Optimization Of Briquette Stove from Rice Husk and Sawdust Mixture as A Renewable Energy Source

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**Abstract.** The rising demand for renewable energy has prompted efforts to utilize agricultural waste such as rice husk and sawdust for biomass briquette production. This study aims to optimize the composition of rice husk and sawdust to produce briquettes with improved thermal and mechanical properties. Conducted between July 2024 and January 2025 at the Chemical Engineering Laboratory of Universitas Muhammadiyah Malang, the research employed a quantitative experimental approach. The independent variable was the material composition, while the dependent variables included calorific value, moisture content, ash content, compressive strength, and combustion rate. Controlled variables comprised compaction pressure, drying temperature, and particle size. The briquette fabrication process involved initial drying of raw materials, mixing with tapioca binder, mechanical molding, secondary drying, and laboratory testing. Instruments used included a bomb calorimeter, oven, furnace, and compression testing machine. Results showed that the produced briquettes had a calorific value of 5,160 kcal/kg, ash content of 27%, moisture content of 96.4%, compressive strength ranging from 5–15 kg/cm², and a combustion duration of 1–2 hours. Compared to previous studies, the calorific value was relatively high; however, the elevated moisture and ash content exceeded the typical commercial standards. These deficiencies were likely caused by incomplete drying and the high silica content of rice husk. Although compressive strength was moderate, it was still lower than that of briquettes made with lignin. Overall, rice husk–sawdust briquettes show promising potential as an alternative energy source, provided that the production process is further optimized, particularly in drying and binder selection.

# INTRODUCTION

Indonesia, as an agrarian country, generates vast quantities of biomass waste, particularly rice husks and sawdust, as byproducts of its agricultural and timber industries. Despite this abundance, a significant portion of these materials remains underutilized or improperly disposed of, such as through open burning, which contributes to environmental degradation and air pollution. At the same time, Indonesia faces a growing energy demand and an overreliance on fossil fuels, which raises concerns about sustainability, cost, and environmental impact. In this context, biomass briquettes present an attractive solution: they are renewable, environmentally friendly, economically viable, and capable of converting organic waste into valuable energy [1].

Concurrently, the continuous increase in energy demand—both for household and industrial use—drives the need for alternative energy sources that are not only renewable but also sustainable in the long term [2]. Biomass briquettes fulfill these criteria and offer a practical option that is especially relevant for a country like Indonesia, where biomass resources are plentiful. Rice husks and sawdust, often considered waste, can be repurposed into high-energy, low-emission fuel sources, contributing to both waste management and energy diversification [3]. Additionally, biomass briquettes have the potential to reduce dependency on fossil fuels and significantly lower greenhouse gas emissions, aligning with global environmental goals and national energy strategies.

Research in [4] demonstrated that the optimal formulation for biomass briquettes was achieved using a 1:5 ratio of rice husks to wood twigs with a 100 mesh particle size. This combination produced briquettes with a moisture content of 4.5%, ash content of 2.19%, volatile matter of 13.73%, a density of 2.2502 g/cm³, and a calorific value of 6,653.6 cal/g [5]. These parameters reflect excellent thermal and structural characteristics, indicating the viability of proper material blending in enhancing briquette performance.

Numerous studies have shown that the quality of biomass briquettes is largely influenced by the composition of the raw materials and the techniques applied during the production process [6]. Rice husks, while abundant and inexpensive, are known to contain high levels of silica, which result in elevated ash content—an undesirable property for efficient combustion. On the other hand, sawdust contributes beneficial characteristics, including higher calorific values and stronger mechanical integrity, making it an ideal complementary material in mixed briquette formulations. However, existing research still shows a gap in achieving optimal performance. High moisture and ash contents, along with low compressive strength, continue to be challenges that limit the applicability of biomass briquettes on a broader scale [2].

Based on the issues identified above, the present study is designed to optimize the formulation of briquettes made from a combination of rice husks and sawdust. The goal is not only to explore the influence of various composition ratios but also to evaluate the resulting briquettes in terms of both physical (density, compressive strength) and thermal (calorific value, ash content) properties. This study aims to identify the optimal raw material blend that achieves the most desirable balance of performance indicators [7].

