to Wahyullah et al. (2018), to calculate the weight of the water content, you can use the following formula:

$$\textbf{Moisture (\%)} = \frac{M1-M2}{M1} \times 100\%$$

Information:
M1= Weight of the sample before drying (g)
M2= Weight of sample after drying (g)

2.3.2. Ash Content

Ash content is determined by comparing the heavy ash after burning with the heavy starting sample. The more low-level ash is contained, the better the quality of the pellets produced; on the contrary, if more tall-level ash is contained, the quality of the pellets decreases. For the ash Biopellets determination, steps taken: place the porcelain oven cup in the oven for 1 hour at 105°C, then remove it and cool the cup in the desiccator. After that, weigh the cup empty. Take a sample of biopellets. Then insert into the oven for 2 hours at 600°C to burn off all the carbon. The cup was cooled in the desiccator and weighed. According to Rozi et al. (2023), levels of ash can be counted with the formula as follows:

$$\textbf{Ash Content} = \frac{A}{B} \times 100\%$$

Information:
A= Ash weight (g)
B= Sample weight (g)

2.3.3. Calorific Value

According to Mustamu & Pattiruhu (2018), value heat is the amount of heat produced by combustion from several combustion units. Testing is done. For now, how many marks of heat are contained in Biopellets ? Each variation of composition: the higher the mark heat, the better the quality of Biopellets produced. The size mark of a material can be counted with the use of equality as follows (Pertiwi, 2024) :

$$\textbf{Calorific Value (kcal /kg)} = \frac{\Delta t \times W}{mbb} - B$$

Information:
Δt = Average temperature difference (°C)
W = Water calorimeter value (cal/°C)
Mbb = Mass of fuel (g)
B = Heat correction on iron wire (cal/g)

2.3.4. Density

According to Mustamu & Pattiruhu (2018), density is determined by comparing the mass and volume of pellets measured under the same conditions. Testing is conducted to determine pellet density and achieve a sufficient density in each composition variation. According to Wahyullah et al. (2018), density can be calculated using the formula:

$$\textbf{Density} \; (p) = \frac{m\,(g)}{v\,(cm^3)}$$

Information:
M= Mass of test sample (g)
V= Volume of test sample (cm^3)

2.3.5. Burning Rate

Burning rate testing involves burning pellets to determine a fuel's burning time, then weighing the burned pellets. The ignition time is measured using a stopwatch, and the pellet mass is measured using a digital scale. The following formula for conducting a burning rate test is used (Rozi et al., 2023) :

$$\textbf{Rate Combustion} = \frac{m}{t} \textbf{(grams/minute)}$$

Information:
m =Biopellet mass burned
t =Burning Time

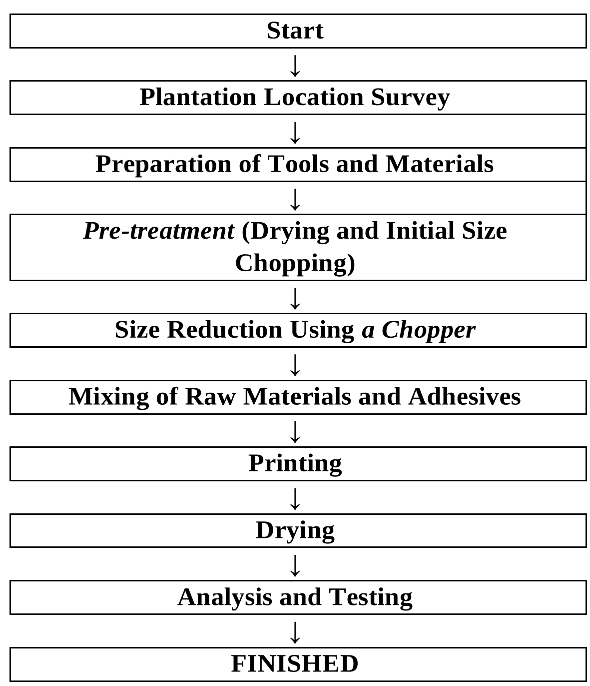

Figure 1. Research flow diagram

3. Results and Discussion

3.1. Biopellet Characteristics Test Results

After the biopellet manufacturing process is complete, a series of laboratory tests is conducted to assess the characteristics of each biopellet. The main test performed is the test mark heat, an important indicator of biopellet energy efficiency. Besides, some testing additions for known parameters, such as water content, ash content, density, and combustion rate. All of these parameters are carefully analyzed to provide a comprehensive picture of the biopellet quality produced from each composition. The following is the result of the quality test of biopellets from waste from harvesting fresh fruit bunches of oil palm and coconut shells.

