

Optimizing Biobriquette Quality : The Role of Raw Material Selection in Tapioka Based Binder System

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Article Information	ABSTRACT
Article History Received : August 28, 2025 Revised : October 07, 2025 Published : October 20, 2025	The continuous increase in energy consumption, along with the gradual depletion of fossil fuel reserves, highlights the need for sustainable alternative energy sources. Oil palm biomass waste is a promising raw material due to its abundance and high calorific value. This study aims to investigate the production process of biobriquettes made from four types of oil palm waste leaves, fronds, trunks, and shells using natural tapioca starch as a binder. The experimental procedure consisted of several stages: raw material preparation (cleaning, cutting into 1–3 cm pieces, and sun-drying), carbonization by incomplete combustion (pyrolysis) for approximately three hours, grinding and sieving through a 60-mesh screen, mixing the charcoal with 17% tapioca binder solution (starch-to-water ratio of 1:7), manual pressing, and oven drying at 105°C for ten hours. The resulting biobriquettes were evaluated based on SNI 01-6235-2000 standards, including moisture content, ash content, volatile matter, fixed carbon, and burning rate. The trunk-based biobriquette exhibited the best performance, with 5.10% moisture, 5.95% ash, 12.95% volatile matter, 76.00% fixed carbon, and a burning rate of 0.1256 g/min. Most parameters met the SNI requirements, except for slightly lower fixed carbon content. Therefore, oil palm trunk biomass is recommended as the most suitable raw material for producing high-quality, eco-friendly biobriquettes.
Keywords: <i>Biobriquette;</i> <i>Biomass;</i> <i>Palm oil residues;</i> <i>Tapioca flour binder.</i>	

INTRODUCTION

The population in Indonesia continues to increase every year, which directly impacts the rising national energy demand. Unfortunately, the growing energy demand is not matched by the availability of energy resources, particularly fossil fuels such as petroleum and coal, which are increasingly limited and non-renewable. To address this challenge, the development of alternative energy sources that are more environmentally friendly and sustainable is required (Kune et al., 2022). Various studies have been conducted to explore the potential of new energy sources that can be optimally utilized (Susantini & Oktariani, 2021) (Fatmayati & , Razita Hariani, 2024).

One of the most promising alternative energy sources is biomass, particularly those derived from agricultural and plantation residues. Biomass possesses high sustainability potential and is widely available across various regions. In Indonesia, palm oil plantation residues, such as fronds, leaves, trunks, and shells, represent abundant biomass that has not yet been fully utilized (Tim Riset PASPI, 2020). These residues contain substantial calorific value, making them suitable for conversion into solid fuels such as biobriquettes (Rismayani & Tayibnapis, 2011).

Bio briquettes are solid fuels produced through the processes of biomass carbonization, mixing with a binder, molding, and drying. The advantages of biobriquettes as an alternative energy source include their environmentally friendly nature, high calorific value, and their role in reducing organic

waste in the environment. Moreover, the use of natural binders such as tapioca flour in the bio briquette production process is considered safer for health and does not cause environmental pollution (Dewi & Hudha, 2022).

An important factor influencing the quality of biobriquettes is the type of raw material used. Each part of the oil palm plant possesses distinct physical and chemical characteristics, which may result in variations in the quality of the produced biobriquettes (Meyrin Hamzah et al., 2025). Previous studies have generally utilized only one or two types of oil palm residues, such as shells or fronds, without comprehensively comparing the characteristics of all plant components. Furthermore, research integrating the analysis of bio-briquette quality parameters including moisture content, ash content, volatile matter, fixed carbon, and combustion rate with reference to the SNI 01-6235-2000 standard remains limited. This research gap highlights the need for a comprehensive study comparing the effects of various types of oil palm residues on the quality of biobriquettes produced, using an environmentally friendly natural binder.

Therefore, this study aims to examine the production process of biobriquettes made from four types of oil palm residues leaves, fronds, trunks, and shells using tapioca flour as a natural binder. Furthermore, the study seeks to evaluate the characteristics of each bio-briquette produced and identify the most suitable raw material capable of yielding high-quality biobriquettes that comply with the SNI 01-6235-2000 standard.

