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PRODUCTION AND CHARACTERIZATION OF BIOBRIQUETTE FROM BIOMASS OF MANGO LEAF, SAW DUST AND RICE HUSK AS EFFICIENT ENERGY SOURCES FOR COOKING

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ABSTRACT

The increasing demand for sustainable energy solutions has driven interest in alternative biomass sources for energy production. This study investigates the production and characterization of bio briquettes made from different biomass of mango leaves, sawdust, and rice huskusing limestone as binder. The objective is to evaluate the potential of these biomass materials as efficient energy sources for cooking. The bio briquettes were produced using a standard briquetting process, involving mixing, compaction, and drying. Various parameters including ultimate and proximate composition, calorific value, bulk density, hardness and durability as well as mechanical and combustion properties were analyzed to assess their performance. The results demonstrated that the bio briquettes exhibited high calorific values between 20753 to 20506 KJ/kg and high percentage of fixed carbon between 4.18 to 5.58 % which generally indicates good fuel performance.The results also indicated that the bio briquettes has low Sulphur content and high volatile matter content between 50.53 to 62.84 % an indication that they are ecofriendly and can easily burn to yield energy. The bio briquettes of mango leaves, sawdust, and rice husk not only leverages agricultural waste but also contributes to reducing dependency on non-renewable energy sources. This research underscores the potential of utilizing locally available biomass for sustainable energy solutions and offers insights into improving the efficiency of bio briquette production.

Keywords: bio briquette, mango leaf, saw dust, rice husk, carbonization

INTRODUCTION

Bio briquettes are a renewable and eco-friendly energy source that has gained significant attention in recent years. Bio briquettes are a sustainable and renewable source of energy derived from biomass materials [1-2]. They serve as an alternative to conventional fuels such as coal and wood. The production of bio briquettes offers several environmental benefits, including reduced greenhouse gas emissions, waste reduction, and conservation of natural resources. As the world faces the challenges of climate change and the need to reduce greenhouse gas emissions, alternative energy solutions like bio briquettes have emerged as a sustainable option. Bio briquettes are compacted blocks of biomass materials that can be used as a substitute for traditional fossil fuels such as coal, oil, and natural gas [3-4].

The production of bio briquettes typically involves the use of organic materials such as agricultural residues, wood waste, sawdust, or other biomass sources [5-6]. These materials are compressed under high pressure without the need for additional binders or chemicals, resulting in solid fuel briquettes with a consistent shape and density.One of the key advantages of bio

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briquettes is their carbon neutrality. When burned, they release only the amount of carbon dioxide (CO_2) that was absorbed by the biomass during its growth, making them a sustainable and low-carbon alternative [5-6]. Additionally, bio briquettes help mitigate the problem of waste disposal by utilizing agricultural and forestry residues that would otherwise be left unused or burned, contributing to air pollution [1-3].

Bio briquettes offer several benefits over traditional fuels. They have a higher calorific value, which means they provide more energy per unit of mass making them an efficient and cost-effective fuel option. They also have a lower moisture content, which allows for better combustion and reduced emissions. Bio briquettes can be used in various applications, including heating and cooking in households, industrial processes, and power generation [4].The production and use of bio briquettes promote sustainable development by reducing reliance on fossil fuels, minimizing waste, and contributing to rural development. They can be produced locally, creating employment opportunities and income generation in rural areas. Furthermore, bio briquettes contribute to the preservation of natural resources by utilizing biomass that would otherwise decompose or be left unused.

Mango leaves, saw dust and rice husk are abundant agricultural residue and are often considered as waste. Utilizing these waste materials, bio briquette production can provide an effective solution for both waste management and energy generation.

The characterization of bio briquettes is an essential step to evaluate their quality and suitability as a fuel source. Various parameters are assessed, including calorific value, moisture content, ash content, volatile matter, and fixed carbon content. These parameters determine the combustion efficiency, energy content, and environmental impact of the bio briquettes [5]. Additionally, other physical and mechanical properties, such as density, durability, and compressive strength, are also analyzed.

