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Utilization of Palm Oil Waste as Raw Material for Making Environmentally Friendly Biobriquettes

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ABSTRACT

***Purpose**: This study aims to analyze the potential use of palm oil waste, specifically shells, fibers, and empty fruit bunches (EFB), as raw materials for environmentally friendly biobriquettes. The research focuses on chemical composition, calorific value, combustion time, and exhaust emissions to assess the feasibility of biobriquettes as a renewable energy alternative that can help reduce dependence on fossil fuels.*

***Subjects and Methods:** The research subjects consisted of three types of solid palm oil waste: shells, fiber, and empty fruit bunches. Analysis was conducted on moisture, lignin, cellulose, hemicellulose, and ash content. Biobriquettes were then produced through a carbonization process, mixing with adhesive, and pressing. Calorific value testing was performed using a bomb calorimeter, while exhaust gas emissions measured CO, CO_2, SO_2, and particulate matter. Data were analyzed descriptively and comparatively to determine differences in the performance of each type of biobriquette.*

***Results:** The results showed that palm kernel shells had the highest lignin content (38.2%), the highest calorific value (18.2 MJ/kg), a burning time of 95 minutes, and relatively low exhaust emissions (CO 115 ppm and particulate matter 65 mg/Nm³). Palm fiber produced a calorific value of 15.1 MJ/kg with CO emissions of 130 ppm, while EFB showed the lowest quality with a calorific value of 12.3 MJ/kg and the highest emissions (CO 145 ppm and particulate matter 88 mg/Nm³).*

***Conclusions:** Palm kernel shells have proven to be the most promising raw material for biobriquettes, offering high energy quality and low emissions. Fiber can be an additional alternative, and EFB is more suitable for use through biomass blending or emission control technologies. Utilizing palm oil waste as biobriquettes significantly contributes to energy diversification, industrial waste management, and sustainable energy development in Indonesia.*

INTRODUCTION

Indonesia is one of the world's largest palm oil producers, with plantation area increasing annually (Hambali & Rivai, 2017). The development of the palm oil industry not only contributes significantly to the country's foreign exchange but also generates large amounts of solid waste, such as shells, fibers, and empty fruit bunches (Mahlia et al., 2019; Sumathi et al., 2008). To date, much of this waste has not been optimally utilized and is often simply burned or landfilled, creating environmental problems. Foo & Hameed (2010) said that, this situation has prompted the need for innovative efforts to manage palm oil waste to increase its utility.

One approach is to utilize palm oil waste as a raw material for alternative energy. According to Olujobi et al. (2023), Amidst increasing energy demand and limited fossil resources, renewable energy is a strategic solution to ensure a sustainable energy supply. Biobriquettes, as a form of biomass-based renewable energy, offer significant potential for development (Vaish et al., 2022; Hadiyanto et al., 2023). Biobriquettes have the advantages of a relatively high calorific value, a more practical form, and are environmentally friendly because they produce lower emissions compared to fossil fuels.

Utilizing palm oil waste for biobriquette production not only contributes to energy diversification but also supports industrial waste reduction (Siagian et al., 2024; Sulaiman et al., 2011). Empty fruit bunches, shells, and fibers of oil palms contain high levels of lignocellulose, potentially producing sufficient calorific value to serve as an energy source. With the right technology, this waste can be converted into high-quality biobriquettes, which can be utilized by households, small-scale industries, and the large-scale energy sector (Seboka et al., 2024).

Several previous studies have demonstrated that biomass from agricultural and plantation waste has significant potential as a raw material for biobriquettes (Espinoza-Tellez et al., 2020). However, research specifically on the use of oil palm waste requires further development, particularly in improving briquette quality through modifications to the raw material composition, carbonization techniques, and the use of environmentally friendly adhesives. This demonstrates the potential for further research to produce biobriquettes with high calorific value, good mechanical durability, and environmental friendliness (Khan et al., 2023).

From an environmental perspective, utilizing oil palm waste as biobriquettes can reduce greenhouse gas emissions and pollution from open waste burning. Destek et al. (2021) and Müller et al. (2015) said that furthermore, this biomass utilization can support green energy policies and the government's Sustainable Development Goals (SDGs). Thus, developing biobriquettes based on palm oil waste not only has economic value but also has a positive impact on environmental sustainability.

