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# Analysis of Bound Carbon Content and Combustion Rate of Banana Peel Waste Biobriquettes

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## Abstract

This study aims to analyze the fixed carbon content and combustion rate of briquettes made from banana peel waste as a renewable energy alternative. The experimental method was used, involving key stages such as material preparation, carbonization process, briquette molding, and testing of fixed carbon content and combustion rate. The results showed that the fixed carbon content of the produced briquettes reached 87%, indicating good combustion quality and high energy storage capacity. Additionally, the combustion rate of the briquettes varied, with Sample A having a combustion rate of 0.017 grams/s and Sample B at 0.014 grams/s. This difference suggests that Sample B has a longer combustion duration. Thus, banana peel briquettes have the potential to be an efficient and environmentally friendly alternative fuel. Further research is needed to optimize the production process and enhance briquette efficiency.

**Keywords:** analysis, bound carbon, combustion rate, biobriquettes, banana peel

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## 1. Introduction

Energy is a fundamental human need that continues to increase along with population growth and industrial activities (Alexander et al., 2023). The high dependence on fossil fuels such as petroleum, coal, and natural gas (Sirait et al., 2024) has led to various environmental problems, including greenhouse gas emissions and global warming (Sirait et al., 2023). Therefore, alternative energy sources that are more environmentally friendly and sustainable are needed (Pardede et al., 2024). One of the renewable energy sources that can be developed is biomass, which can be processed into solid fuels such as biobriquettes (Alexander et al., 2024).

According to the International Energy Agency (Sinaga et al, 2024), global energy demand increased by approximately 2% in 2023, reaching one of the highest consumption levels in history. Fossil fuels—comprising oil, coal, and natural gas—still account for around 80% of total global

energy use, despite continuous efforts to promote renewable energy (Sirait et al., 2021). Meanwhile, oil supply growth has slowed significantly due to geopolitical tensions, declining production rates in major oil-producing countries, and tightening environmental regulations aimed at reducing carbon emissions (Harita et al., 2024). This growing imbalance between energy supply and demand has led to rising fuel prices and intensified competition for limited resources, especially in developing nations that rely heavily on imported fossil fuels (Sirait., 2025). In addition, the continuous burning of fossil fuels contributes to about 75% of global greenhouse gas emissions, accelerating climate change and environmental degradation (Simatupang et al., 2025). These circumstances underscore the urgent need to explore and utilize renewable and sustainable energy sources that are locally available, cost-effective, and environmentally friendly (Sijabat et al., 2025). Among various renewable options, biomass stands out as a promising alternative due to its abundance, carbon neutrality, and ability to convert organic waste into usable energy (Pardede et al., 2025). Agricultural residues such as banana peels, which are often discarded as waste, can be processed into biobriquettes—a solid biofuel capable of providing a clean and efficient energy source (Alexander et al., 2025). Therefore, the utilization of banana peel waste for biobriquette production not only supports global energy diversification but also contributes to waste reduction and sustainable resource management (Sirait et al., 2025).

Biomass is an organic material derived from living organisms, such as plants and agricultural waste, that can be used as an energy source (Sirait et al., 2023). One form of biomass utilization that is increasingly being developed is the production of biobriquettes, which are solid fuels produced from the densification of biomass waste (Alexander et al., 2024). Biobriquettes have several advantages compared to conventional fuels, including relatively high calorific value (Pardede et al., 2024), being more environmentally friendly due to lower emissions, and reducing the amount of organic waste that would otherwise be discarded (Ansyori et al., 2024).

One of the potential raw materials for making biobriquettes is banana peel waste. Bananas are a tropical fruit widely consumed by the Indonesian community, both fresh and processed. However, high banana consumption also generates large amounts of peel waste, which is often discarded without further utilization. In fact, banana peels contain lignocellulose, which can be converted into an alternative fuel with specific characteristics, such as bound carbon content and combustion rate (Putri et al., 2022).

In biobriquette production, several important parameters must be considered to determine its quality and efficiency as a fuel. One of these parameters is the bound carbon content, which plays a role in determining the calorific value of biobriquettes (Silaban et al., 2024). Bound carbon content is a crucial parameter in determining biobriquette quality. It represents the portion of carbon in the fuel that does not easily volatilize when heated and contributes to increasing the calorific value of biobriquettes (Haryono et al., 2021). The higher the bound carbon content, the greater the energy produced during combustion.