Table 2 Average Results of Biopellet Characteristic Test

Treatment	Parameter				
	Calorific Value (cal /g)	**Water content (%)**	**Ash Content (%)**	**Density (*Density)*) (g/cm3)**	**Rate Burning**
K1	3,226.64	3.53	36.13	0.64	0.0010
K2	3,435.08	6.60	30.37	0.80	0,0009
K3	3.601,55	5,67	26,37	0,83	0,0011
K4	3.759,91	5,63	24,23	0,67	0,0012
K5	3.924,24	5,47	22,80	0,73	0,0006

The table above presents the results of the analysis of the five main parameters used to evaluate the quality of biopellets made from fresh coconut fruit bunch waste. palm oil and coconut shell from five different treatments, that is, K1, K2, K3, K4, and K5. On calorific value parameters, treatment K5 showed the highest value of 3,924.24 Cal/g. This is taller than treatment K4, which produced 3,759.91 Cal/g, and treatment K1, which had the lowest calorific value of 3,226.64 Cal/g. Furthermore, in the water content parameter, the highest value was observed in treatment K2 at 6.60%, whereas the lowest was recorded in treatment K5 at 5.47%.

For parameter-level ash, mark the highest value in K1 at 36.13%, followed by K2 at 30.37%, and the lowest in K5 at 22.80%. Meanwhile, in the density parameter, the K3 treatment had the highest value at 0.83%, followed by the K2 treatment at 0.80%, and the lowest was in the K1 treatment at 0.64%.

For the final parameter, namely the combustion rate, the highest value was observed in the K4 treatment at 0.0012%. The K3 treatment was below it at 0.0011%, while the lowest value was recorded in the K5 treatment at 0.0006%.

3.2. The Effect of Raw Material Composition on Calorific Value

Calorific value is a key parameter for assessing the quality of biopellets. Measuring calorific value aims to determine a fuel's heat of combustion. Calorific value is the energy or heat contained in a material, expressed in units of heat energy per unit mass, and released when the material is burned. It greatly affects the quality of the biopellets produced. The higher a fuel's calorific value, the better its quality. The high and low calorific values produced are influenced by several factors, including the content of the raw materials used and the water and ash contents. The results of the calorific value test are shown in Table 3.

Table 3. Results of the Calorific Value of Biopellets from Stalks, Bunches, Fresh Fruit Bunches, and Coconut Shells.

Treatment	Raw material	Test	Calorific Value *(Kal/G)*	Average *(Kcal/G)*	SNI *(Kal/G)*
K1	TBS stalk: Coconut shell (100:0)	1	3,205.07	3,226.64	3,900
		2	3,236.36		
		3	3,238.51		
K2	TBS stalk: Coconut shell (75:25)	1	3,432.93	3,435.08	
		2	3.433,41		
		3	3.438,90		
K3	TBS Stalk: Coconut Shell (50:50)	1	3,647.65	3,601.55	
		2	3.562,86		
		3	3,594.15		
K4	TBS Stalk: Coconut Shell (25:75)	1	3.747,49	3,759.91	
		2	3,736.03		
		3	3,796.22		
5	TBS Stalk: Coconut Shell (0:100)	1	3.924,95	3.924,23	
		2	3.934,27		
		3	3.913,49		

Based on the calorific value table above, the calorific values of biopellets across various treatments show that treatment 5 has the highest average calorific value of 3,924.23 cal/g, while treatment 1 has the lowest average calorific value of 3,226.64 cal/g. Thus, among the existing average values, the calorific value that meets the quality standard is 3,924.23 cal/g in treatment 5. And for Treatments K1-K4, the Biopellet Quality Standard for Calorific Value has not been met because it is still below 3,900 Cal/g.