Therefore, this research focuses on improving the production process and optimizing the briquette formulation to enhance the fuel quality, stability, and overall efficiency of biomass briquettes. Ultimately, it contributes to addressing energy access challenges while offering an environmentally sound and economically feasible alternative for rural and industrial applications across Indonesia.

# Methodology

This research was conducted at the Chemical Engineering Laboratory, University of Muhammadiyah Malang, during the period from July 2024 to January 2025. The study applied a laboratory experimental method with a quantitative approach, aiming to evaluate the physical and thermal properties of briquettes made from a mixture of rice husk and sawdust.

The independent variable in this study was the composition ratio between rice husk and sawdust, which was varied systematically to observe its effect on briquette characteristics. The dependent variables consisted of the calorific value, moisture content, ash content, compressive strength, and combustion rate, which served as the primary indicators of briquette performance. Meanwhile, the controlled variables included the compaction pressure applied during molding, the drying temperature, and the particle size of the raw materials, all of which were kept constant throughout the experiments to maintain consistency.

The research procedure was carried out through several stages. First, the raw materials (rice husk and sawdust) were subjected to an initial drying process to reduce their moisture content before further processing. The dried materials were then mixed with a binder to enhance cohesion during briquette formation. The resulting mixture was molded into cylindrical briquettes using a mechanical pressing machine under a predetermined pressure setting.

Following the molding process, a secondary drying step was conducted to ensure the removal of residual moisture, which is essential for improving combustion performance and shelf life. Once the briquettes reached a stable moisture level, laboratory testing was carried out. A bomb calorimeter was used to determine the calorific value, while moisture content and ash content were analyzed using an oven and a furnace, respectively. The compressive strength of the briquettes was measured using a compression testing apparatus, and the combustion rate was observed by recording the time required for complete burning under controlled conditions.

All data obtained from the laboratory tests were analyzed descriptively to identify trends and evaluate the performance of each composition. This approach allowed for the comparison of different briquette formulations in terms of both thermal efficiency and mechanical durability.

# Results and Discussion

## Review of Previous Studies

Table 1 presents a comparison of relevant previous research findings on biomass briquette optimization [8]. A study achieved the highest calorific value (4800 kcal/kg) using sawdust as the primary material and lignin as a binder [9]. This high calorific value is attributed to lignin’s dual role as both a binder and a contributor to energy content due to its high carbon content [8].

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| **TABLE 1.** Table of Previzous Research Results. | | | | | | | |
| **Researcher (Year)** | **Raw Material** | **Optimal Composition** | **Calorific Value (kcal/kg)** | **Ash Content (%)** | **Compressive Strength (kg/cm²)** | **Moisture Content (%)** | **Main Method** |
| Zhang et al. (2021) | Rice husk + tapioca flour | 80:20:00 | 4,200 | 18 | 25 | 8 | Carbonization 450°C |
| Rahman et al. (2020) | Rice husk + sawdust | 50:50:00 | 3,950 | 15 | 18 | 10 | Pressure 150 kg/cm² |
| Chen et al. (2022) | Carbonized rice husk | 100% | 4,500 | 12 | 30 | 6 | Carbonization temperature 500°C |
| Poddar et al. (2021) | Sawdust + lignin | 70:30:00 | 4,800 | 5 | 35 | 7 | Lignin binder 10% |
| Tumuluru (2020) | Biomass mixture | 60:40 | 3,800 | 20 | 15 | 12 | Hydraulic pressing |

On the other hand, another study demonstrated that carbonization pretreatment on rice husk successfully reduced ash content to as low as 12%, the lowest among the compared studies [10]. Carbonization at 500°C effectively lowered inorganic compounds such as silica, which are the main contributors to high ash content.

In terms of mechanical strength, the use of lignin as a binder also yielded the highest compressive strength (35 kg/cm²), outperforming other studies that used conventional binders such as tapioca flour [11][12]. These findings provide important references for the present study in optimizing the composition of rice husk–sawdust briquettes, particularly in binder selection and appropriate pretreatment methods.