The utilization of mango leaves,saw dust and rice husk wastes for bio briquette production has several advantages. Firstly, it helps to reduce the environmental impact of waste materials by converting them into a valuable energy source. Secondly, it reduces the dependence on fossil fuels and contributes to the promotion of renewable energy. Lastly, it offers an additional income source for farmers and waste management industries, as the production of bio briquettes can be economically viable [1-4].In this work, mango leaves, saw dust and rice husk wastes were converted to an ecofriendly bio briquette material as an alternative for fossil fuel. The produced material was assessed for combustion and mechanical properties to ascertain the usefulness as an ecofriendly heating material.

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MATERIALS AND METHOD

Collection of biomass samples and binder

Dried mango leaves, saw dust and rice husk were used in the study. Mango leaves were collected from mango trees within Ebonyi State University, permanent site, Abakaliki,saw dust was collected from timbre shade, Abakaliki, Rice husks was collected from rice mill, Abakaliki. The binder used was $CaCO_3$ sourced from Umuoghara mines in Ebonyi State.

Carbonization of the biomass samples

The collected biomass of mango leaf, rice husk and saw dust were dried for 7 days in the sun and cleaned to remove soil, and then loaded separately to a carbonizer. The carbonization was effected at a temperature of 450^0C. The carbonized samples were ground into powder and kept for further use.

Briquette Production

The production of the bio briquettewas done at chemistry laboratory, Ebonyi State University, Abakaliki. In each production, the proportions of sample (saw dust, rice husk and mango leaf) to binder ratios were 100:0, 90: 10, 80: 20, 70: 30, 60: 40 and 50: 50. Exactly 50 cm^3 of water was carefully added to the mixture for easy compaction of the briquettes.The sample-binder mixture was then hand fed gradually into a hand mould and compacted at a pressure of 344.82 kNm^{-2} and maintained for 20 min with the aid of a plunger. The plunger was then hammered to make the briquette compact after which the bio briquette was removed from the mould. At each level of the binder, 5 replicates were made. The diameter of the bio briquettes were taken at two different points with the help of a digital caliper, the thickness and the weight were carefully recorded.The bio briquette was sun dried for 7 days before further analysis.

Characterization of samples

The produced bio briquette samples were characterized for combustion and mechanicalproperties at Ebonyi State University, Abakaliki and for proximate and ultimate compositions and calorific value at Energy research Centre, University of Nigeria Nsukka. Proximate composition: The method of Efetobor *et al.*, [7] was used for the determination of volatile matter, fixed carbon content, ash content (wt %) and moisture content (%). The calorific value of the bio briquette was determined using oxygen bomb calorimeter model (model XRY-1A). Combustion properties: The ignition time and burning time were evaluated using the method of Davies and Abolude [8]. Water boiling test was determined applying the procedure of Birthwatkar *et al*.,[9] and Kuti [10].

Mechanical properties: The mechanical properties were evaluated using the method of Birtwatkar et al., [9]. Bulk density(g/cm^3) was evaluated as ratio of mass to volume of bio briquette, compressive force was determined using compressive strength testing machine

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(model 2419), the area of the bio briquettedetermined, and compressive strength evaluated as compressive force cross sectional area (mm^2). The durability and porosity index of the fabricated bio briquettes were evaluated using the method of Birtwatkar et al., [9] while the hardness of each bio briquette was evaluated using Seaway Hardness Tester (Type DVRB-P).

RESULTS AND DISCUSSION

The volatile matter content in the sawdust, rice husk, and mango leaf bio briquettes plays a critical role in determining the combustion characteristics and overall efficiency of the briquettes. Mango leaf bio briquettehas the highest volatile matter among the three, which indicates that it has strong potential for combustion (Table 1). A high volatile matter percentage typically means that the material will ignite easily and burn faster because a significant portion of the material is released as gases during combustion. Therefore, rice husk bio briquettes will likely have a longer burn time and might release heat more steadily compared to saw dust and mango leaf bio briquette. Other studies on briquette are consistent with this observation [11-12].