RESEARCH METHODS

Materials and Equipment

The materials used in this study included leaves and fronds of oil palm obtained from the Educational Plantation of Politeknik Kampar. Other research materials, namely oil palm trunks and shells, were sourced from PT PN IV Reg.3 PKS Tandun. Additional materials included water and tapioca flour.

The equipment used comprised an oven, desiccator, porcelain dishes, hotplate, furnace, metal cans, 60-mesh sieve, analytical balance, spatula, trays, stirring sticks, beakers, aluminum dishes, mortar and pestle, briquette molds, stove, and stopwatch.

Research Design

This study was designed to investigate the effect of variations in oil palm biomass raw materials on the quality of biobriquettes produced, using a natural binder in the form of tapioca flour. The raw materials used included leaves, fronds, trunks, and shells of oil palm. The research procedure consisted of the following steps:

1. Raw Material Preparation

Oil palm residues (leaves, fronds, trunks, and shells) were collected and sorted. The materials were cleaned and cut into pieces measuring 1–3 cm. The raw materials were then sun-dried for 2–3 days to reduce moisture content, ensuring optimal carbonization during the subsequent process.

2. Carbonization Process

Each type of prepared raw material was placed in a metal can. A stove was constructed, and the cans containing the biomass were positioned on the stove in a closed state. The lids of the cans were punctured with 3–4 small holes to allow air circulation. Each type of raw material was carbonized for approximately 3 hours using incomplete combustion (pyrolysis) until all materials were transformed into black charcoal.

3. Grinding and Sieving

The resulting charcoal was ground and sieved using a 60-mesh sieve to obtain a uniform powder size.

4. Mixing with Binder

The binder used was a tapioca flour solution prepared at a ratio of 1:7 (tapioca flour to distilled water by weight). Tapioca flour was weighed to 17% of the charcoal powder weight, mixed with distilled water, and heated on a hotplate while stirring until homogeneous. For each type

of sieved charcoal powder, 120 g was measured and mixed with the prepared binder solution. The mixture of charcoal powder and tapioca binder was stirred until uniform.

5. Bio briquette Molding

The homogeneous mixture of charcoal powder and tapioca binder was molded using molds of specific sizes, followed by manual pressing to compact the briquettes.

6. Drying

The molded biobriquettes were dried in an oven at 105 °C for 10 hours until the moisture content significantly decreased.

7. Bio briquette Quality Testing

Biobriquettes from each type of raw material were tested according to SNI 01-6235-2000, based on the following parameters:

- Moisture content (%)
- Ash content (%)
- Volatile matter content (%)
- Fixed carbon content (%)
- Combustion rate (grams/minute)

8. Data Analysis

The test results were analyzed using a comparative descriptive approach to determine which raw material produced biobriquettes with the highest quality, closest to the SNI 01-6235-2000 standard.

The experimental flow diagram for the biobriquette production study is presented in Figure 1.

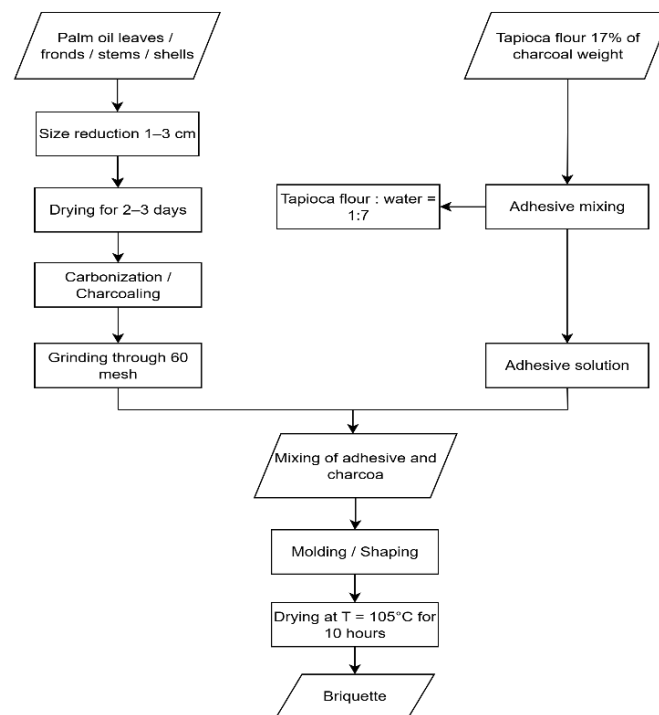


Figure 1. Experimental Flow Diagram of Biobriquette Production

RESULTS AND DISCUSSION

Analysis of Moisture Content in Produced Biobriquettes

Moisture content is a crucial parameter in evaluating the quality of biobriquettes. Excessively high moisture content can reduce the calorific value and slow down the combustion process. Therefore, a low moisture content is highly desirable to produce biobriquettes with optimal combustion performance, thereby extending their burning duration (Imam Ardiansyah et al.,

2022). The results of the moisture content analysis of the biobriquettes produced in this study are presented in Figure 2.

