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Comparative Analysis of the Combustion Characteristics of Pure and Composite Briquettes from Melon, Locust, and Groundnut Shells

BY

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ABSTRACT

Briquetting is an effective method for optimizing resource utilization, that entails the collection of combustible trash and its compression into a manageable form of solid fuel suitable for combustion, akin to wood or charcoal. Biomass briquettes provide a validated method for deriving energy from waste materials. The overconsumption of fossil fuels, firewood, and natural gas is resulting in significant environmental issues and deforestation.

This study examined the combustion characteristics of briquettes composed of melon, locust, and groundnut shells. Cassava starch served as the binder in a weight ratio of 1:50, and the flammability of the resultant composite briquette was assessed. The calorific value of the briquette was determined utilizing a bomb calorimeter.

The composite briquettes exhibited an average moisture content of 7%, and ash content of 5.5%. Exhibit the highest average volatile content at 62%, a density of 680 kg/m^3. The highest average fixed carbon content and average calorific values are 18% and 21000 kcal/kg, respectively. The results indicated that the produced briquette had favorable combustion qualities, rendering them appropriate for home applications and small-scale industries, in comparison to existing literature.

Keywords: Comparative Analysis; Combustion Properties; Composite Briquettes; Melon Shell, Locust Shell, and Groundnut Shell

Introduction

The significance of energy in national development cannot be overstated, since it greatly contributes to the economic and social fabric of the nation. The aspiration for Nigeria to rank among the twenty greatest economies globally by 2030 may ultimately prove illusory if the energy crisis is not effectively resolved. Currently, there exists a global energy crisis, including in Nigeria (Oladeji, 2012). The primary energy source for numerous rural household activities, including cooking and heating, is the combustion of wood, charcoal, and various agricultural products. As an increasing number of individuals depend on diminishing sources of combustible materials (fossil fuels and wood) for cooking and heating, these resources will ultimately become scarce unless immediate measures are implemented to counteract this trend (El-Saeidy 2004). Kaliyan and Morey (2009) asserted that 86% of global energy consumption derives from fossil fuels. The utilization of fossil fuels is undeniably convenient. Nevertheless, numerous issues are linked to its implementation. Consequently, it is essential to progressively redirect focus from fossil fuels, and in this context, agricultural leftovers can significantly contribute to renewable energy generation. Numerous agricultural leftovers and wastes are produced in the country; however, their utilization and management are inadequate, since most of these wastes are either left to degrade or incinerated, leading to environmental pollution and deterioration (Jekayinfa and Omisakin, 2005). Scientific research has determined that these residues contain significant potential energy (Jekayinfa and Scholz, 2009). Oladeji (2012) investigated the utilization of biomass for alternative energy production through the briquetting of agro-residues in Nigeria. A briquetting machine was built to generate four briquette units per batch. The residues were ground and sifted, and their mechanical characteristics and calorific value were assessed. The findings indicated that the moisture levels of the residues were comparable to those of the briquettes, whereas the briquettes exhibited varying compressive strengths. This may mitigate global energy deficits.

Biomass charcoal briquettes represent an effective utilization of available resources. Briquetting entails the aggregation of combustible trash that is unsuitable for use due to insufficient density, followed by its compression into a manageable solid fuel form that can be combusted similarly to wood or charcoal (Khadatkar and Gangwani (2016). Biomass briquette formation compresses substantial quantities of agricultural

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waste, with or without binders, to generate compact solids under pressure. Briquettes are goods that have been physically and mechanically converted from dry, granular, fine materials into a solid form, defined by an appropriate shape, with or without the inclusion of additives (Inegbedion, and Erameh 2023). Akintaro et al. (2017) recognized the potential of utilizing charred corncobs for briquette production as a substitute for firewood. The parameters of the resultant charred corn cobs and briquettes were selected and quantified: moisture content, volatile matter, ash content, fixed carbon, and calorific value. The findings indicated that with the increase in binder concentration and compaction pressure, there was a corresponding rise in moisture content, volatile content, ash content, fixed carbon, and heating value. The average content and calorific values of moisture, volatile matter, ash, and fixed carbon were 4.43-7.62%, 10.31-16.48%, 3.03-5.06%, 72.68-81.30%, and 28.85-32.36 MJ/kg, respectively. Their research demonstrated the feasibility of utilizing carbonized corn cobs as an alternate resource for briquette manufacturing.