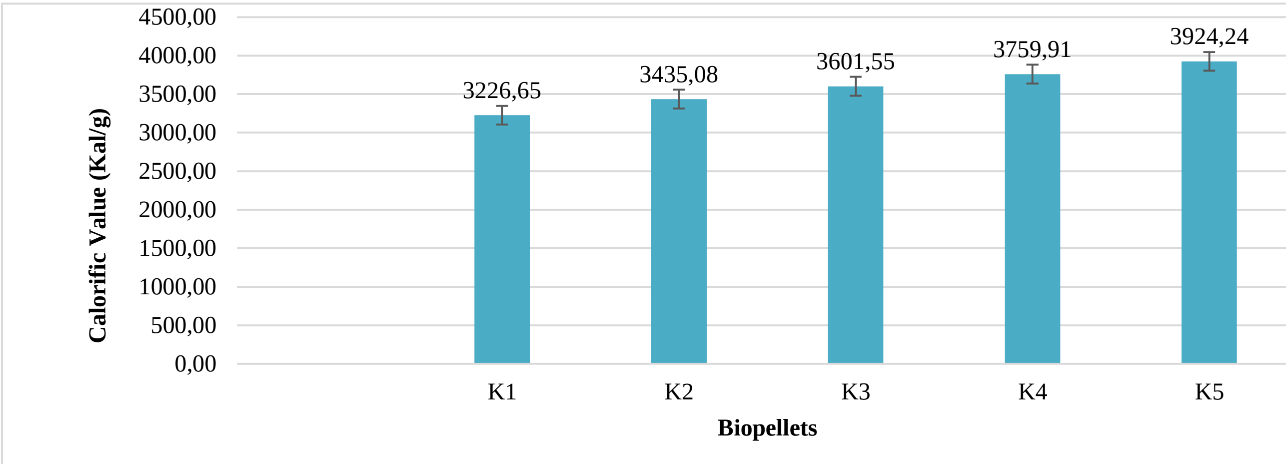

Figure 1. Graph of Average Calorific Value

3.3. Biopellet Water Content

Moisture analysis is a test of the amount of water present in a product. The moisture content of biopellets significantly determines the resulting quality. Moisture content significantly influences the calorific value and the ignition process. biopellets and the amount of smoke produced during combustion. If the resulting moisture content is high, the calorific value of the biopellets will be lower, which affects the biopellet combustion rate because some of the energy stored in the test material is used to evaporate the water. If the moisture content is lower, the calorific value will be higher. Biopellets with high calorific values will burn more slowly. The following is a graph of the average results of biopellet moisture content testing :

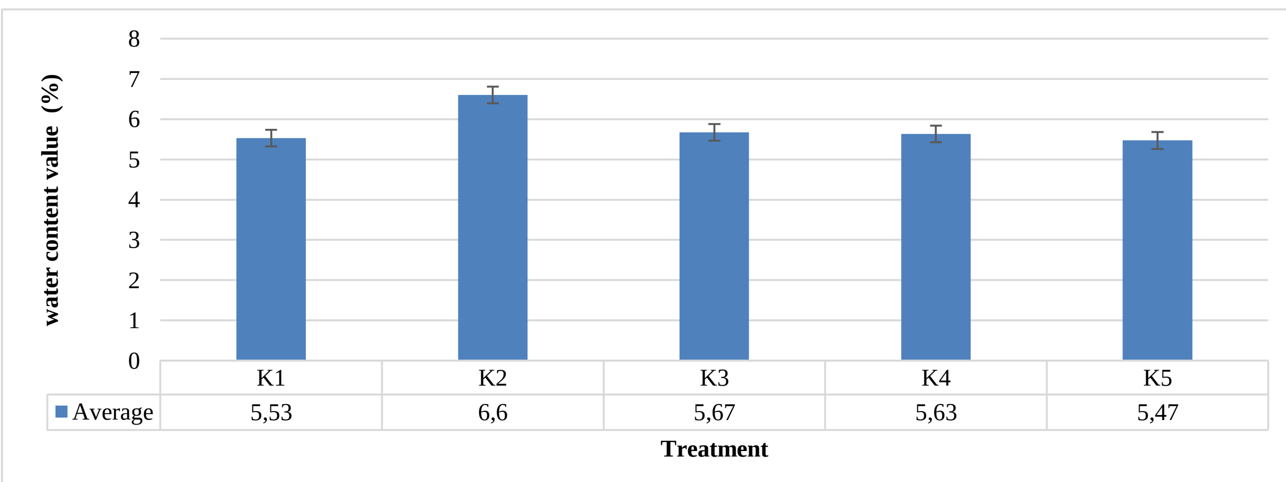

Figure 2. Graph of Average Water Content of Biopellets from Fresh Fruit Bunch Harvest Stalks and Coconut Shells

From the image above, it can be seen that the biopellet with the lowest water content is in the K5 treatment with a value of 5.47% produced from biopellets with a composition of 0:100 using 0% Stalks, Bunches, Harvest Waste, Fresh Fruit Bunches, and 100% Coconut Shells and the highest amount of water content is in the K2 treatment with a value of 6.60% with a raw material composition of 25: 75, namely 25% Stalks, bunches, harvest waste, fresh fruit bunches, and 75% Coconut Shells. The amount of water content remaining in the treated material is influenced by several factors, including the drying time of the raw materials used. Each of the biopellet samples tested for water content analysis above meets SNI BSN 8675:2018, namely, a maximum of 12%.