Based on this background, this research focuses on analyzing the use of palm oil waste as a raw material for environmentally friendly biobriquettes. The main objective is to assess the potential calorific value, combustion efficiency, and environmental impact of the resulting biobriquettes. This research is expected to contribute to the development of biomass-based renewable energy and provide alternative solutions for managing palm oil waste in Indonesia.

METHODOLOGY

This research method uses solid palm oil waste in the form of shells, fibers, and empty fruit bunches (EFB) obtained from palm oil mills with the addition of tapioca starch adhesive of 5% of the dry weight. The samples were cleaned, dried at 105°C until the moisture content was <10%, then milled and sieved through 60 mesh. The carbonization process was carried out at 400–500°C to increase the fixed carbon content. The carbonized product was mixed with adhesive, molded using a hydraulic mold with a pressure of 100 kg/cm², then dried again at 105°C for 24 hours. Laboratory tests included chemical composition analysis (moisture content, lignin, cellulose, hemicellulose, and ash) according to ASTM standards, measurement of calorific value using a bomb calorimeter, and testing the performance of briquettes including burning time, flame color, and flame stability. Exhaust gas emissions were analyzed using a gas analyzer for CO, CO_2, SO_2, and a dust sampler for particulates. The test results data were then analyzed descriptively-comparatively to compare the quality of biobriquettes from each type of palm oil waste, and compared with the quality standards for biomass briquettes.

RESULTS AND DISCUSSION

Table 1. Chemical Composition of Palm Oil Waste

Type of Waste	Moisture Content (%)	Lignin (%)	Cellulose (%)	Hemicellulose (%)	Ash (%)
Shell	8.5	38.2	32.5	18.0	2.8
Fiber	10.2	34.5	30.8	20.5	3.1

Empty Fruit Bunch (EFB)	12.8	28.7	29.5	23.6	5.4

Based on Table 1, it can be seen that palm kernel shells have the highest lignin content compared to fiber and empty fruit bunches. High lignin content significantly impacts calorific value, as lignin serves as the most combustible component in biomass. This makes shells the most potential raw material for producing biobriquettes with high energy quality.

Meanwhile, palm kernel shells have a relatively high cellulose content, so they can still produce adequate calorific value. However, the fibers have a higher moisture content than the shells, requiring a more optimal drying process before being used as raw material for biobriquettes.

Unlike the other two types of waste, empty fruit bunches (EFB) have a relatively high ash content. This high ash content can potentially produce more combustion residue, reducing the energy efficiency of biobriquettes. Nevertheless, EFB remains strategically valuable due to its abundant availability in oil palm plantations.

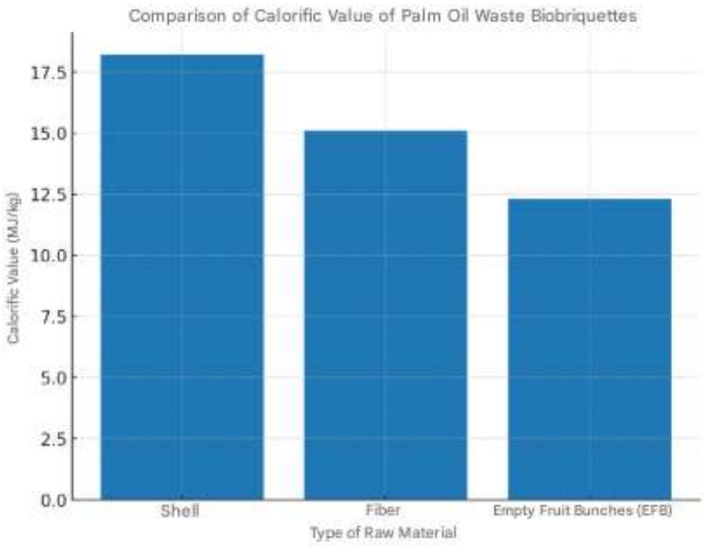

Figure 1. Comparison of the Calorific Value of Biobriquettes from Shells, Fibers, and Empty Fruit Bunches (EFB).