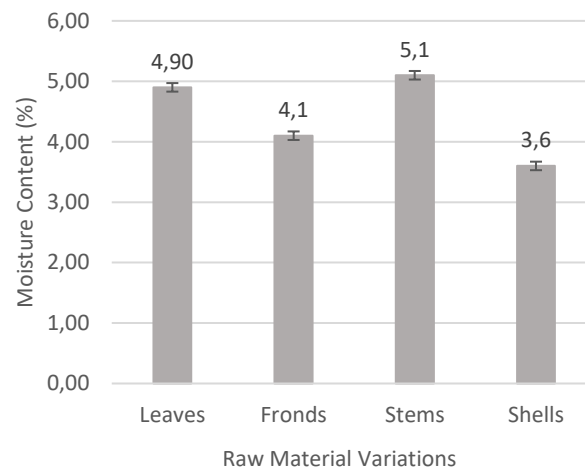


Figure 2. Effect of raw material variations on the moisture content of the produced biobriquettes

In Figure 2, it can be observed that the moisture content of biobriquettes varies depending on the type of raw material used. Biobriquettes made from leaves have a moisture content of 4.90%, from fronds 4.10%, from stems 5.10%, and from shells the lowest at 3.60%. The standard deviation for all variations was 0.07, indicating that the test results are consistent. Based on these results, biobriquettes made from oil palm shells, with the lowest moisture content (3.60%), have the potential to provide better combustion performance compared to the other variations. Conversely, the highest moisture content was found in biobriquettes made from oil palm stems (5.10%), which may reduce energy efficiency during combustion.

Compared to the Indonesian National Standard (SNI 01-6235-2000), the maximum moisture content allowed for charcoal briquettes is 8%. The results of this study indicate that all variations of raw materials produced moisture content values within this limit, suggesting that all four types can be considered suitable as biobriquettes or alternative fuels in terms of moisture content. The low moisture content also indicates that the drying process was carried out effectively (Iswara et al., 2024) and that the binder used (tapioca flour) did not contribute excessive moisture to the final product (Restin et al., 2025).

The lowest moisture content was observed in biobriquettes made from shells. This indicates that oil palm shells have a higher degree of dryness compared to the other raw materials. This is likely due to the denser physical structure of the shells, which limits their ability to absorb water compared to other materials, thereby accelerating the drying process and reducing the moisture content in the biobriquettes (Wiranata et al., 2017).

These findings are also consistent with previous studies, which reported that the moisture content of biomass-based briquettes generally ranges from 3% to 8%, depending on the type of raw material and the drying process (Eka Putri & Andasuryani, 2017) (Yanti et al., 2022) (Zuhri, 2023) (Meyrin Hamzah et al., 2025). Therefore, the variation in raw materials affects the moisture content of biobriquettes, and oil palm shells can be considered a superior raw material in terms of this parameter.

Analysis of Ash Content in Produced Biobriquettes

Ash content is an indicator of the amount of inorganic residue remaining after the combustion of biobriquettes (Zuhri, 2023). Higher ash content indicates a greater presence of non-volatile substances in the fuel (Kinanthi Pangestuti & Darmawan, 2021). The results of the ash content analysis of the biobriquettes produced in this study are presented in Figure 3.