In addition, the combustion rate is also a key factor that determines the efficiency of biobriquette usage (Puspita et al., 2024). A combustion rate that is too high can cause the biobriquette to burn out quickly, while a rate that is too low can reduce its usage efficiency (Sinaga et al., 2024). Therefore, an analysis of the bound carbon content and combustion rate is necessary

to determine the potential of banana peel waste biobriquettes as a high-quality alternative energy source (Harahap et al., 2023).

This study aims to analyze the bound carbon content and combustion rate of biobriquettes made from banana peel waste. By understanding these characteristics, it is expected that banana peel-based biobriquettes can be developed as a more efficient and environmentally friendly renewable energy alternative (Alexander et al., 2024). Furthermore, this research is expected to contribute to reducing organic waste while supporting sustainable energy management efforts (Sinurat et al., 2024).

## 2. Methods

This study employs an experimental method with the aim of analyzing the bound carbon content and combustion rate of biobriquettes made from banana peel waste. This research is a continuation of the previous study entitled "*Analisis Nilai Kalor, Kadar Abu dan Kadar Air Biobriket Kulit Pisang*" (Sigirot et al., 2024). The study was conducted in several stages, including material preparation, biobriquette production, bound carbon content testing, and combustion rate testing.

The first stage is material preparation, where banana peels are collected, cleaned, and dried to reduce moisture content. Once dried, the banana peels undergo carbonization through pyrolysis at a specific temperature to produce charcoal. The resulting charcoal is then ground and mixed with a natural binder, such as tapioca flour, in a certain ratio. This mixture is then molded into briquettes and dried until it reaches the appropriate moisture content.

The second stage is the bound carbon content testing, conducted using the proximate method. The biobriquette samples are characterized to determine their proximate composition, including moisture content, ash content, volatile matter, and bound carbon. The bound carbon content is calculated based on the difference between the total dry matter and the content of volatile matter and ash. The calculation formula is as follows:

$$\text{Fixed Carbon (\%)} = 100 - (A + B)$$

Notes :

A = Volatile matter (%)

B = Ash content (%)

The third stage is the combustion rate testing, which involves weighing the initial mass of the biobriquette and then burning it under controlled conditions. The time required to burn the biobriquette completely is recorded, and the combustion rate is calculated by dividing the difference between the biobriquette mass before and after combustion by the combustion time (Sirait et al., 2025). The formula used to calculate the combustion rate is as follows:

$$\text{Rate of Combustion (Rc)} = \frac{\text{mass of dry briquette (grams)}}{\text{time until briquette is completely burned (seconds)}}$$

The collected data are analyzed quantitatively and presented in the form of tables and graphs to show the relationship between bound carbon content and the combustion rate of the biobriquettes. The analysis is performed to evaluate the quality of the biobriquettes and their effectiveness as an alternative fuel.

### 3. Result and Discussion

#### 3.1 Results

##### 3.1.1 Bound Carbon Content Analysis Results

The analysis results of fixed carbon content in banana peel biobriquettes are presented in the following table:

**Table 1.**

*Bound Carbon Content Analysis Results*

<b>Biobriquette Sample</b>	<b>Bound Carbon Content (%)</b>
Sample A	87%
Sample B	87%

Based on the analysis, the fixed carbon content in both Sample A and Sample B shows the same value of 87%. This high fixed carbon content indicates that the produced biobriquettes have good characteristics in storing energy, as fixed carbon plays a role in determining combustion quality and the amount of heat generated. The high fixed carbon content can result from an optimal carbonization process, where the temperature and heating time are sufficient to remove volatile compounds without damaging the carbon structure in the raw material. Additionally, the type of banana peel waste used may have a sufficiently high lignocellulose content, contributing to the formation of more stable fixed carbon. Compared to the standard biobriquettes made from other biomass waste, a fixed carbon content of 87% is considered very good. This finding suggests that banana peel biobriquettes can be an alternative fuel with high efficiency in generating heat and competing with conventional biomass fuels.