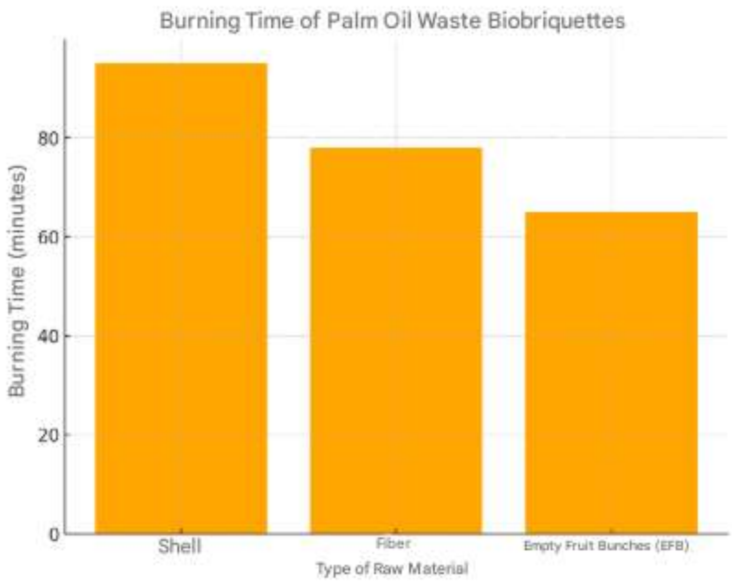

Figure 2. The Burning Time of Each Biobriquette is Based on the Type of Raw Material

The calorific value test results showed that palm kernel shell biobriquettes had the highest calorific value, at 18.2 MJ/kg. This value is comparable to the quality of several types of lignite, making it suitable as an alternative fuel. Furthermore, the resulting flame is bright yellow, indicating more stable and efficient combustion.

Fiber-based biobriquettes have a lower calorific value (15.1 MJ/kg), with a burning time of approximately 78 minutes. The reddish flame color indicates a relatively high carbon content, although the flame stability is not as good as that of shell-based biobriquettes. This still makes palm kernel shell biobriquettes a potential raw material, especially for household and small-scale industrial use.

Meanwhile, empty fruit bunch (EFB) biobriquettes have the lowest calorific value, at 12.3 MJ/kg. The burning time is also relatively short, only 65 minutes. The dim flame color indicates the low energy efficiency of this raw material. However, even in its abundant supply, EFB remains useful when mixed with other biomass materials to improve the quality of the biobriquettes.

Table 2. Exhaust Gas Emissions from Palm Oil Waste Biobriquettes

Type of Biobriquette	CO (ppm)	CO_2 (%)	SO_2 (ppm)	Particulates (mg/Nm³)
Shell	115	12.4	12	65
Fiber	130	11.8	15	72
Empty Fruit Bunch (EFB)	145	10.9	18	88

Table 2 shows that shell-based biobriquettes produce the lowest exhaust emissions. Their carbon monoxide (CO) content is only 115 ppm, while particulate matter reaches 65 mg/Nm³. This value is still below the emission threshold for biomass combustion, making shells more environmentally friendly than other palm oil waste.

Fiber biobriquettes exhibit higher CO emissions, at 130 ppm, with a SO_2 content of 15 ppm. This is influenced by their higher moisture and ash content compared to shells. However, these emission levels are still considered safe for use on a household and small industrial scale.

Empty fruit bunch (EFB) biobriquettes, on the other hand, produce the highest emissions, particularly particulate matter, at 88 mg/Nm³. The high ash content of EFB contributes to increased solid emissions during combustion. However, emission control technologies such as filters or cyclones can help mitigate the negative impacts of burning EFB-based biobriquettes.

Discussion

Chemical Composition Analysis of Palm Oil Waste

The chemical composition analysis results show that each type of palm oil waste has different characteristics in terms of lignocellulose content. Palm kernel shells have the highest lignin content, at 38.2%, compared to fiber (34.5%) and empty fruit bunches (28.7%). High lignin content significantly impacts the calorific value because lignin is a biomass component with high chemical bond energy. Therefore, the shells have great potential as the primary raw material for biobriquettes with high energy quality.