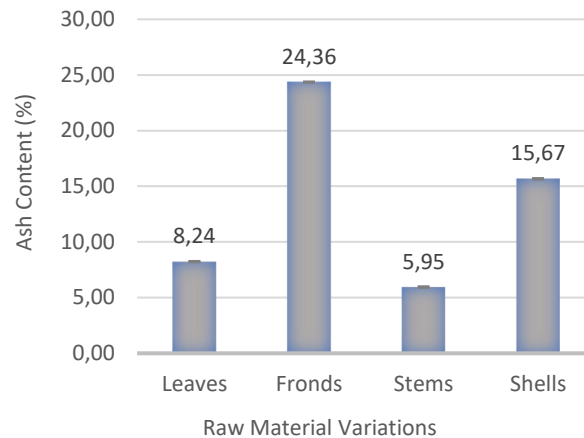


Figure 3. Effect of raw material variations on the ash content of the produced biobriquettes

The ash content test results of biobriquettes from four different raw material variations, as presented in Figure 3, indicate a significant difference. Biobriquettes made from oil palm leaves had an ash content of 8.24% with a standard deviation of 0.06, those from oil palm stems had 5.95% with a standard deviation of 0.07, and those from oil palm shells had 15.67% with a standard deviation of 0.07. Meanwhile, biobriquettes produced from oil palm fronds exhibited the highest ash content at 24.36% with a standard deviation of 0.06. The relatively small standard deviation values indicate that the test results demonstrate good consistency.

Ash content is an important parameter in assessing the quality of biobriquettes. A high ash content may reduce combustion efficiency and negatively affect the overall energy performance (Napitupulu et al., 2025). According to SNI 01-6235-2000, the maximum allowable ash content for charcoal briquettes is 8%. Based on the findings of this study, biobriquettes derived from stems (5.95%) meet this standard, while those from leaves (8.24%) slightly exceed the limit. In contrast, biobriquettes from shells (15.67%) and fronds (24.36%) significantly surpass the established threshold.

The results of the ash content analysis indicate that oil palm stems are the most suitable raw material for producing high-quality biobriquettes, as they yield low ash content that complies with the standard criteria. In contrast, oil palm shells and fronds produce significantly higher ash levels, while oil palm leaves slightly exceed the permissible limit, making them less favorable due to their potential to reduce combustion efficiency (Meyrin Hamzah et al., 2025).

The results of this study are consistent with previous literature, which indicates that biomass raw materials with high mineral content, such as fronds, tend to produce higher ash content compared to woody parts (Sugiharto & Firdaus, 2021). Therefore, the selection of raw materials is a crucial factor in determining the quality of the resulting biobriquettes (Binar, 2021).

Analysis of Volatile Matter Content in Produced Biobriquettes

Volatile matter refers to the fraction of organic compounds that easily vaporize when biobriquettes are heated in the absence of oxygen (Wati & Supriyono, 2025). High volatile matter content can lead to unstable combustion and increased smoke production (Duke Brayen Ra*, Rika Yolanda Putri Windiartib*, Erlinawati, 2022). The results of the volatile matter content analysis of the biobriquettes produced in this study are presented in Figure 4.

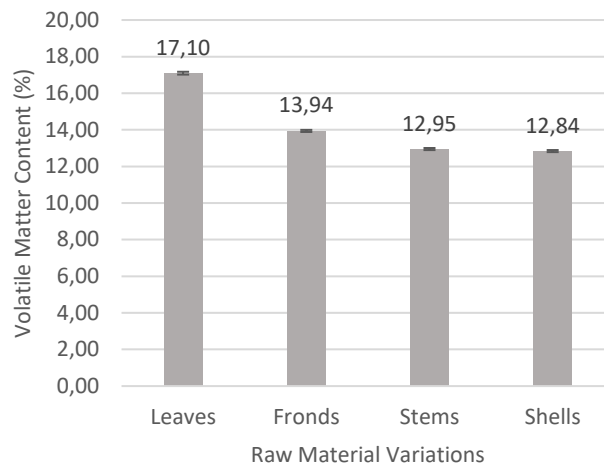


Figure 4. Effect of raw material variations on the volatile matter content of the produced biobriquettes

The volatile matter content tests of biobriquettes from the four raw material variations showed clear differences, as illustrated in Figure 4. Biobriquettes made from oil palm leaves had the highest volatile matter content at 17.10% with a standard deviation of 0.08. Those from oil palm fronds had 13.94%, stems 12.95%, and shells 12.84%, each with a standard deviation of 0.06. The low standard deviation values indicate that the test results are consistent and reliable.

