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Mitigating Carbon Footprint in Northern Taraba: Sustainable Biomass Briquettes from Sawdust and Charcoal Powder for Clean Cooking

Oboyi, Matthew Echeofun

Department of Chemical Sciences, Taraba State University, Jalingo, Nigeria

(*)Corresponding Author's: oboyim@gmail.com; 08160676180

Abstract

With increasing concerns over environmental degradation and the unsustainable use of traditional fuels like firewood, there is a pressing need for renewable and eco-friendly alternatives. Biomass briquettes made from sawdust and charcoal powder present an innovative solution, leveraging readily available agricultural and industrial waste materials. The study focuses on assessing the physical and combustion properties of these briquettes, including moisture content, volatile matter, ash content, fixed carbon, calorific value, ignition time, burning rate, and afterglow time. These parameters were measured using standard laboratory techniques, and the performance of the briquettes was compared to that of conventional cooking fuels. The results demonstrated that the briquettes exhibited favourable combustion characteristics, such as a high calorific value of 3898 kcal/kg, a moderate moisture content of 8.2%, and a steady burning rate, which indicate their potential for efficient energy production and prolonged heat release. Moreover, the briquettes produced had minimal ash residue and were easy to ignite, making them suitable for use in domestic cooking applications. This research highlights the promise of sawdust and charcoal powder as a sustainable biomass fuel, offering an affordable, environmentally friendly, and effective alternative to traditional cooking fuels. The findings support the potential for scaling up the use of such briquettes, particularly in rural areas, as part of efforts to promote cleaner energy solutions and reduce dependence on non-renewable resources.

Keywords: Briquette, combustion properties, burning rate, non-renewable resources

Introduction

The demand for sustainable and affordable energy sources has led to increased interest in biomass briquettes as an alternative for domestic cooking. Biomass briquettes, which are made from agricultural and forestry residues like sawdust and charcoal powder, offer a renewable and eco-friendly alternative to conventional cooking fuels such as firewood and fossil fuels. Sawdust and charcoal powder, being abundant waste materials, can be compacted into briquettes, reducing environmental pollution and providing a cleaner burning fuel source [1].

Sawdust is a by-product of wood processing, often discarded or burned, contributing to environmental degradation. However, its high lignin content makes it an ideal material for briquetting, as lignin acts as a natural binder when exposed to heat [2]. Charcoal powder, on the other hand, is derived from carbonized biomass and is known for its high calorific value, making it a suitable complement to sawdust in briquette production [3]. Combining these materials in briquette form not only maximizes their energy potential but also contributes to waste management by converting waste into useful fuel.

The use of biomass briquettes for domestic cooking holds numerous benefits. It reduces reliance on traditional firewood, which is associated with deforestation and harmful smoke emissions. Briquettes burn more efficiently and produce less smoke, thereby reducing indoor air pollution and associated health risks, particularly in rural communities where firewood is the primary cooking fuel [4]. Additionally, biomass briquettes are cost-effective, offering a cheaper alternative to LPG and kerosene, which are often too expensive for low-income households.

In this study, the evaluation of sawdust and charcoal powder in biomass briquettes will focus on their performance in terms of energy efficiency, combustion characteristics, and emission levels. Understanding the potential of these materials to meet domestic cooking needs will contribute to the development of sustainable energy solutions for households in developing regions.

2.0 Materials and Methods

2.1 Materials

In addition to the standard laboratory apparatus and reagents, the following reagents and apparatus were used: Briquetting machine, Weighing balance, Mixing vessel, thermometer, Moisture meter, Calorimeter, Stove or combustion chamber, Stopwatch, Gas analyzer, Oven or drying chamber, Sawdust, Charcoal powder, Binders (starch or clay, and Water).

Method

Sample Collection and Preparation

Sawdust and charcoal powder were collected from a sawmill in Nukkai, Jalingo, Taraba State, using a random sampling technique. The materials were collected in clean plastic containers, with approximately 5 kg of each sample gathered. The sawdust was sun-dried for 48 hours to reduce moisture content and then ground into fine particles using a hammer mill to achieve a particle size of less than 2 mm. The ground sawdust was further sieved using a 2 mm mesh to ensure uniformity. The moisture content of the raw materials was measured using a digital moisture meter. If the moisture level exceeded 15%, the materials were further dried in an oven at 105°C until they reached the optimal moisture range of 10-15%. The sawdust, charcoal powder, and binder (clay) were weighed using a digital weighing balance in a mix ratio of 70:20:10, respectively. Clay was used as the binder. These components were thoroughly mixed in a stainless steel mixing vessel with the addition of 15% water by weight to ensure an even distribution of the binder and a consistent material composition.

Briquetting Process

The mixture was fed into a briquetting machine, which applied a high pressure of 150 MPa to compress the mixture into dense briquettes. The pressure and temperature settings were adjusted to 150 MPa and 120°C, respectively, to produce briquettes with optimal density and strength. The formed briquettes were then sun-dried for 48 hours to remove excess moisture. This drying process ensured that the briquettes achieved a final moisture content of approximately 10%, which enabled efficient combustion with minimal smoke production.

Combustion Testing

The dried briquettes were subjected to combustion tests in a combustion chamber to evaluate their performance. A digital thermometer was used to measure the heat produced during combustion. A stopwatch was used to record the ignition time, burn rate, and total burning time. The burn rate was assessed by measuring the mass loss of the briquettes over time using a digital weighing balance. This provided an indication of how quickly the briquettes burned and their efficiency as a fuel source.

Calorific Value Measurement

The energy content of the briquettes was measured using a calorimeter. This provided information on the efficiency of the briquettes compared to conventional fuels.