## Experimental Results and Comparison

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**Figure 1.** Initial stages of briquette production: (a) heating of raw material (rice husk) over an open fire stove, (b) carbonization process indicated by smoke release during pyrolysis, (c) continued heating to ensure complete conversion to char, and (d) cooled and crushed char ready for mixing in the next stage.

Table 2 compares the experimental results with those of various other briquette types, including coal, coconut shell charcoal, rice husk, and sawdust.

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| **TABLE 2.** Experimental Results Compared to Other Briquettes. | | | | | |
| **Test Parameter** | **Coal** | **Coconut Charcoal** | **Rice Husk** | **Sawdust** | **This Study** |
| Calorific Value (kcal/kg) | 5000–7000 | 6500–7500 | 3000–4500 | 4000–4800 | 5160 |
| Ash Content (%) | 5–15 | 2–5 | 10–20 | 1–5 | 27 |
| Moisture Content (%) | 8–12 | ≤8 | ≤10 | ≤12 | 96.4 |
| Compressive Strength  (kg/cm²) | 30–50 | 20–40 | 15–30 | 10–25 | 5–15 |
| Burning Rate (hours) | 1.5–3 | 2–4 | 1–2 | 1–2 | 1–2 |

The experimental phase of this study began with the carbonization of rice husk, as depicted in Fig. 1. The process involved heating rice husk over an open flame using a traditional stove. Initially, the biomass was exposed to direct heat to initiate pyrolysis. This was marked by the release of smoke; a visual indicator of volatile compounds being driven off. Continued heating ensured the full carbonization of the material, producing rice husk char. The final product, shown after cooling, was subsequently ground into fine particles for mixing with sawdust and binder in the briquette fabrication stage. This pretreatment step is essential for reducing moisture content and enhancing the calorific value of the final product.

Laboratory tests on the resulting briquettes revealed a calorific value of 5,160 kcal/kg, which is notably high for biomass briquettes and indicates significant energy potential. This value exceeds those typically found in pure rice husk briquettes (3000–4500 kcal/kg) [10] and pure sawdust briquettes (4000–4800 kcal/kg) [6], placing it closer to the range of coal briquettes (5000–7000 kcal/kg).

Despite the promising energy content, the briquettes showed several limitations. Ash content was measured at 27%, surpassing the recommended commercial standard of <20%, likely due to the naturally high silica content in rice husk. Moisture content was extremely high at 96.4%, well above the acceptable threshold, potentially caused by incomplete drying and the hygroscopic nature of the binder. This condition may lead to inefficient combustion and excessive smoke.

Mechanically, the briquettes exhibited a compressive strength between 5–15 kg/cm², indicating limited durability in comparison to commercial briquettes made from coconut shell (20–40 kg/cm²) or coal (30–50 kg/cm²). The burning rate ranged from 1 to 2 hours, which is comparable to other biomass briquettes, although the high moisture content might delay ignition and affect combustion stability.

In summary, the experimental briquettes demonstrated favorable energy properties but were hindered by high ash and moisture contents and relatively low mechanical strength. These findings suggest that while the rice husk–sawdust mixture holds promise as a renewable fuel source, further optimization—particularly in drying and binder selection—is necessary to meet commercial standards.

## Detailed Analysis

The high calorific value of 5160 kcal/kg confirms the substantial energy potential of the briquette composed of rice husk and sawdust. This value surpasses that of pure rice husk (3000–4500 kcal/kg) and pure sawdust briquettes (4000–4800 kcal/kg), though it remains below that of coconut shell briquettes (6500–7500 kcal/kg). The discrepancy is likely attributed to differences in fixed carbon and volatile matter content [6].

The ash content, measured at 27%, exceeds the commercial standard of less than 20% as outlined in the Indonesian SNI for biomass briquettes [5]. This elevated ash level may stem from the high silica (SiO₂) content naturally present in rice husk, as well as from a carbonization process that was not optimally executed.

