



Production and Characterization of Biomass Briquettes from Water Hyacinth (*Pontederia crassipes*) and Ipil-Ipil (*Leucaena leucocephala*) as an Alternative Industrial Energy Source

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ABSTRACT :

The growing demand for energy and increasing biomass waste have created environmental challenges that require sustainable solutions. Biomass briquettes offer an alternative fuel by converting organic waste into useful energy while reducing dependence on fossil fuels. Water Hyacinth (*Pontederia crassipes*) and Ipil-Ipil (*Leucaena leucocephala*) are abundant biomass resources with potential for briquette production. Water Hyacinth threatens aquatic ecosystems, while Ipil-Ipil produces underutilized biomass. This study aims to produce and characterize charcoal briquettes from these materials by evaluating their physical and fuel properties and potential as an industrial energy source. It also supports SDGs 7, 12, 13, and 15

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Introduction

Charcoal briquettes are widely recognized as a sustainable and renewable alternative fuel because they are produced from biomass and agricultural waste materials that would otherwise be discarded or burned. Their production contributes to waste reduction, environmental conservation, and the efficient utilization of renewable resources while providing a practical source of energy for household and industrial use. The quality of charcoal briquettes depends on several factors, including the type of raw materials, calorific value, and the binder used during production. A higher calorific value indicates greater heating efficiency, while suitable binders such as starch improve the briquettes' durability and combustion performance. Compared to conventional fossil fuels, biomass briquettes generate lower net greenhouse gas emissions and promote cleaner energy utilization, making them a cost-effective and environmentally friendly fuel option. These characteristics highlight the potential of charcoal briquettes as an alternative energy source that supports both sustainable waste management and renewable energy development (Nonsawang, 2024). According to (Gao, 2026) Biomass has gained increasing attention as a renewable energy source because it can convert waste materials into cleaner and more sustainable fuels. A recent study investigated an integrated combustion system that combined wood biomass with charcoal in a porous media burner to improve combustion efficiency and hydrogen-rich syngas production. The findings showed that adding charcoal affected the combustion process, with some types extending the reaction time and increasing hydrogen production more effectively than others. Furthermore, the amount and particle size of longan charcoal influenced the hydrogen yield, with moderate levels producing the highest hydrogen concentration. The researchers also found that the characteristics of the heat storage material and the composition of the wood biomass contributed to better combustion performance and greater hydrogen selectivity. These results suggest that the properties of biomass materials and combustion conditions greatly influence the quality and energy output of biomass-based fuels. This study supports the continued development of biomass fuels, including charcoal briquettes made from plant-based materials, as an environmentally friendly alternative energy source while helping reduce waste and pollutant emissions.

Biomass briquetting has become a practical approach for converting agricultural and forestry residues into smokeless fuel, providing a cleaner and more sustainable alternative to traditional solid fuels. This technology helps reduce the amount of biomass waste that is often discarded or burned openly, while also producing a renewable energy source for household and industrial applications. In many developing countries, large quantities of agricultural residues, such as rice husks, corn cobs, groundnut shells, cotton stalks, and other crop by-products, remain underutilized despite their potential as energy resources. As a result, briquetting offers an effective method of improving biomass utilization through carbonization, which transforms raw organic materials into compact, energy-rich briquettes with lower smoke emissions. Moreover, biomass is considered a dependable renewable energy source because it can generate heat and electricity while helping reduce carbon dioxide emissions compared with conventional fossil fuels. Since biomass originates from biological materials such as plant residues, forestry waste, and other organic resources, its conversion into briquettes supports waste

management and promotes a more sustainable energy system. These findings highlight the growing importance of biomass briquettes as an environmentally friendly fuel that can address waste disposal challenges while contributing to cleaner energy production (Tanko, 2023). Furthermore, numerous studies (Melenia, 2024) have explored different biomass materials and production factors to improve the quality and performance of biomass briquettes. Corncoobs have been widely investigated, with findings showing that increasing the adhesive concentration can enhance combustion performance and calorific value, particularly in square-shaped briquettes. Likewise, biomass briquettes have been recognized as a more affordable and renewable alternative to conventional fuels, making them suitable for both household and industrial applications. Similar research has examined the use of water hyacinth, rice husks, peanut shells, and coconut shells as raw materials, demonstrating that the type of biomass, adhesive composition, and production conditions all influence the fuel's quality and burning efficiency. Studies also reported that higher adhesive concentrations generally improve the calorific value and thermal properties of briquettes, especially those produced from coconut shells. These findings suggest that a wide range of agricultural and plant-based wastes can be converted into efficient biomass briquettes when appropriate materials and processing methods are applied. Organic biomass waste contains lower sulfur and nitrogen than coal, its lower combustion efficiency makes direct use less practical for energy production. To overcome this limitation, bio-coal briquetting has been developed to improve fuel performance while reducing emissions of pollutants such as NO_x, SO_x, CO, and H₂S. However, studies have reported that the use of bio-coal briquettes may still cause respiratory discomfort when used in poorly ventilated kitchens or with traditional stove designs. As a result, researchers have improved stove designs to enhance ventilation and heat efficiency, while emphasizing the need for further evaluation of their environmental, economic, and health impacts (Khan, 2023).