The research conducted by Inegbedion and Erameh (2023) involved the preparation of briquettes from palm fruit peel, utilizing cassava starch as a binder in a weight ratio of 100:15. The researchers assessed the mean percentage of moisture content, mean percentage of volatile matter, mean percentage of ash, mean percentage of fixed carbon content, and calorific value of the manufactured briquettes. The combustion parameters of the produced palm briquettes were as follows: average moisture content 7.56%, average volatile content 17.45%, average ash content 6.68%, average fixed carbon content 68.28%, and average calorific value 9,717.74 kcal/kg. Their findings indicated that the produced briquettes have a high calorific value and were adequate for residential utilization in small-scale industrial families. Inegbedion (2022) assessed the moisture content, volatile matter, ash content, fixed carbon, and calorific value of briquettes fabricated from sawdust particles, utilizing cassava starch as a binder in a weight ratio of 100:15. The calorific value of the sawdust briquettes was as follows: average moisture content 5.04%, average volatile fraction 10.80%, average ash content 3.85%, average fixed carbon content 80.95%, and average calorific value 26918.02 Kcal/kg. The findings indicate that the produced briquettes possess a high calorific value and are enough for residential application in small-scale industrial households.

Inegbedion and Ikpoza (2022) assessed the moisture content, volatile content, ash content, fixed carbon, and calorific value of rice husk briquettes utilizing cassava starch as a binder at a weight ratio of 100:15. The average moisture content, volatile content, and ash content, fixed carbon rate, and calorific value of the generated rice husk briquettes were 5.87%, 14.35%, 5.34%, 74.45%, and 14,304.61 Kcal/kg, respectively. Their findings indicated that the produced briquettes possess a high calorific value and are enough for home application in small industrial households. Kishan et al. (2016) developed an economical briquetting machine and assessed the calorific value of biomass briquettes composed of sawdust, dried leaves, and minimal quantities of flour. Consequently, briquettes composed of sawdust, dried leaves, and a minimal quantity of flour (binder) exhibit greater density, reduced moisture content, and a decreased calorific value compared to briquettes formulated with sawdust, dried leaves, and coffee husks (binder). Kumar et al. (2016) documented the assessment of the calorific value of bio-briquettes composed of palm tree branches combined with varying amounts of coconut coir, sawdust, screw pine, and Indian bdellium tree powder. The briquettes were formulated in various ratios: 100:0 with and without binder (PW100, PWO100), 100:50 (PW50), 100:20 with and without binder (PW20, PWO20), and 0:100 utilizing solely additives (AW100). The proximate analysis was performed and compared with Indian coal. The moisture content for AW100 is 8.53%, the ash content for AW100 is 12.2%, the volatile content for PWB100 is 86.9%, the fixed carbon for PW20 is 17.38%, and the calorific value for PWO100 is 19,351 kJ/kg.

Obi et al. (2013) designed a viable commercial biomass briquette machine for rural populations, and performance assessments were conducted using sawdust. The physical and combustion characteristics of the briquette were assessed at different biomass-binder ratios of 100:15, 100:25, 100:35, and 100:45, utilizing cassava starch as the binding agent. Conversely, the optimal blending ratio based on heating value was found at a 100:35 blending ratio, resulting in a compressed density of 0.7028 g/cm³. Their findings indicated that the heating values at the optimal biomass-binder ratios were adequate to generate the heat necessary for domestic cooking and small-scale industrial applications.

Ogwu et al. (2014) conducted the comparative performance of calorific value was assessed for binary and ternary briquettes made from Afzelia africana, Daniela Oliveri, and rice husk biomass (sawdust) at starch binder concentrations of 20%, 30%, and 40%. The comprehensive study of the samples revealed substantial variations when combining different binders and aggregates with starch paste and gum Arabic. The amalgamation was subjected to a compression of 110 kN utilizing a manual hydraulic briquette press and subsequently desiccated under sunlight. The calorific value, volatile content, and flame temperature were assessed. The findings indicated that briquettes utilizing starch as a binder outperformed those made with gum Arabic in every aspect.

Sangotayo, et al (2017) investigated the characterization of activated carbon produced from local materials like coconut shells, coconut husks, maize husks, and palm kernel shells. The carbons were activated using potassium hydroxide and phosphoric acid at room temperature. The mass of the activated carbons was found to be higher than the imported carbon, with the highest adsorption capacity. The study suggests that using locally produced carbon from agricultural residues could reduce dependence on foreign products and enhance the economy by reducing dependence on the dollar index. Therefore this research developed composite briquettes made from melon, locust, and groundnut shells, and characterized the combustion parameters of the composite briquette

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Materials and Methods

The agricultural residues were obtained from Folawiyo Farm in Ilora, Afijio Local Government, Oyo State, Nigeria. The shells were cleansed, sun-dried for fourteen days, and subsequently oven-dried at 105°C to eliminate any remaining moisture. They were subsequently ground to a homogenous particle size of 0.345 mm, to guarantee consistency in the production of briquettes. The composite combining ratios were created within a 20% to 60% range using the simplex lattice mixture design procedure, utilizing Design Expert Software version 13.0.1.0. Each of the seventeen (17) experimental briquette samples was produced with 5%wt cassava flour as a binder and potassium oxide as a catalyst. The samples were compressed in a hydraulic jack briquette machine at a pressure of 30 MPa. The energy potential of the composite briquettes was determined by evaluating the calorific values, which included both the higher heating value (HHV) and lower heating value (LHV). Proximate and ultimate analyses were implemented to assess the fuel properties, which included the determination of the ash content, moisture content, fixed carbon, volatile matter, and elemental composition, which encompassed carbon, oxygen, hydrogen, and nitrogen components.