The moisture content reached 96.4%, far above the acceptable limit of 12% for commercial-grade briquettes. This extreme level of moisture can impair combustion efficiency and produce excessive smoke. It is likely caused by an incomplete drying process or the use of binders with hygroscopic properties that absorb moisture from the environment.

The compressive strength, ranging from 5 to 15 kg/cm², falls below the typical range for commercial briquettes—which is approximately 30–50 kg/cm² for coal-based briquettes and 20–40 kg/cm² for coconut shell briquettes [13]. This relatively low mechanical strength suggests that the briquettes may not withstand handling, storage, or transport effectively. Contributing factors may include low-density biomass composition and insufficient compaction pressure during the forming process.

The burning rate of 1–2 hours is within the typical range for biomass briquettes, indicating reasonable combustion duration. However, the excessive moisture content may delay ignition and hinder combustion stability.

## Summary of Findings

The briquettes produced in this study exhibit several promising attributes that support their potential as a renewable energy source. One of the most notable findings is the calorific value of 5,160 kcal/kg, which surpasses that of typical biomass briquettes derived from pure rice husk (3,000–4,500 kcal/kg) [10] and sawdust (4,000–4,800 kcal/kg). This energy level approaches the calorific range of coal (5,000–7,000 kcal/kg) [8], highlighting the briquettes’ suitability as a competitive alternative fuel. Furthermore, the primary raw materials—rice husk and sawdust—are readily available waste products from agricultural and wood processing activities, making them both economically and environmentally sustainable feedstocks [3].

However, the briquettes are not without limitations. The recorded ash content of 27% is significantly higher than the commercial standard, which generally recommends a maximum of 20%. Elevated ash levels reduce combustion efficiency and increase residue disposal burdens. As indicated by previous studies [9], this issue is primarily attributed to the high silica (SiO₂) content inherent in rice husk. To mitigate this, two technical strategies are recommended: (1) elevating the carbonization temperature to 500–600°C to volatilize more mineral content, and (2) pretreating the rice husk via washing before carbonization to remove surface impurities and soluble inorganic compounds.

The most critical concern lies in the moisture content, which was found to be excessively high at 96.4%. Optimal moisture content for efficient briquette combustion is typically below 12% [14]. Excessive moisture hinders ignition, prolongs drying time during combustion, and generates smoke. To resolve this, intensive drying is necessary—such as oven-drying at 105°C for 24 hours in accordance with ASTM D3173. Additionally, selecting binders with lower hygroscopicity, such as tapioca starch [10], may help prevent moisture absorption during storage and handling.

The briquettes’ mechanical strength is also a concern, with compressive strength ranging only from 5 to 15 kg/cm², rendering them vulnerable to cracking and fragmentation during transport or storage. One effective measure to enhance structural integrity is increasing the compaction pressure during the molding process, ideally to at least 150 kg/cm², to achieve denser and more cohesive briquettes.

In summary, while the briquettes show substantial promise in terms of calorific value and material availability, further optimization—especially in pretreatment, drying, and compaction techniques—is essential to meet industry performance standards and ensure the briquettes' viability as a sustainable fuel option.

# CONCLUSION

This study demonstrates that rice husk-sawdust blended briquettes exhibit a high calorific value (5,160 kcal/kg), positioning them as a viable renewable energy alternative. However, critical challenges were identified, including elevated ash content (27%), excessive moisture levels (96.4%), and suboptimal compressive strength (5–15 kg/cm²). These limitations primarily stem from inadequate drying processes, raw material pretreatment, and binder efficiency.

To enhance briquette quality, three key optimizations are recommended: (1) implementing higher drying temperatures (>100°C) to reduce moisture content, (2) introducing chemical or thermal pretreatment (e.g., torrefaction) to minimize ash formation, and (3) adjusting compaction pressure (200+ psi) and binder composition (e.g., starch derivatives) to improve mechanical strength.

With these refinements, the optimized briquettes hold significant potential for household and small-scale industrial applications, offering a sustainable solution to both energy demands and agricultural waste management. Future work should focus on scalability and cost-benefit analysis to facilitate commercial adoption.

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