The study (Melenia, 2024) investigated how different proportions of coconut shell charcoal and corncob charcoal affect the characteristics of biomass briquettes. The results showed that increasing the amount of coconut shell charcoal improved the calorific value and overall fuel quality, while higher corncob content produced briquettes that burned more quickly but with lower energy efficiency. Briquettes containing 90% coconut shell charcoal and 10% tapioca starch adhesive exhibited the best overall performance and satisfied most of the required quality standards. These findings demonstrate that the type and proportion of biomass materials directly influence briquette performance and can guide the production of more efficient and sustainable alternative fuel. The growing demand for energy in Southeast Asia has increased the search for renewable and environmentally friendly energy sources. While fossil fuels remain the primary source of energy, their continued use contributes to greenhouse gas emissions, air pollution, and the depletion of nonrenewable resources. These concerns have encouraged researchers to explore biomass as an alternative fuel because it is renewable, widely available, and can utilize agricultural and invasive plant waste that might otherwise be discarded. Converting biomass into briquettes also improves its energy density, handling, storage, and combustion efficiency, making it more suitable for industrial and domestic applications (Nikhom, 2024). Energy is essential for daily life, and the growing demand for cleaner energy has increased interest in renewable and environmentally friendly alternatives (Siharath, 2024). At the same time, agricultural residues, plantation by-products, and other biomass wastes provide a readily available resource that can be converted into useful energy while supporting waste reduction and circular economy practices. Furthermore, biomass fuels with lower ash, sulfur, and nitrogen contents can help reduce environmental pollution, making them a cleaner option than many conventional fuels. Previous studies have also reported promising calorific values for coconut shell charcoal, bamboo charcoal, and mixed charcoal, indicating their potential as effective biomass-based fuel sources. Energy is essential for daily life, and the increasing demand for cleaner energy has encouraged the development of renewable and environmentally friendly alternatives. In this context, agricultural residues, plantation by-products, and other biomass wastes have gained attention because they can be converted into useful energy while reducing waste and supporting sustainable resource use. Moreover, biomass fuels generally contain lower amounts of ash, sulfur, and nitrogen, which can help lessen air pollution compared with many conventional fuels. Previous studies have also reported favorable heating values for biomass materials such as coconut shell charcoal, bamboo charcoal, and mixed charcoal, demonstrating their potential as efficient and sustainable fuel sources (Sari, 2026).

The continuous rise in global energy demand, driven by population growth and economic development, has increased the need for renewable and sustainable energy sources as fossil fuel reserves continue to decline. Among the available alternatives, biomass has gained attention because it can be obtained from agricultural residues, forest waste, aquatic plants, animal manure, and other organic materials that are widely available. However, the traditional practice of directly burning biomass remains inefficient and may contribute to environmental pollution and health concerns, making improved utilization methods necessary. Consequently, converting biomass into briquettes offers a practical solution because it improves combustion efficiency, increases energy density, and makes the fuel easier to store, handle, and transport compared with loose biomass (Abie, 2025). The growing demand for energy driven by industrialization has increased dependence on fossil fuels, resulting in higher greenhouse gas emissions that contribute to climate change and environmental degradation. As these emissions continue to accumulate, their effects have become more evident through rising global temperatures, prolonged droughts, stronger flooding events, disruptions to natural ecosystems, and changes in ocean conditions, including warming, acidification, and rising sea levels. Furthermore, industrial activities and transportation remain the largest sources of greenhouse gas emissions because they rely heavily on fossil fuel consumption (Alemán-Ramírez, 2022). Consequently, researchers continue to explore cleaner energy technologies and carbon reduction strategies to reduce emissions and support the transition toward a more sustainable energy system.