Sotannde et al. (2010) and Martin et al. (2008) described the process of homogeneously mixing briquettes with cassava starch at a mass ratio of 1:50. The briquette machine, which was developed and manufactured by Inegbedion and Francisco-Akilaki (2022) was uniquely supplied with each mixture to generate the various briquettes that were necessary. The primary components of this single-screw extrusion press are a drive motor, gearbox, input screw, die, and hopper housing. The auger is directly powered by the drive motor through a transmission. The raw materials (Figure 1) are delivered into the compression chamber through the hopper during the machine's operation, and the screw compresses it into the cylinder before forcing it out of the nozzle. The materials are continually pushed into the die by the screw. In an extrusion die screw press, pressure accumulates along the screw, as opposed to in a singular location, as is the case with piston machines. The composite briquettes produced from locust shell melon shell, and groundnut shell are bonded with cassava starch in Figure 2

Locust shell   Melon shell.   Groundnut shell

Figure 1: Raw materials locust shell melon shell, groundnut shell

Figure 2: Prepared biomass briquette from locust shell melon shell, groundnut shell

2.1 Assessment of Briquette Moisture Content

The percentage moisture content (PMC) was ascertained by weighing 2g of each briquette sample in a crucible of known mass, which was subsequently placed in an oven maintained at 105°C ± 5°C for 1 hour. The crucible and its contents were extracted from the oven, permitted to cool to ambient temperature, and subsequently reweighed. The procedure was reiterated until the weight stabilized post-cooling, at which point it was documented as the final weight. The moisture content of the sample was ascertained using equation (1).

$$PMC = \frac{W_1 - W_2}{W_2} \times 100\% \qquad (1)$$

Where W_1 is the initial weight of the briquette sample and W_2 is the final weight of the briquette sample.

2.2 Assessment of Volatile Matter in the Briquettes

The proportion of volatile matter (PVM) for each briquette sample was assessed by placing 2g of the sample in a crucible and subjecting it to a furnace for 10 minutes at a temperature of 950°C ± 5°C, followed by weighing after cooling. The proportion of volatile matter in the sample was calculated using equation (2).

$$PVM = \frac{W_2 - W_3}{W_3} \times 100\% \qquad (2)$$

Where W_2 is the weight of the oven-dried sample (g); W3 is the weight of the sample after 10 minutes in the furnace at 950 °C

2.3 Assessment of Ash Content in the Briquettes

2 grams of each briquette sample were placed in a sealed furnace and incinerated entirely. The residue's weight was measured using an electronic balance. The percentage weight of residue indicates the ash content in the sample and is determined using equation (3).

$$PAC = \frac{W_4}{W_2} \times 100\% \qquad (3)$$

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2.4 Assessment of Fixed Carbon Content in the Briquettes

The formula for calculating percentage fixed carbon (PFC) is represented by equation (4) [13].

$$PFC = 100\% - (PMC + PVM + PAC) \qquad (4)$$

2.5 Assessment of the Calorific Value of the Briquettes

The calorific value of each briquette sample was assessed utilizing a bomb calorimeter. 2 grams of each briquette sample were entirely combusted in oxygen oxides. The released heat was absorbed by the water and the calorimeter. The heat expended by the combustion of the briquette was the heat absorbed by the water and calorimeter. The calorific value (CV) of the fuel was derived from the measured data [14] utilizing equation (5).

$$CV = \frac{BFx\ \Delta t - 2.3\ length\ of\ wire}{W} \qquad (5)$$

Where: BF = Burn Factor; Δt = Change of temperature ($t_2 - t_1$)oC; t_2 = final temperature; t_1 = initial temperature; W = mass of the sample used and BF = constant = 13,257.32

Results and Discussions

The physicochemical parameters of the composite briquettes derived from Melon, Locust, and Groundnut Shells were confined to the assessment of moisture content, volatile matter content, ash content, fixed carbon content, and calorific value. Figures 3 and 3 illustrate the proximate analysis of the composite briquette samples. Figure 3 indicates a maximum moisture value of 7% and an ash content of 5.5%. Figure 4 indicates that the highest volatile matter is 62% and the fixed carbon is 18%. Table 1.0 presents the proximate analysis of pure Melon, Locust, and Groundnut Shells Figure 3 demonstrates that the moisture content of composite briquettes is lower (7%) compared to Mellon Shell of 8.9%. This indicates that briquettes produced from Melon, Locust, and Groundnut Shells will ignite more rapidly than those produced from Melon shells, The briquettes are more susceptible to ignition and a higher calorific value is anticipated when the moisture content is low (Pallavi et al 2013). The moisture content of briquettes increases as the binder concentration increases, while it decreases as the compaction pressure increases for all briquettes (Romallosa and Kraft, 2017). The results of the briquettes that were produced are consistent with the prescribed moisture content of 5–10% for high-quality briquettes (Moore and Johnson 1999)