The relatively low ash content (compared to rice husk and mango leaf bio briquettes) suggests that sawdust bio briquettes could have better combustion efficiency (Table 1). Lower ash content generally correlates with cleaner combustion, producing fewer residues.With less ash formed during combustion, the heat output is likely to be higher, making sawdust bio briquettes more efficient for use in heating or cooking applications [13-14]. Rice husk is known to have a higher ash content compared to many other biomass materials, which is reflected in the 35.84% ash content. The higher ash content can lower the calorific value of the bio briquette, meaning that it may produce less energy per unit mass compared to sawdust.Rice husk ash contains a high level of silica, which could impact the use of the ash post-combustion, such as for agricultural or industrial applications [3-4].

The moisture content plays a significant role in the combustion efficiency and durability of bio briquettes. According to Table 1, mango leaf bio briquette has the lowest moisture content which enhances its combustion properties, resulting in higher energy efficiency and reduced smoke during burning.The rice husk bio briquette has the highest moisture content (Table 1) which could negatively affect its combustion by requiring more energy to evaporate the moisture before ignition, thus lowering its heating value and producing more emissions [4-5].

The fixed carbon content in a bio briquette is a key parameter that influences its energy content and combustion characteristics. Sawdust has the highest fixed carbon content among the three bio briquettes (Table 1). Fixed carbon represents the solid combustible material left after volatile substances are released during combustion. A

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higher percentage of fixed carbon generally indicates better fuel performance, as it contributes to a longer burn time and higher energy output [10]. The low fixed carbon may lead to incomplete combustion, contributing to higher emissions as seen in rice husk and this observation is consistent with other studies [11].The calorific value of a material is a key factor in determining its potential as a fuel. In the case of sawdust, rice husk, and mango leaf bio briquettes, their calorific values indicate how much energy can be produced when they are burned. Sawdust is widely available as a byproduct of wood processing industries. A calorific value of 20506 kJ/kg is relatively high, indicating that it can produce a significant amount of heat when burned. Its abundance makes it a popular choice for bio briquette production. Rice husk bio briquette has a calorific value of 20519 kJ/kg, an indication of good burning characteristics which can be a sustainable alternative to traditional fuels. Rice husk however has a higher silica content, which can lead to slagging and fouling in combustion systems and can affect its usability in certain stoves or industrial applications [3-5].

Table 1: proximate and ultimate composition of the bio briquettes

Properties	Saw dust-bio briquette	Rice husk bio briquette	Mango leaf bio briquette
Volatile matter (%)	50.54	61.17	62.64
Ash content (%)	29.89	35.84	40.63
Moisture content (%)	3.59	3.86	3.55
Fixed carbon (%)	5.58	4.13	5.26
Calorific value(KJ/Kg)	20506	20519	20753
Carbon content	44.74	44.10	44.24
Nitrogen content	0.47	0.45	0.46
Sulphur content	0.33	0.35	0.32

The bulk density of bio briquettes made from sawdust, rice husk, and mango leaves shows variations in their compactness and material characteristics. Sawdust bio briquettes, with the highest bulk density of 1.470 g/cm³, are more compact, which may enhance their energy density and combustion efficiency. Rice husk briquettes, at 1.593 g/cm³, have the highest density, potentially indicating better mechanical stability [4]. Mango leaf briquettes, with the lowest density of 1.360 g/cm³, might have lower energy density and could be less durable compared to the other bio briquette.

The porosity index of a bio briquette is an important measure of the material's ability to allow air to pass through it, which is crucial for efficient combustion and energy release[3-4]. Higher porosity typically improves oxygen

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access during combustion, leading to more complete burning and higher energy output.Sawdust has the highest porosity index among the three materials. A higher porosity implies that the briquette made from mango leaf bio briquette has more void spaces, allowing better air circulation [5-7]. This should result in faster and more efficient combustion, which can lead to higher thermal efficiency. However, excessively high porosity can also reduce the density of the briquette, which might lead to quicker burning, potentially lowering burn duration[8-9].The moderate porosity observed in rice husk is beneficial for combustion, as it still allows for good air flow without compromising too much on the density. This balance can result in efficient burning with a longer burn time compared to sawdust. Rice husk bio briquettes might provide a more sustained heat output due to their lower burn rate compared to sawdust.