Results and Discussions

This chapter presents, analyzes, and interprets the experimental results on the proximate and combustion properties of the fuel briquettes produced using the Control and three treatment formulations. The discussion is organized according to the statements of the problem. Descriptive statistics are first used to characterize ash content, volatile matter, fixed carbon content, and fuel ignition time. One-way analysis of variance (ANOVA) is then used to determine whether the four formulations differ significantly for each fuel property, followed by Tukey HSD post-hoc comparisons to identify the specific formulation pairs responsible for the observed differences. The findings are interpreted in terms of combustion behavior and practical fuel performance and are compared with recent studies on biomass and bio-briquette characterization.

Table 1: The fuel properties of the Control and three treatment formulations were described in terms of ash content, volatile matter, fixed carbon content, and fuel ignition time.

Table 1 presents the mean and standard deviation obtained from three trials for each formulation. These descriptive values provide the initial basis for comparing the combustion-related characteristics of the briquettes before inferential statistical testing.

Table 1. Descriptive Statistics of the Fuel Properties of the Briquette Formulations

Property Control	Control	Treatment 1	Treatment 2	Treatment 3
Ash Content (%)	9.25 ± 0.15	7.82 ± 0.12	6.18 ± 0.13	6.74 ± 0.14
Volatile Matter (%)	66.40 ± 0.30	69.15 ± 0.25	72.10 ± 0.30	72.10 ± 0.30
Fixed Carbon (%)	24.35 ± 0.45	23.03 ± 0.37	21.72 ± 0.43	21.72 ± 0.43
Ignition Time (s)	54.67 ± 2.52	43.33 ± 1.53	31.67 ± 1.53	36.33 ± 1.53

Figure 1. Mean Ash Content of the Briquette Formulations

Figure 1 provides a visual comparison of ash content across the four formulations. The error bars represent one standard deviation across the three trials.

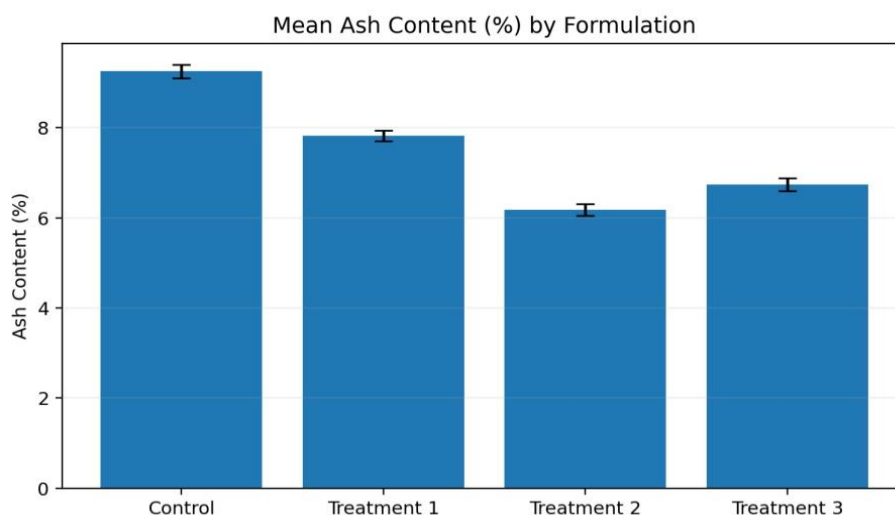


Figure 2. Mean Volatile Matter of the Briquette Formulations

Figure 2 shows the corresponding pattern for volatile matter, emphasizing the progressive increase from the Control to Treatment 2 before a slight decrease in Treatment 3.

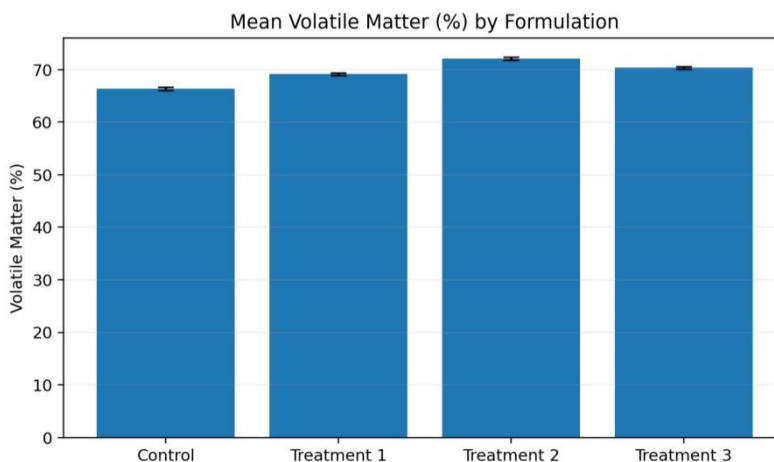
**Figure 3. Mean Fixed Carbon Content of the Briquette Formulations**

Figure 3 presents the mean fixed carbon content of each formulation and highlights the comparatively higher value retained by the Control.

