

## Effect of Latex Adhesive Variation on the Quality of Torrefied Palm Shell Bio-briquettes

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ARTICLE INFO	ABSTRACT
<p><i>Keywords:</i></p> <p>Bio-briquettes</p> <p>Palm shells</p> <p>Latex adhesive</p> <p>Torrefaction</p> <p>Alternative energy</p>	<p>This study examined the impact of latex adhesive variations on torrefied palm shell bio-briquette quality. Bio-briquettes were produced using palm shell waste with latex adhesive ratios of 9:91%, 13:87%, 16:84%, 20:80%, and 23:77%. The torrefaction process was conducted at 300°C for 30 minutes. The bio-briquette quality parameters analyzed included calorific value, moisture content, ash content, volatile matter, fixed carbon content, and burning rate according to SNI 01-6235-2000 standards. Results showed that the calorific values ranged from 6,076-6,895 cal/gr, exceeding the minimum SNI requirement of 5,000 cal/g. Ash content met standards at 3.15-3.74% (requirement <math>\leq 8\%</math>). However, moisture content (15.32-20.16%), volatile matter (26.05-30.85%), and fixed carbon (45.79-55.47%) did not meet SNI specifications. The burning rate tests yielded 2,892-3,120 seconds. The optimal bio-briquette quality was achieved at a 23:77% latex adhesive:palm kernel shell ratio, demonstrating the highest calorific value and longest burning time. This research indicates that latex-bonded palm shell bio-briquettes show promise as an alternative fuel source, though further optimization is needed to meet all quality standards.</p>

### 1. Introduction

The increasing demand for energy across various sectors of life is driven by economic development in the era of globalization. While this affects not only developed nations but nearly all countries including Indonesia experiencing economic impacts, energy consumption continues to grow. Meanwhile, national energy reserves will continue to diminish unless new energy sources are discovered. Therefore, various preventive measures

are needed to avoid an energy crisis (Setyono & Kiono, 2021).

Briquettes are a form of renewable fuel produced from biomass that has been compacted. This biomass can consist of various types of organic materials, one of which is palm kernel shell (Sudradjat et al., 2006). Palm kernel shell is one of the abundant waste products in Indonesia, derived from the palm oil industry, which has become one of the country's major export commodities. This

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shell contains carbohydrates and cellulose, which can be converted into energy through combustion, making it a renewable and environmentally friendly energy source (Indah et al., 2024).

**Table 1.** Standards for Briquettes (Wicaksono & Nurhatika, 2018)

Parameter	SNI 01-6235-2000 Standard
Calorific value (cal/gr)	≤ 5,000
Moisture content (%)	≤ 8
Ash content (%)	≤ 8
Volatile matter (%)	≤ 15
Fixed carbon (%)	≤ 77

Bio-briquettes are defined as solid fuel that can be developed on a large scale in a relatively short time at low cost. The briquettes are processed from soft materials into hard charcoal with specific shapes using latex as a binder. Adding binder in bio-briquette production can minimize briquette damage and bind particles to reduce pore size (Indah et al., 2024).

**2. Research Method**

This research used palm shells obtained from PT. Bukit Bintang Sawit in Muaro Jambi as the main raw material, with natural latex as the binder.

**2.1. Materials**

The raw material used for the production of biobriquettes was palm kernel shell powder, which was obtained from local palm oil processing facilities in Indonesia and latex adhesive was sourced from local suppliers in Indonesia. The latex was used as a binding agent in different proportions with the palm kernel shell powder.

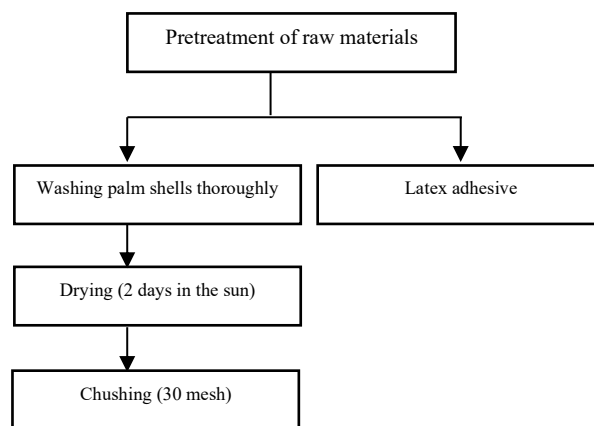
**2.2. Preparation of Palm Kernel Shell Briquettes**

The palm kernel shell obtained from the factory is first washed and dried. Afterward, it is ground and sieved using a 30 mesh size. Meanwhile, latex binder can be used directly without any additional treatment.