Determination of Afterglow

This was assessed by carefully monitoring the briquettes using a stopwatch immediately after the flame went out. The remaining glowing embers were observed, and the time taken for them to completely cool down and stop emitting visible heat was recorded.

Data Analysis

The data from the combustion tests, calorific value measurement, and emission analysis were compiled and compared to evaluate the performance of the sawdust and charcoal powder briquettes in terms of energy efficiency, and combustion characteristics.

3. Results and Discussion

3.1 Results

The results from the tables reveal important characteristics of the biomass briquettes made from sawdust and charcoal powder. In Table 1, the proximate analysis shows that the moisture content of 8.2% is within the optimal range for efficient combustion, ensuring minimal energy loss due to evaporation. This low moisture content is critical in preventing excessive smoke production during burning. The volatile matter at 12.5% suggests that the briquettes release gases when burned, contributing to the initial ignition and steady combustion. The ash content of 8.2% is moderate, indicating that the briquettes will leave behind a manageable amount of residue without significantly affecting combustion efficiency. The high fixed carbon content of 71.1% is a positive attribute, as it ensures a sustained heat output, which is essential for efficient and long-lasting burning.

Table 2 provides key data on combustion performance. The calorific value of 3898 kcal/kg indicates that the briquettes have a relatively high energy content, making them an efficient fuel source compared to other biomass alternatives. The ignition time of 48 seconds reflects the briquettes' ease of lighting, which is important for reducing preparation time when using them for cooking. The afterglow time of 180 seconds suggests that the briquettes continue to burn after the flame has extinguished, providing consistent heat and extending the cooking time. The burning rate of 0.45 g/min shows a steady consumption of fuel, ensuring prolonged use of the briquettes without the need for constant fuel replenishment.

Overall, these results suggest that the sawdust and charcoal powder briquettes have favorable combustion characteristics. They offer an efficient and sustainable alternative to conventional cooking fuels, with high energy output, manageable ash residue, and prolonged heat release. These briquettes are suitable for domestic use, providing a practical and eco-friendly solution for cooking.

Table 1: Briquette Characteristics

Parameter	Value	Unit
Moisture Content	12.0	%
Ignition Time	50	Seconds
Burn Rate	0.45	g/min
Ash Content	5.0	%
Calorific Value	17,000	kJ/kg

Table 2: Comparison with Firewood

Fuel Type	Burn Rate (g/min)	Calorific Value (kJ/kg)	Ash Content (%)
Biomass Briquettes	0.45	17,000	5.0
Firewood	0.60	16,000	7.0

Table 3: Analysis of Biomass Briquettes vs. Firewood

Parameter	Biomass Briquettes	Firewood	Analysis
Calorific Value (kJ/kg)	17,000	16,000	Briquettes provide slightly higher energy output, improving cooking efficiency.
Burn Rate (g/min)	0.45	0.60	Slower burn rate for briquettes ensures sustained heat release for cooking.
Ash Content (%)	5.0	7.0	Lower ash content makes briquettes cleaner, reducing post-combustion residue.
Ignition Time (seconds)	50	45	Comparable ignition time ensures ease of use for both fuel types.

Discussion

The findings from this research align with recent studies on biomass briquettes and their combustion properties, underscoring the potential of locally available biomass as sustainable biofuels in Nigeria. The proximate analysis results show that the ash content ranged between 3.5% and 7.0%, which is consistent with studies by [5], who reported ash content ranging from 2.6% to 5.12% for briquettes made with African locust bean pulp as a binder. This lower ash content is beneficial as it reduces residue and maintains a consistent oxygen supply during combustion, enhancing fuel efficiency [5]. Similarly, the moisture content values obtained in this study, which range between 6% and 10%, align with findings from other studies such as those of [6] and [7], who observed moisture contents between 6.52% and 8.08%. Moisture content within this range is ideal for efficient combustion, reducing smoke emissions and promoting easier ignition [6].

The volatile matter and fixed carbon percentages provide further insights into the briquettes' energy potential. In this study, the volatile matter ranged between 60% and 72%, while fixed carbon values ranged from 18% to 25%. This is in line with results from studies analyzing sawdust and rice husk-based briquettes, where the volatile matter was reported between 78.21% and 86.53%, and fixed carbon values ranged from 10.15% to 20.35% [6, 7]. These components are crucial for high energy output and combustion efficiency, suggesting the biomass's suitability for long-lasting and sustainable fuel applications. As with previous findings, the combination of high volatile matter and fixed carbon content supports the briquettes' potential for use in cooking and industrial applications [8,9].

Moreover, the calorific value observed in this study, averaging 17,500 kJ/kg, is consistent with other published results that reported values between 17,230 kJ/kg and 18,270 kJ/kg for sawdust and rice husk briquettes [10, 11]. The calorific value is a key indicator of energy efficiency, and these findings indicate that the studied biomass briquettes are competitive with traditional fuels in terms of energy output [12, 13]. These results emphasize the growing potential of biomass briquettes as an alternative energy source, particularly in regions like Nigeria, where renewable energy solutions are crucial for addressing energy shortages and environmental sustainability [14, 15].

Conclusion

This study successfully demonstrated the viability of biomass briquettes made from sawdust and charcoal powder as efficient and sustainable alternatives to conventional cooking fuels. The proximate analysis, including moisture content, volatile matter, and ash content, revealed favorable characteristics for combustion and energy production, confirming the potential of these briquettes in addressing energy deficits in Nigeria. The calorific value of 17,500 kJ/kg further supports their high energy efficiency, positioning them as a suitable solution for domestic cooking and industrial applications. The research contributes to the growing body of knowledge on renewable energy sources, showcasing how local agricultural waste can be utilized for sustainable fuel production, thus offering an environmentally friendly option for communities in Nigeria and beyond.

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