Volatile matter content is a key parameter affecting the combustion characteristics of biobriquettes. Higher volatile matter content makes biobriquettes easier to ignite but results in faster consumption. Conversely, excessively low volatile matter content can make initial ignition more difficult. Therefore, a balanced volatile matter content is essential to ensure that biobriquettes are easy to ignite while maintaining a sustained flame for a sufficient duration (Amin et al., 2023).

Based on the results of this study, biobriquettes made from oil palm leaves have the highest volatile matter content, indicating that they ignite easily but are less stable in maintaining a long-lasting flame. In contrast, biobriquettes made from oil palm shells and stems exhibit lower volatile matter content, which may result in more stable combustion, although initial ignition is slightly more challenging (Rahmanita et al., 2024).

Compared to the Indonesian National Standard (SNI 01-6235-2000), the maximum volatile matter content allowed for charcoal briquettes is 15%. The results indicate that biobriquettes made from fronds (13.94%), stems (12.95%), and shells (12.84%) comply with this standard, whereas biobriquettes made from leaves (17.10%) exceed the specified limit.

These findings are consistent with previous studies, which reported that biomass materials with high cellulose and hemicellulose content, such as leaves, tend to produce higher volatile matter content compared to wood or shells (Murda et al., 2025). Therefore, the appropriate selection of raw materials is crucial in determining the quality of biobriquettes, particularly in terms of ignition ease and combustion stability (Binar, 2021).

Analysis of Fixed Carbon in Produced Biobriquettes

Fixed carbon refers to the fraction of solid carbon in biobriquettes that does not volatilize during heating in the absence of oxygen. The fixed carbon content is a key determinant of solid fuel quality, as it directly influences the combustion process. Higher fixed carbon content corresponds to greater energy potential of the biobriquettes (Saputra et al., 2021). The fixed carbon content values for the four types of biobriquette raw materials in this study are presented in Figure 5.

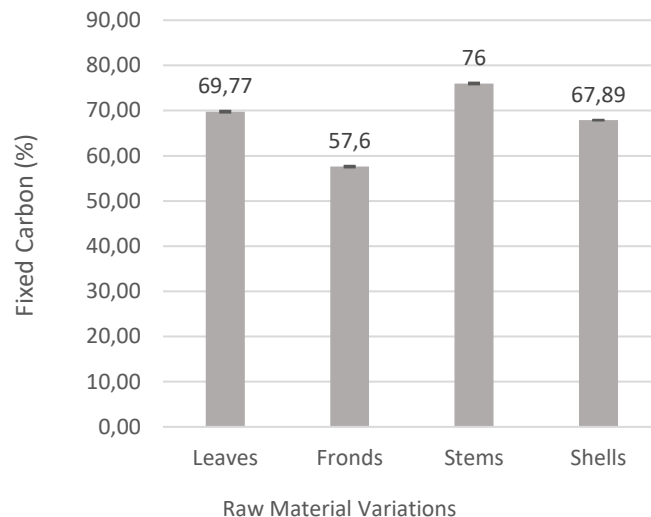


Figure 5. Effect of raw material variations on the fixed carbon content of the produced biobriquettes

The fixed carbon content tests of biobriquettes from the four raw material variations, as shown in Figure 5, revealed considerable differences. Biobriquettes made from oil palm leaves had a fixed carbon content of 69.77% with a standard deviation of 0.21, those from fronds 57.60% with a standard deviation of 0.18, stems 76.00% with a standard deviation of 0.20, and shells 67.89% with a standard deviation of 0.08. The relatively low standard deviation values across all variations indicate a high level of consistency in the test results.

Based on the results of this study, biobriquettes made from oil palm stems have the highest fixed carbon content (76.00%), indicating their potential to produce a longer lasting and more stable flame. Biobriquettes from leaves (69.77%) and shells (67.89%) also exhibit relatively high fixed carbon content, remaining within a favorable range for solid fuels (Cholilie & Zuari, 2021). In contrast, biobriquettes from fronds (57.60%) have the lowest fixed carbon content, suggesting a relatively shorter burning duration compared to the other variations.

According to several studies, the fixed carbon content of biomass briquettes generally ranges from 60% to 80% (Dewi et al., 2021)(B.R. Purba & Sirajuddin, 2021) (Dewi & Hudha, 2022) (Murda et al., 2025), depending on the type of raw material and the carbonization process. The results of this study indicate that biobriquettes made from stems, leaves, and shells of oil palm fall within the recommended range, whereas biobriquettes from fronds are slightly below the optimum range. This demonstrates that the selection of raw materials significantly affects biobriquette quality, with oil palm stems showing the greatest potential to produce briquettes with optimal combustion performance (Binar, 2021).