3.4. The Effect of Raw Material Composition on the Ash Content of Biopellets

Ash content testing determines the amount of material that remains unburned and forms ash. Ash is the inorganic material remaining after biomass combustion. Biopellets with a high ash content will make the ignition process more difficult. biopellets cause deposits or crusts to form during combustion, resulting in the furnace surface becoming dirty and corroded. High ash content in the product reduces the quality of the biopellet. Ash content testing is very important for determining the quality of biomass products, as ashless fuels such as oil or gas have good combustion properties. From the results of the ash content analysis test of the biopellet stalks, bunches, FFB harvest waste, and coconut shells, the average value of biopellets with the lowest ash content was obtained in the K5 treatment with a value of 22.80% with a composition of a mixture of raw materials of 0% stalks, bunches, FFB harvest waste, and 100% coconut shells and the ash content with the highest content was in the K1 treatment with a value of 36.13% with a composition of a mixture of raw materials of 100% stalks, bunches, FFB harvest waste, and 0% coconut shells. The following is a graph of the average results of the ash content analysis test:

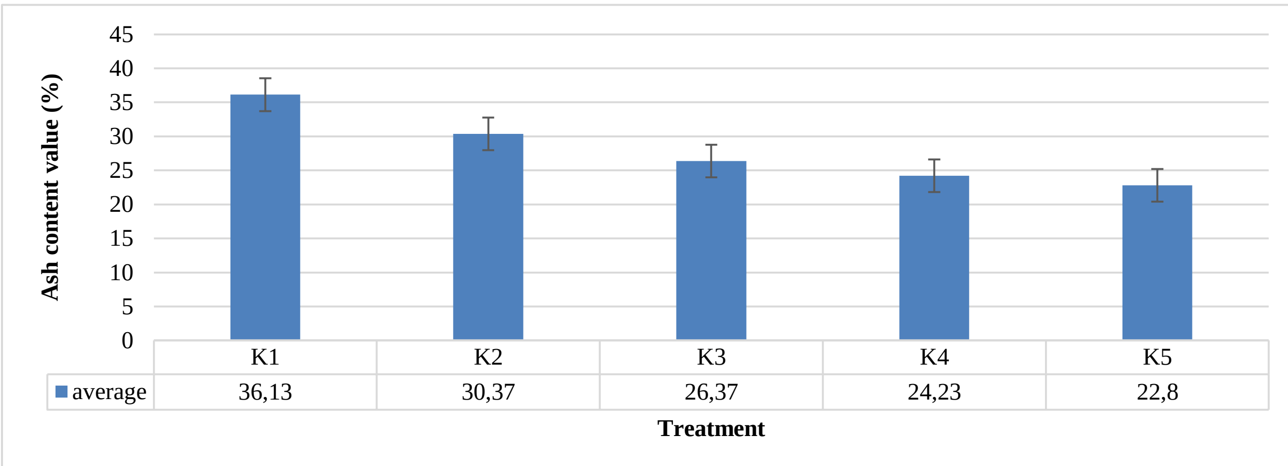

Figure 3. Average Value Graph of A Bu Level Biopellets from Fresh Fruit Bunch Stalks and Coconut Shells

In the data above, the ash content ranges from 22.80% to 36.13%. Based on the quality requirements of BSN 8675:2018, the ash content produced across all treatments does not meet the existing biopellet quality standards in Indonesia. Based on the Indonesian biopellet quality standard, the maximum is 5%. In the ash content test, the ash content is influenced by the raw material composition of the biopellet and the type of biomass used. The ash content of the stalks in the FFB harvest waste bunches is higher than that of the coconut shells, so the greater the number of stalks in the composition used, the higher the ash content produced, and vice versa.

3.5. The Effect of Raw Material Composition on Biopellet Density

Density is one of the characteristics or standards used in biopellet production . The higher the density, the stronger the biopellet, and the longer the burning time. Higher density results in longer burning times, but it can be difficult to ignite.