##### 3.1.2 Combustion Rate Analysis Results

The analysis results of fixed carbon content in banana peel biobriquettes are presented in the following table:

**Table 2. Combustion Rate Analysis Results**

<b>Biobriquette Sample</b>	<b>Combustion Rate (grams/second)</b>
Sample A	0,017
Sample B	0,014

The combustion rate analysis shows that Sample A has a combustion rate of 0.017 grams per second, while Sample B has a combustion rate of 0.014 grams per second. This difference indicates

that Sample B has a slower combustion rate compared to Sample A. The lower combustion rate in Sample B may indicate that the biobriquette has a higher density or a more compact structure, allowing the combustion process to last longer with more controlled energy release. Conversely, the faster combustion rate in Sample A may be due to a more porous structure, allowing oxygen to enter more easily and accelerate the combustion process. Generally, a lower combustion rate is often preferred in biobriquettes as it indicates that the fuel can last longer, making it more efficient for long-term uses such as cooking or room heating.

## **3.2 Discussion**

### **3.2.1 Analysis of Bound Carbon Content**

Based on the analysis results, the banana peel waste biobriquettes showed the same fixed carbon content in both samples, amounting to 87%. This value is considered very good compared to the standard biobriquettes made from other biomass waste (Silaban et al., 2021). A high bound carbon content indicates that the biobriquette has a significant energy storage capacity. This is due to the role of bound carbon in determining the combustion quality and the amount of heat produced (Sirait et al., 2021). The high bound carbon content in both biobriquette samples can be attributed to several factors, primarily the optimal carbonization process (Aldillah et al., 2024). During carbonization, adequate temperature and heating time are able to remove volatile compounds without damaging the carbon structure in the raw material. In addition, banana peel waste, as the raw material for biobriquettes, contains a high amount of lignocellulose, which contributes to a more stable fixed carbon formation (Alexander et al., 2024).

Fixed carbon is the portion of carbon in fuel that does not easily volatilize when heated. The higher the fixed carbon content, the greater the energy that can be generated by the biobriquette during combustion. Therefore, the fixed carbon content of 87% in banana peel biobriquettes indicates that the product can produce a significant amount of heat and compete with conventional biomass fuels.

### **3.2.2 Analysis of Combustion Rate**

In addition to fixed carbon content, the combustion rate is an important parameter in determining the quality of biobriquettes as a fuel. According to the analysis results, the combustion rate of banana peel biobriquettes showed differences between the two tested samples. Sample A had a combustion rate of 0.017 grams/s, while Sample B had a combustion rate of 0.014 grams/s.

This difference in combustion rate indicates variations in the physical characteristics of the biobriquettes, particularly in terms of structure and density. Sample B, which had a lower combustion rate, likely had a higher density or a more compact structure compared to Sample A. A higher density causes combustion to occur more slowly as oxygen has more difficulty entering the biobriquette's pores. Conversely, the faster combustion rate in Sample A may be due to a more porous structure, allowing oxygen to enter more easily and accelerating the combustion process (Baihaqi et al., 2024).

Generally, a lower combustion rate is often preferred in biobriquettes because it indicates that the fuel can last longer during use (Silaban et al., 2021). This is especially important in long-term applications such as cooking or room heating. Therefore, biobriquettes with a lower

combustion rate are considered more efficient because they can produce heat over a longer duration.

Based on these two parameters, it can be concluded that banana peel-based biobriquettes have good potential as an alternative fuel. The high fixed carbon content and controlled combustion rate indicate that these biobriquettes can be effectively used as a sustainable and environmentally friendly energy source. However, further optimization of the production process is needed, especially in maintaining the uniformity of the biobriquette's physical structure, to achieve more consistent combustion quality (Noprianti et al, 2024).

#### 4. Conclusion

Based on the results of the research conducted, it was found that the bound carbon content in the biobriquette reached 87%, indicating good combustion quality and a high energy storage capacity. In addition, the combustion rate of the biobriquette showed differences between the two tested samples, where Sample A had a combustion rate of 0.017 g/s, while Sample B had a combustion rate of 0.014 g/s. The lower combustion rate of Sample B indicates that this biobriquette has a longer durability during use, making it more efficient.

From these results, it can be concluded that banana peel-based biobriquettes have the potential to be a high-quality alternative fuel with good combustion characteristics. However, to further improve efficiency, additional research is needed, especially in optimizing the raw material composition and carbonization methods used.

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