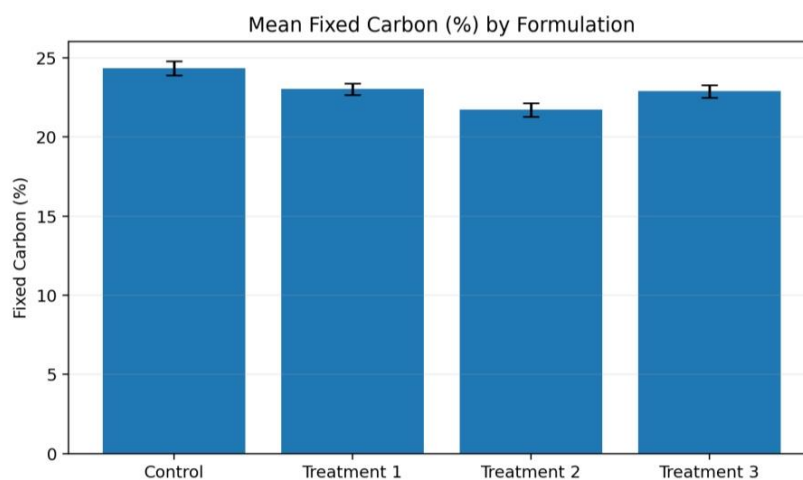
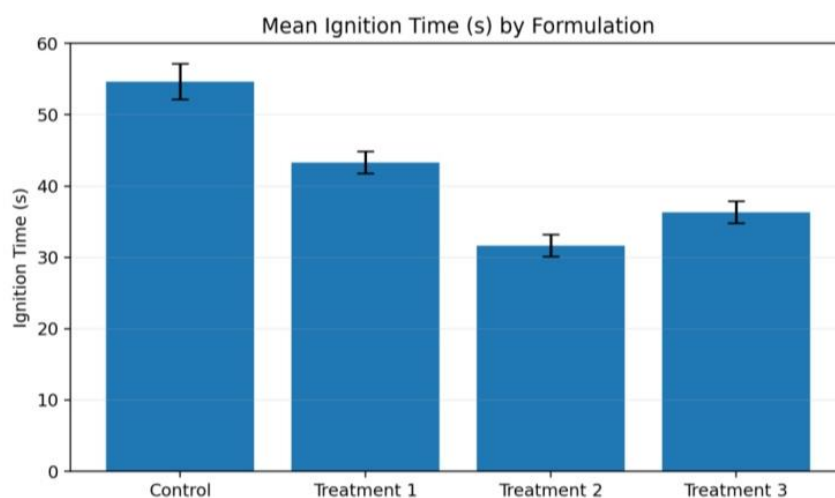
**Figure 4. Mean Fuel Ignition Time of the Briquette Formulations**

Figure 4 shows the ignition-time pattern, where the treatment formulations required less time to ignite than the Control.



The descriptive results suggest that modifying the briquette formulation can substantially change how the fuel behaves during combustion. Treatment 2 is particularly promising when the desired properties are low ash residue and rapid ignition, because it combined the lowest ash content with the highest volatile matter and shortest ignition time. However, its lower fixed carbon indicates that formulation selection should not be based on ignition performance alone. Treatment 3 may represent a more balanced profile because it retained more fixed carbon than Treatment 2 while still producing relatively low ash and a short ignition time. These findings indicate that the preferred formulation should depend on the intended application, such as rapid household ignition versus a stronger emphasis on sustained char combustion. The observed relationships are consistent with recent biomass-briquette literature. Liu et al. (2021)

reported that corn-straw briquettes with relatively high volatile matter and low ash showed favorable combustion behavior and noted that volatile matter influences the early combustion stage. Kebede et al. (2022) similarly demonstrated that biomass residue and binder selection changes ash, volatile matter, fixed carbon, and calorific performance, showing that briquette quality is strongly formulation-dependent. Yirijor and Bere (2024) also found that binder type, binder concentration, and particle size changed proximate properties and ignition performance in coconut-shell bio-briquettes. More recently, Gebrezgabher et al. (2025) observed that briquette formulations with higher volatile matter could exhibit lower ignition time, directly supporting the pattern observed between Treatment 2 and the Control in the present study. The numerical values should not be expected to match across studies because feedstock composition, carbonization, binder, particle size, moisture, compaction pressure, and test procedures differ.

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