Mango leaf bio briquettes have the lowest porosity index, indicating the least void spaces. While this may result in slightly reduced air flow during combustion, the increased density can lead to a slower and more sustained burn, which is beneficial for prolonged heat release.

The durability of bio briquettes made from mango, sawdust, and rice husk, in Table 2has values of 0.600, 0.650, and 0.730 respectively. The durability shows the ability of the bio briquettes to maintain their physical integrity under various conditions, such as handling, storage, and combustion. The mango bio briquette are more prone to breaking or disintegrating during handling and use. The mango biomass might have less binding strength or structural cohesion, leading to a weaker product [6-8]. Rice husk bio briquettes are the most durable. Rice husks have a relatively high silica content, which can contribute to better binding and overall structural strength of the bio briquettes.

The relatively high hardness of saw dust bio briquetteindicates that sawdust bio briquettes are quite robust. The high hardness value suggests that the sawdust has been compressed effectively, making it dense and capable of withstanding significant pressure or stress [3-5].

With the highest hardness among the three, rice husk bio briquettes are very firm. Rice husk's hardness could be attributed to its fibrous structure and the presence of silica, which contributes to the strength and rigidity of the briquette[11] Harder briquettes usually have a more controlled and steady combustion process. Given their hardness, sawdust and rice husk briquettes are expected to burn more uniformly and for a longer duration compared to the mango leaf briquettes.

The sawdust bio briquette demonstrated efficient combustion with an ignition time of 2.20 minutes, indicating a quick start (Table 3). Its burning time of 45.50 minutes shows a sustained release of energy, ideal for prolonged heating applications. The water boiling time of 18.20 minutes suggests that it is capable of delivering steady heat for

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cooking purposes. The results highlight the bio briquette's potential as an alternative fuel with decent performance in terms of ignition and sustained heating. The balance between ignition and burn time is promising for domestic energy use.

Table 2: Mechanical properties of the bio briquettes

	Saw dust bio briquette	Rice husk bio briquettes	Mango leaf bio briquettes
Bulk density (g/cm^3)	1.470	1.593	1.360
Compressive strength (N/mm^2)	2.210	2.300	2.112
Durability	0.650	0.730	0.600
Porosity index	1.85	1.80	1.95
Hardness	654	665	438

The rice husk bio briquette exhibited an ignition time of 2.20 minutes, indicating quick flammability and ease of lighting. [5] With a burning time of 45.50 minutes, it maintained a steady burn, making it suitable for prolonged use. The water boiling time of 18.20 minutes suggests moderate thermal efficiency, ideal for basic cooking needs. These characteristics highlight the bio briquette's potential for domestic applications. The mango leaf bio briquette showed a quick ignition time of 1.50 minutes, indicating good flammability. Its burning time of 30.30 minutes suggests moderate fuel efficiency, while the water boiling time of 20.45 minutes reflects reasonable heat output for cooking applications [5].

Table 3: Combustion properties of the bio briquettes

	Saw dust bio briquette	Rice husk bio briquettes	Mango leaf bio briquettes
Ignition time	2.20	2.40	1.50
Burning time	45.50	60.53	30.30
Water boiling time	18.20	15.80	20.45

CONCLUSION

The production and characterization of bio briquettes from mango leaf biomass, sawdust, and rice husk present a viable and efficient alternative for cooking energy needs. This study demonstrates that bio briquettes made from these biomass sources not only offer a sustainable solution to manage agricultural and forestry

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waste but also provide an effective and cleaner energy source for cooking. Summarily, the findings underscore the potential of bio briquettes from mango leaves, sawdust, and rice husk as effective, eco-friendly energy sources. Their adoption can play a crucial role in transitioning towards more sustainable energy solutions, enhancing both environmental and socio-economic benefits.