**2.3. Bio-briquette Production and Molding Stages**

The process of making the bio-briquette begins with the torrefaction of the ground palm kernel shell in a furnace at 300°C for 30 minutes. Afterward, the

torrefied shell is mixed with a binder according to the predetermined ratio and stirred until homogeneous. The mixture is then placed into a mold and pressed with a force of 3 tons for 30 minutes. The molded briquette is stored at room temperature for a week to ensure stability and rigidity.



**Figure 1.** Pretreatment bio-briquettes diagram

**2.4. Biobriquette Quality Analysis**

The analysis of the briquette quality focused on key parameters including:

**1. Calorific Value**

The energy content per unit weight of the bio-briquette is measured using a bomb calorimeter. Calorific value is determined by weighing a 0.2 g sample, placing it in a platinum crucible, and inserting it into a bomb calorimeter filled with oxygen at 30 bar pressure and 1,250 ml of cooling water. The calorimeter is tightly sealed, a thermometer is installed, and the cooling water stirrer is turned on for 5 minutes. Then, ignition is performed, and the temperature rise is recorded. The calorific value is calculated using the formula:

$$Calorific\ Value = (T_2 - T_1 - 0.05) \times C_v \times 0.24$$

Where:

T<sub>1</sub>: initial water temperature (°C); T<sub>2</sub>: temperature after combustion (°C); C<sub>v</sub>: calorimeter density (73529.6 kJ/kg); 0.05: temperature rise of the ignition wire; 1 Joule: 0.24 cal.

**2. Moisture Content**

The moisture content is determined by oven drying to ensure it is within the acceptable range for

optimal combustion. Moisture content of briquettes is determined by weighing an empty porcelain crucible, then placing the briquette sample into the crucible. The sample is leveled and heated in an oven at 105°C for 3 hours. Afterward, the crucible is cooled in a desiccator and reweighed. The moisture content is calculated using the formula:

$$\text{Moisture content} = \frac{m_1 - m_2}{\text{sample weight}} \times 100\%$$

Where:

$m_1$ : weight of the empty crucible + sample before heating (gr);  $m_2$ : weight of the empty crucible + sample after heating (gr).

### 3. Ash Content

The briquettes are measured by ashing them at 750°C to determine the non-combustible residue. Ash content is determined by drying a porcelain crucible in a furnace at 600°C for 30 minutes, then cooling it in a desiccator and weighing its empty weight. A 1-gram sample is placed into the crucible and heated in a furnace at 850°C for 4 hours until the sample turns into ash. The crucible is then cooled in a desiccator and weighed. The ash determination is repeated twice and calculated using the formula:

$$\text{Ash Content (\%)} = (A/B) \times 100\%$$

Where:

A = weight of ash (gr); B = weight of sample (gr)

### 4. Volatile Matter

Materials are analyzed to assess the proportion that vaporize during combustion. The determination of volatile matter (VM) content in briquettes is carried out by weighing a porcelain crucible, adding 1 gram of the sample, and weighing it again. The sample is heated in a furnace at 750°C-900°C for 7-15 minutes, then cooled in a desiccator for 30 minutes and reweighed. The volatile matter content is calculated using the formula:

$$\text{VM Content (\%)} = ((W1 - W2) / W1) \times 100\%$$

Where:

$W_1$ : initial weight of the sample (gr)

$W_2$ : weight of the sample after heating (gr)

### 5. Fixed Carbon

Determined as the remaining carbon after combustion of the volatile components. The fixed carbon content (FC) is determined using the equation (SNI-06-3730-1995):

$$\begin{aligned} FC + VM + KA + KB &= 100\% \\ FC &= 100\% - (KA + KB + VM) \end{aligned}$$

Where:

FC: Fixed Carbon content (%); KA: Inherent; Moisture content (%); KB: Ash content (%); VM: Volatile Matter content (%).