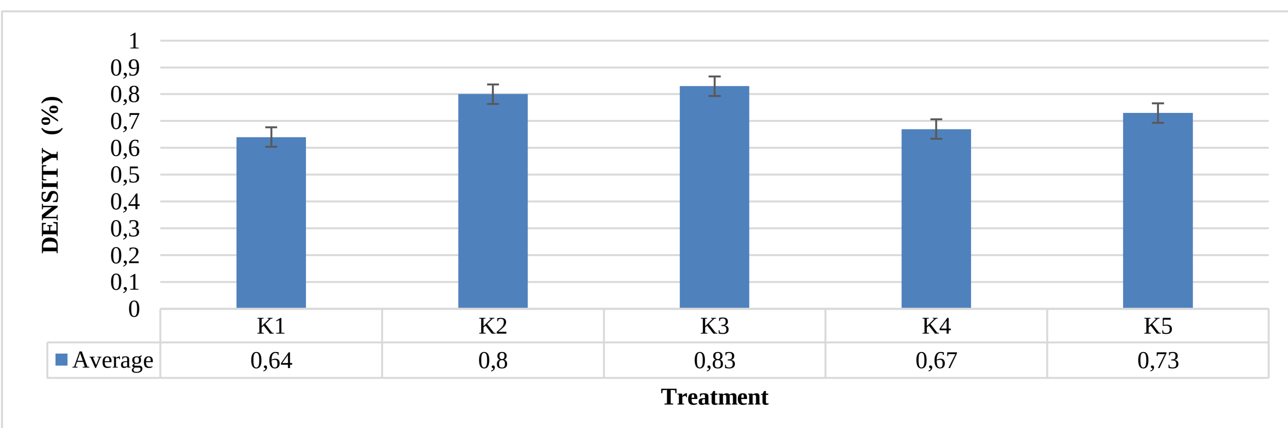

Figure 4. Graph of Average Density Value of Biopellet from Fresh Fruit Bunch Harvest Stalk and Coconut Shell Waste

Based on the table above, it can be seen that the average density value obtained from the K1 treatment is 0.64 grams/cm ^{3}, the K 2 treatment with an average density value of 0.8 grams/cm ^{3} and the K 3 treatment with an average density value of 0.83 grams/cm ^{3}, the K4 treatment with an average density value of 0.67 grams/cm ^{3}, and K5 treatment with average value 0.73 grams/cm^3. Based on the table above, all treatments meet the biopellet standard 8675-2018, namely, no more than 0.8 g/cm^3. Compared with the study by Karlina et al. (2022), which reported a mark density of approximately 0.5 g/cm^3, the biopellets in this study exhibit a higher mark density.

3.6. The Effect of Raw Material Composition on Biopellet Combustion Rate

Testing rate burning is Wrong. One characteristic of a pellet is to look for good quality. Where on testing is this done? On the composition of different sample raw materials to obtain effective results on fuel, Which Is Good. The rate of burning is fast or slow; something biopellets finish becomes ash. Standard rate burning on biopellets, especially Biomass biopellets, does not have a fixed value. Several factors influence the combustion rate. that is composition, material burn, level water, level per e kat, and density on biopellets. The faster the biopellet becomes ash, the faster the burning rate.