Analysis of Combustion Rate in Produced Biobriquettes

The combustion rate is an important parameter that indicates the speed at which biobriquettes burn per unit of time. It is expressed in grams per minute and significantly affects both the efficiency and stability of the energy produced. A high combustion rate indicates that the biobriquette burns quickly, which may lead to fuel wastage. Conversely, a low combustion rate may suggest inefficient combustion and increased smoke production (Tampubolon, 2023). The combustion rate results for the four types of biobriquette raw materials in this study are presented in Figure 6.

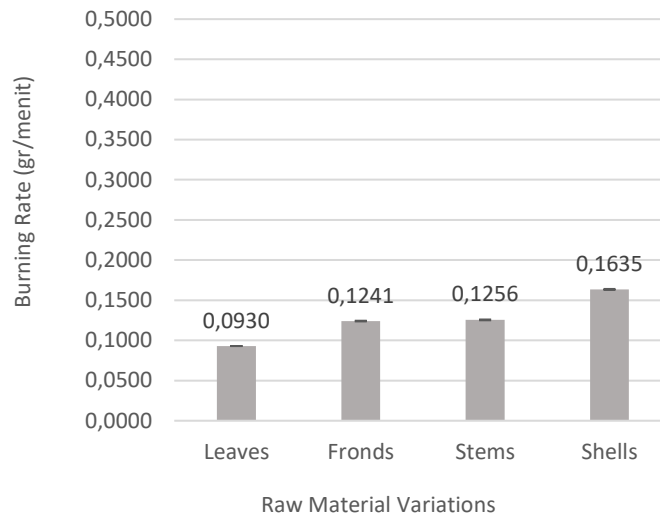


Figure 6. Effect of raw material variations on the combustion rate of the produced biobriquettes

The combustion rate tests of biobriquettes from the four raw material variations, as shown in Figure 6, revealed varying values. Biobriquettes made from oil palm leaves had a combustion rate of 0.0930 g/min, from fronds 0.1241 g/min, from stems 0.1256 g/min, and from shells 0.1635 g/min. The standard deviation for all four variations was 0.005, indicating that the test results are consistent and reliable.

Based on the results of this study, biobriquettes made from oil palm shells have the highest combustion rate (0.1635 g/min). This may be attributed to the hard and dense structure of the shell material, which allows the combustion process to proceed relatively quickly despite its high fixed carbon content (Muarif et al., 2024). In contrast, biobriquettes made from oil palm leaves exhibit the lowest combustion rate (0.0930 g/min), indicating that they can sustain combustion for a longer period, although they ignite easily due to their high volatile matter content (Samudro et al., 2023).

In relation to other quality parameters, the combustion rate is influenced by moisture content, ash content, volatile matter, and fixed carbon (Rusman et al., 2023). Biobriquettes with high fixed carbon content generally exhibit more stable combustion, while high volatile matter content tends to facilitate ignition but accelerates fuel consumption. In this context, biobriquettes made from oil palm stems, which have the highest fixed carbon content (76.00%), exhibit a moderate combustion rate (0.1256 g/min), indicating a good balance between ease of ignition and flame longevity (Cholilie & Zuari, 2021).

In conclusion, the variation of raw materials has a significant effect on the combustion rate of biobriquettes. Biobriquettes made from oil palm leaves excel in flame longevity, whereas those made from oil palm shells are more suitable for energy applications that require high heat over a short period.

CONCLUSION

The results of the study showed that variations in raw materials had a significant effect on the quality of the produced biobriquettes. Based on the five tested parameters moisture content, ash content, volatile matter, fixed carbon, and combustion rate all biobriquettes types met the SNI 01-6235-2000 standard for moisture content. However, leaf based biobriquettes did not meet the standard requirements for ash and volatile matter content. The biobriquettes made from oil palm trunks demonstrated the best performance, with the highest fixed carbon content (76.00%), low ash and moisture levels, and a moderate combustion rate. These characteristics indicate that oil palm trunk biomass is the most promising raw material for producing high quality biobriquettes that meet national standards and have strong potential as a renewable alternative energy source.

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