### 6. Burning rate

This test is conducted by igniting the biobriquette and measuring the time using a stopwatch until the briquette extinguishes (Meldhazet al., 2023). The experimental results were compared to SNI 01-6235-2000 standards for biomass briquettes to determine whether the biobriquettes produced in this study met the quality requirements for effective fuel use.

## 3. Result and Discussion

### 3.1. Raw Material Characterization

The research utilized palm oil shells obtained from PT. Bukit Bintang Sawit (Bukit Baling, Sekerman District, Muaro Jambi Regency) as the primary raw material, with latex serving as a binding agent. The bio-briquettes were produced in a cylindrical shape with dimensions of 2.6-2.7 cm in diameter and 4-4.5 cm in height, making them economical and efficient for household use.

Initial analysis of the 30-mesh palm oil shell powder before and after torrefaction at 300°C for 30 minutes showed significant improvements in several parameters:

- Calorific value increased from 4,498 cal/gr to 6,130 cal/gr
- Moisture content decreased from 4.65% to 2.66%
- Ash content increased slightly from 1.65% to 4.55%
- Volatile matter decreased from 92.56% to 36.75%

- Fixed carbon content increased from 1.13% to 56.03%

The analysis results showed that latex binder variations significantly affected bio-briquette quality parameters. Six different ratios of raw material to latex binder were investigated.

### 3.2. Calorific Value

Calorific value is the maximum heat energy released by a fuel through complete combustion per unit mass or volume. It is crucial for determining the quality of the produced briquettes as it indicates the heat energy they can generate (Aljarwi et al., 2020). The impact of latex variation on calorific value is shown in Figure 2.

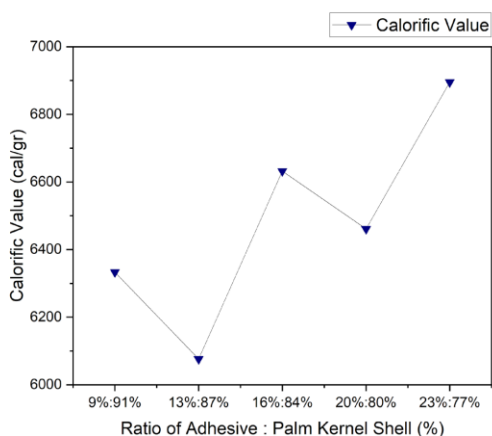


Figure 2. Calorific value graph

In Figure 2, the highest calorific value is found in the composition ratio of binder and shell (23%:77%), while the lowest is in (13%:87%). All samples met the SNI 01-6235-2000 standard. However, this contradicts the research by (Saukani et al., 2019), which stated that increasing the binder amount decreases the calorific value, and vice versa. High moisture content generally lowers the calorific value and combustion rate. The addition of latex binder, made from palm kernel shell, also affects the calorific value. The higher the calorific value, the better the quality of the briquettes (Alfernando et al., 2023).

According to the ASTM D 388-99 classification, the calorific value of the biobriquettes in this study falls between Subbituminous A Coal and High Volatile C

Bituminous Coal, ranging from 6,076 to 6,895 cal/gr.