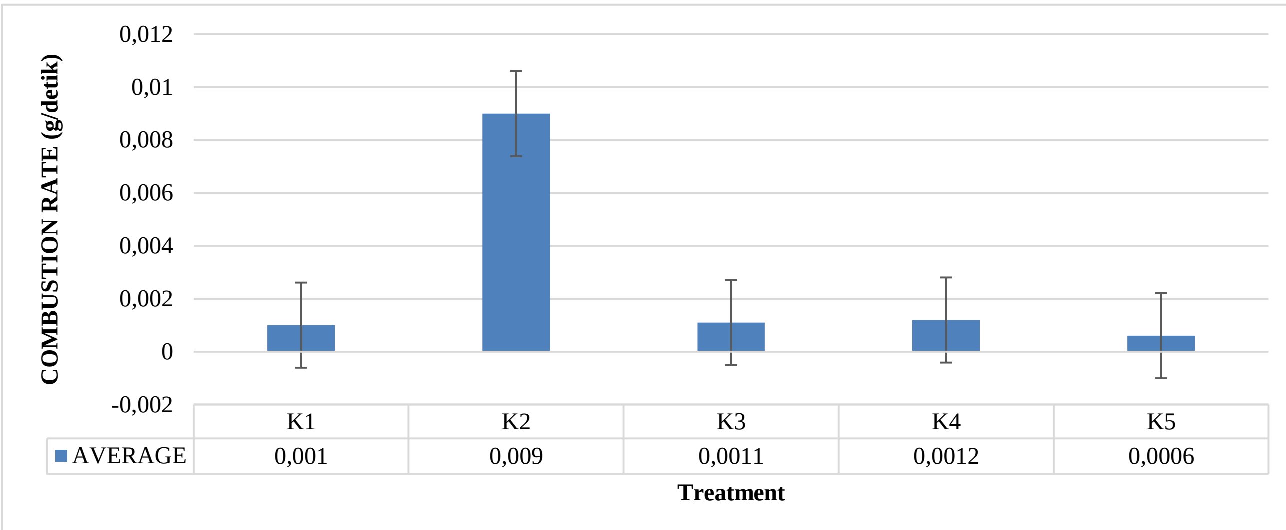

Figure 5 Graph of the Average Burning Rate of Biopellets from Fresh Fruit Bunch Harvest Stalks and Coconut Shells

Based on the table above, the average growth rate was obtained from the K1 treatment. Combustion is 0.001 grams/ second, K2 treatment with an average combustion rate value of 0.009 grams/ second, K3 treatment with an average rate value of 0.0011 grams/ second, K4 treatment with an average rate value of 0.0012 grams/ second, and K5 treatment with an average value 0.0.0006 grams/ second. Based on the table above, all treatments meet the standard biopellet 8675-2018, namely, no more than 0.08-0.15 grams/second.

Figure 6. Rate Burning Biopellets

4. Conclusion

Based on the results of the research conducted, the following conclusions were drawn that the tilization of Waste: Fresh fruit bunch (FFB) stalks from coconut and palm oil, as well as coconut shells, have been proven effective when processed into high-quality biopellets. These biopellets serve as a promising solution for new renewable energy sources. Calorific Value: Substituting with coconut shell significantly increases the heat value of biopellets. The K5 treatment (100% coconut shell) yields the highest heat value of 3,924.24 cal/g, meeting the SNI 8675:2018 quality standard. Superior Physical Quality: All variations of the composite material meet the national standards (SNI) for water content (average 5.78%), density (0.73 g/cm³), and combustion rate (0.00096 g/sec).

References

Alamsyah, F. L., Rizal, K., Mustamu, N. E., Septyani, I. A., & Care, P. (2025). Improving the growth of tomato plants (*Lycopersicum esculentum* L.) by providing ash from empty oil palm fruit bunches. 7(2), 3–7.

Ezward, C., Nopsagiarti, T., Haitami, A., Indrawanis, E., Marlina, G., & Susanto, H. (2025). Analysis of C-organic, nitrogen, and C/N ratio contents in oil palm plantation soil owned by the people of Pulau Binjai Village, Kuantan Mudik District, Kuantan Singingi Regency, Riau Province. 7(3).

Indonesia, B. (2024). *Volume 17, 2024*, 17.

Karlina, D., Fatoni, F. C., Hidayatullah, F., Akil, E., Manggala, A., & Ridwan, K. (2022). Biopelet dari eceng gondok, sekam, dedak, serbuk gergaji, dan tongkol jagung ditinjau dari komposisi terhadap kualitas biopelet. *Jurnal Pendidikan dan Teknologi Indonesia*, 2(2), 583–588. https://doi.org/10.52436/1.jpti.135

Mustamu, S., & Pattiruhu, G. (2018). Pembuatan biopelet dari kayu putih dengan penambahan gondorukem sebagai bahan bakar alternatif. *Jurnal Hutan Pulau-Pulau Kecil*, 2(1), 91–100. https://doi.org/10.30598/jhppk.2018.2.1.91

Pertiwi, I. A. (2024). *Peningkatan nilai kalor bahan bakar pelet dari limbah serbuk gergaji melalui penggunaan asam asetat pada proses torefaksi basah*.

Rozi, M. F., Fathoni, A., Nusantara, P., & Bahri, M. H. (2023). Analisa karakteristik pembakaran biopelet berbahan limbah kelapa muda dengan penambahan variasi zeolit alam. *Journal of Engineering Science and Technology (JESTY)*, 1(3), 120–128.

Wahyullah, O. D. P., & Ismail. (2018). Pemanfaatan biomassa tumbuhan menjadi biopellet sebagai alternatif energi terbarukan. *Hasanuddin Student Journal*, 2(1), 239–247.