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REFERENCES

1. F.S.Nworie (2021). From waste to wealth: Production of smokeless bio-briquettes from waste materials for use as an alternative energy resource. United Nations Development Programme Good Practices in South-South and Triangular Co-operation: Scaling up made-in-Africa Solutions. New York, NY, 10017, USA. pp. 30-31

2. S. K. Kimutai and I. K Kimutai, (2019), Investigation of Physical and Combustion Properties of Briquettes from Cashew nut shell and Cassava Binder, International Journal of Education and Research, 7(11): 15-26.

3. N. O Eze and W. Oti, (2017), Characterization Of Selected Nigerian Indigenous Biomass Wastes For Their Suitability In Biofuel Production, International Journal of Pharmaceutical Science Invention, 6 (9) 01-08.

4. E. A. Emerhie, (2011), Physical and Combustion Properties of Briquettes from Sawdust of three Hard wood Species and Different Organic Binders, Advanced Applied Science Resources. 2(6): 236-246.

5. H. A. Ajimotokan, A. O. Ehindero, K. S. Ajao, A. A. Adeleke, P. P. Ikubanni and Y. L. ShuaibBabata, (2019), Combustion Characteristics of Fuel Briquettes Made from Charcoal Particles and Sawdust Agglomerates. Scientific Africa. http://dx. doi.org/10.1016/j.sciaf.2019.e00202.

6. T. U. Onuegbu, I. M. Ogbu, N. O. Ilochi, I. Okafor, O. F. Obumselu. and U. E Ekpunobi (2010), Enhancing theCoal Briquette in Rural Nigeria Using *pennisetum purpurem*, Advances in Natural and Applied Sciences, 4(3): 299-304

7. U. J. Efetobor, S. C Ikpeseni & S. O. Sada. 2022. Determination of Proximate, Ultimate and Structural Properties of Elephant Grass as Biomass Material for oil Production. Journal of Applied Science and Environmental Management. 26(12): 1903-1907.

8. R. M. Davies and D. S. Abolude, (2013), Ignition and Burning Rate of Water Hyacinth Briquettes, Journal of Scientific Research and Reports 2(1): 111-120.

9. V. R. Birtwatker, Y. P. Khandetod, A. G. Mohod and K. G. Dhande, (2014). Physical and thermal properties of biomass briquetted fuel. Indian Journal of Science and Technology, 4 (1), 55- 62.

10. O. A Kuti, (2009), Performance of Composite Sawdust Briquette Fuel in a Biomass Stove Under Simulated Condition, International of Mechanical Engineering, 12(4): 284-288

11. N. O. Eze and W. J. Oti, (2017), Investigation on Combustion Properties of Coal Briquette Blends from Mangonut Shells and Empty Fruit Bunches, Indo American Journal of Pharmaceutical Sciences. http://doi.org/10.5281/zenodo.377016

ISSN 0795 - 22066

12. N. O Eze, I. Ikelle, F. S. Nworie, J Nworu, and T Onuegbu, (2021), Fabrication, Characterization, Mechanical and Combustion Properties of Bio-Briquettes Derived from Agro-Wastes of Bush Mangonut Shell and Sugarcane Bagasse, Asian Journal of Energy Transformation and Conservation. 5:(1) 8-18 DOI: 10.18488/journal.81.2021.51.8.18

13. E. Kodji, J. T. Koda, A. Awono and R. D. Djoulde, (2022), Effects of Binders on the Physical and Energetic Properties of Ecological Coal, SSRN Electronic Journal, Doi: 10.2139/ssrn.4141968

14. T. U Onuegbu, N. O. Ilochi and I. Okafor, (2012), Preparation of Environmentally Friendly Bio- coal Briquette from Groundnut Shell and Maize Cob Biomass waste. Comparative Effect of Ignition Time and Water Boiling Studies, Current Research in Chemistry 4: 110- 118

15. O. C. Chin and K. M. Siddiqui, (2000), Characteristics of Some Biomass Prepared Under Modest Die Pressure. Biomass and Energy, vol 18 3: 223-228.

ISSN 0795 - 22066