### 3.3. Moisture Content

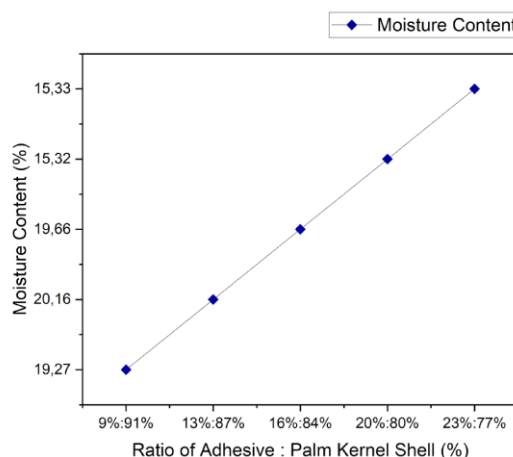


Figure 3. Moisture content graph

In Figure 3, the moisture content of the produced biobriquettes ranges from 15.32% to 20.16%, with the highest moisture content found in the composition ratio of binder and shell (13%:87%) and the lowest in the ratio of (20%:80%). These results differ from the study by (Saukani et al., 2019), which showed that moisture content increases with the amount of binder. The moisture content increased after mixing with latex binder, influenced by factors such as clone type, season, tapping time, temperature, and tree age, where clone type and season (especially the rainy season) have significant effects. Biobriquettes also possess hygroscopic properties, causing them to absorb water from the surrounding air, which is affected by the porosity of the biobriquettes. Overall, the moisture content of the biobriquettes in this study is quite high and does not meet the SNI standard, due to factors such as humid storage and large pore sizes.

### 3.4. Ash Content

Ash content is influenced by factors such as the combustion method, type of material, and drying temperature and time. According to (Norhikmah et al., 2021), the ash content in charcoal briquettes can be affected by the amount of fibers in coconut or palm kernel shells that are still attached. The

diagram showing the effect of latex binder variation on ash content is shown in Figure 4.

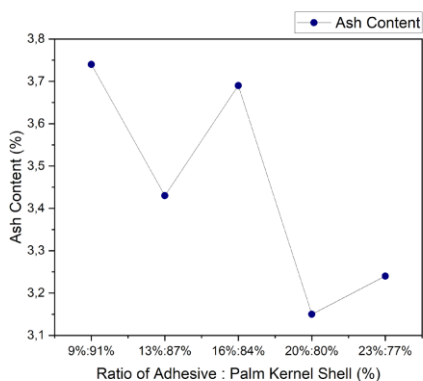


Figure 4. Ash content graph

In Figure 4, the ash content of the biobriquettes ranges from 3.15% to 3.74%, with the highest ash content found in the binder and shell composition ratio of (9%:91%) and the lowest in (20%:80%). This is due to contaminants in the raw materials, which increase the mineral content and leave more ash as a residue after combustion. The results of this study show that the ash content meets the SNI standard, indicating that the contaminants in the biobriquettes are relatively low. The addition of binder reduces the ash content, and the lower the ash content, the better the quality of the biobriquettes. Furthermore, a higher ash content results in a lower calorific value of the biobriquettes.

### 3.5. Volatile Matter

Volatile Matter refers to compounds in charcoal briquettes, excluding water, ash, and carbon, which are easily vaporized. These include hydrocarbons, methane, and carbon monoxide (Deglas & Fransiska, 2020). The effect of latex variation on volatile matter content is shown in Figure 5.

Figure 5 shows the highest volatile matter content is found in the binder and shell composition ratio of (16%:84%), and the lowest in (20%:80%). This is due to the high initial content of the palm kernel shell, which is 36.75%. The volatile matter content decreased slightly after mixing with latex binder. According to (Wicaksono & Nurhatika, 2018), an increase in volatile matter is due to the water content in the binder material. High volatile

matter causes more smoke when the briquette is ignited. Additionally, the amount of volatile matter in the briquette is influenced by the perfection of the torrefaction process. The higher the temperature and time during torrefaction, the more volatile matter is released. Based on ASTM D 388-99, the volatile matter content in this study ranges from 26.05% to 30.85%, classifying it as Medium Volatile Bituminous Coal.