In addition to lignin, cellulose and hemicellulose content also affect the combustion properties of biobriquettes (Kebede et al., 2022). Palm kernel fiber with a cellulose content of 30.8% still provides sufficient energy, although its efficiency is lower than that of the shells. Meanwhile, empty fruit bunches have a higher ash content (5.4%), resulting in higher combustion residues. This reduces combustion quality and decreases energy efficiency.

Overall, the chemical composition results confirm that raw material selection is crucial in biobriquette production. The shell provides the best energy quality, the fiber can be a good alternative, while the empty bunches require additional treatment such as mixing with other materials to improve their quality.

Calorific Value and Burning Time Analysis

The calorific value test showed significant differences between the three types of palm oil waste. The shell-based biobriquettes produced a calorific value of 18.2 MJ/kg with a burning time of 95 minutes. This value is close to the quality of low-grade coal, making them highly suitable as a partial substitute for fossil fuels.

The fiber-based biobriquettes had a calorific value of 15.1 MJ/kg and a burning time of 78 minutes. These results indicate that fiber remains a viable alternative fuel, especially for households or small industries that do not require very high heat. The reddish flame color also indicates adequate carbon combustion, although the flame stability is not as strong as that of the shells.

Meanwhile, the empty fruit bunch (EFB) biobriquettes produced the lowest calorific value, at 12.3 MJ/kg with a burning time of 65 minutes. This lower value is due to the high moisture and ash content of EFB. Nevertheless, the abundant availability of EFB makes it a potential biomass source when mixed with other wastes with higher calorific values.

Exhaust Gas Emission Analysis

Exhaust gas emissions testing showed that shell-based biobriquettes produced the most environmentally friendly emissions. The carbon monoxide (CO) concentration was only 115 ppm with particulate matter at 65 mg/Nm^3. These results indicate that shells burn more completely than other waste types, making them more suitable for large-scale use, such as in biomass-based power plants.

Conversely, fiber-based biobriquettes showed higher CO levels (130 ppm) and particulate matter at 72 mg/Nm^3. This is due to the higher moisture content, which results in less complete combustion. However, the emissions are still within reasonable limits for biomass combustion. Fiber biobriquettes are more suitable for use in small industries or households with good ventilation systems.

Meanwhile, empty fruit bunch (EFB) biobriquettes produced the highest emissions, with CO at 145 ppm and particulate matter at 88 mg/Nm^3. The high ash content contributes to an increase in solid pollutants during combustion. Therefore, the use of EFB as a raw material for biobriquettes should be accompanied by emission control technology, such as the use of cyclone separators or filters, to reduce the impact of air pollution.

Implications for Renewable Energy Development

The results of this study indicate that the use of palm oil waste in the form of biobriquettes has great potential for development in Indonesia. Palm kernel shells have been proven to have the best energy and emission quality, making them suitable as the primary raw material. Fiber also has significant potential, although optimization of the drying process is required. Empty fruit bunches, although of the lowest quality, remain important due to their abundance and potential for utilization through biomass co-firing.

From a sustainability perspective, utilizing palm oil waste into biobriquettes can help reduce dependence on coal while lowering greenhouse gas emissions. Furthermore, this can also create new economic opportunities for communities surrounding palm oil plantations by establishing small-scale waste processing industries.

With the support of appropriate regulations, incentives, and technology, palm oil waste-based biobriquettes can play a significant role in achieving the national renewable energy mix target and supporting climate change mitigation efforts.

CONCLUSION

The results of the study indicate that palm oil waste has great potential as a raw material for environmentally friendly biobriquettes, with shells as the most superior material due to their high lignin content (38.2%) which produces a calorific value of 18.2 MJ/kg and a burning duration of 95 minutes and the lowest exhaust emissions. Palm fiber with a calorific value of 15.1 MJ/kg and empty fruit bunches (12.3 MJ/kg) still have potential despite their lower energy quality and emissions, especially EFB which produces higher particulates and CO. This difference confirms that the chemical quality of the raw materials greatly influences the energy performance and emission levels of biobriquettes. Overall, the use of palm oil waste as biobriquettes can support national energy diversification, reduce dependence on fossil fuels, reduce environmental pollution caused by palm oil industry waste, while also opening new economic opportunities for communities around plantations if supported by appropriate technology, government policies, and community involvement in their development.

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