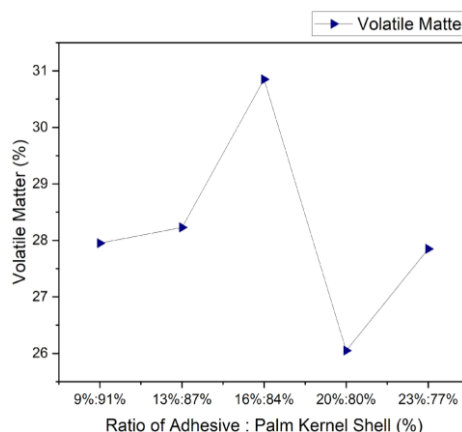


Figure 5. Volatile matter graph

### 3.6. Fixed Carbon

Fixed carbon refers to the carbon content in a sample after removing moisture, ash, and volatile matter. It represents the pure carbon content in the briquette. In Figure 6, the highest fixed carbon content is found in the binder and shell composition ratio of (20%:80%), and the lowest in (16%:84%). The graph indicates that the addition of binder decreases the fixed carbon content. According to (Mufti et al., 2024), fixed carbon is influenced by moisture content, volatile matter, and ash content. As fixed carbon increases, volatile matter decreases, and vice versa. The addition of latex binder increases moisture content, which affects the ash content. Based on the fixed carbon test, none of the samples met the SNI 01-6235-2000 standard, likely because the palm kernel shell used as raw material has a high volatile matter content, which lowers the fixed carbon level.

According to ASTM D 388-99, the fixed carbon content in this study ranges from 45.79% to 55.47%, classifying it as High Volatile A Bituminous Coal to Lignite B ( $\leq 69\%$ ).

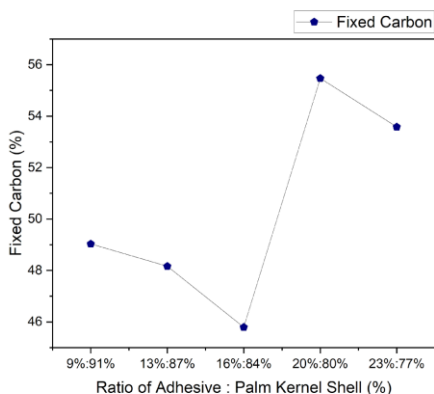


Figure 6. Fixed carbon graph

### 3.7. Burning Rate

Burning time refers to the duration from the start of sample combustion until the fire is extinguished and the sample is consumed. This test is conducted to assess the effectiveness of a fuel and its feasibility for application. The data on the effect of latex variation on burning time can be seen in Figure 7.

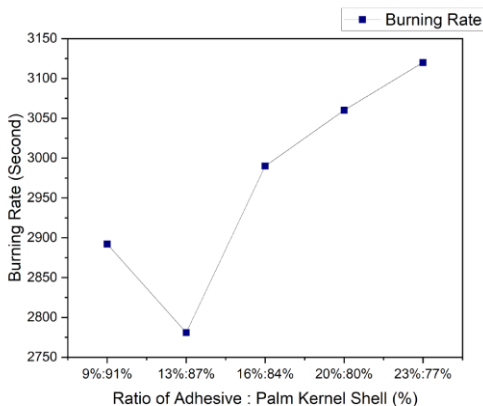


Figure 7. Burning rate graph

From the figure, it can be observed that the highest burning time occurs at the binder and shell composition ratio of (23%:77%), and the lowest at (13%:87%). According to (Mufti et al., 2024), the better the briquette quality, the longer the burning time. Burning time is also influenced by the briquette's moisture content. The lower the moisture content, the higher the calorific value and combustion rate. Conversely, the higher the moisture content, the lower the calorific value and combustion rate, because the water must be evaporated before the carbon burns.



Figure 8. Bio-briquette product

## 4. Conclusion

The research results show that the palm kernel shell bio-briquettes have a calorific value of 6.076 – 6.895 cal/gr, meeting the minimum standard of 5000 cal/gr as set by SNI. The ash content also meets the SNI requirement of  $\leq 8\%$ , ranging from 3.15% to 3.74%. However, the moisture content (15.32% – 20.16%), volatile matter (26.05% – 30.85%), and fixed carbon (45.79% – 55.47%) do not meet the SNI standard due to the high water content and volatile substances, which affect the bound carbon. The combustion rate test results show a time of 2892-3120 seconds; the more binder used, the better the briquette quality. The best bio-briquette quality is achieved with a shell-to-binder ratio of 23%:77%. The bio-briquette with latex binder mixture is feasible for use as it meets the SNI 01-6235-2000 (wood charcoal briquette) standard.

For the preparation of palm kernel shell powder, it is recommended to prepare more material than calculated and use higher temperatures to reduce the volatile content. Further research is suggested to explore the minimum lignin needed for producing high-quality bio-briquettes and to test the compressive strength of the bio-briquettes, ensuring that the briquettes are suitable not only for household use (cooking or heating stoves) but also for industrial applications, such as tin smelting.

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