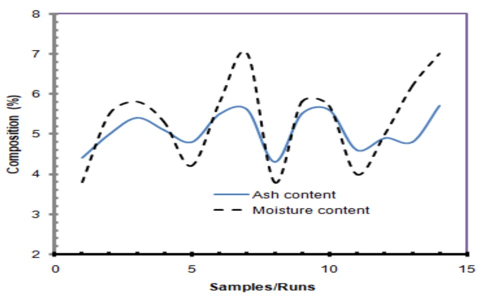

Fig. 3: Profile of Ash Content and Moisture Content of Composite Briquette versus Runs

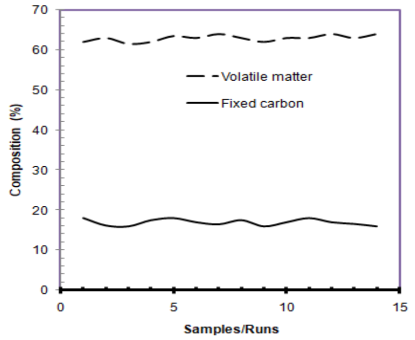

Fig. 4: Profile of Volatile Matter and Fixed Carbon of Composite Briquette versus Samples

Table 1.0: Proximate Analysis of Pure Samples

Briquette samples	Ash content (AC%)	Moisture content (MC%)	Volatile matter (VM%)	Fixed carbon (FC%)
15(GS)	4.2	2.6	65	22.5
16(MS)	7	8.9	67	14
17((LS)	5	6.2	60.4	16

GS = Groundnut shell, MS = Melon shell, LS = Locust shell

AC = Ash Content, MC = Moisture Content, FC = Fixed Carbon, VM = Volatile Matter

Figures 5 and 6 illustrate the ultimate analysis of the composite briquette samples. Figure 3 indicates a maximum Nitrogen value of 1.3 % and hydrogen value of 4 %. Figure 4 indicates that the highest value of Carbon is 44% and the Oxygen is 27%. Table 2.0 presents the ultimate analysis of pure melon, locust, and groundnut shells. The ultimate examination results for the seventeen (17) samples including pure samples, indicate that carbon concentration surpasses other elemental compositions, with oxygen being the second biggest component after carbon, while hydrogen levels range from 3.8% to 4.75%.

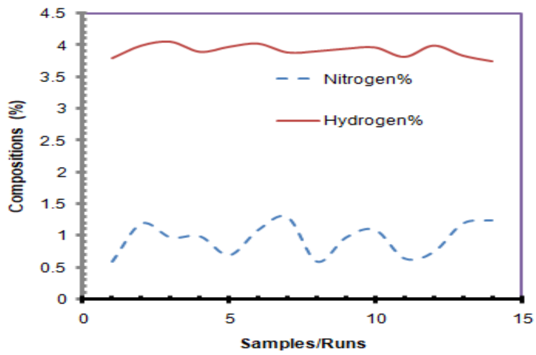

Fig. 5: Profile of Nitrogen and Hydrogen of Composite Briquette versus Samples

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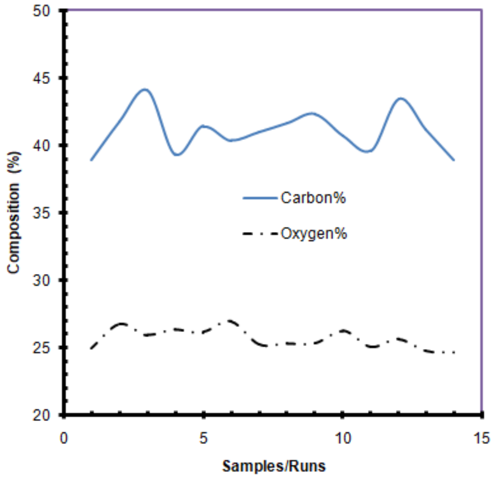


Fig, 6: Profile of Carbon and Oxygen of Composite Briquette versus Samples

Table 2: Results of ultimate analysis for melon shell, locust shell, and groundnut shell composite briquette samples

Briquette samples	Carbon %	Nitrogen %	Oxygen %	Hydrogen %
15(GS)	41.1	0.42	31.9	4.53
16(MS)	42.2	1.54	31.4	4.52
17((LS)	42.17	0.96	33.8	4.75

The composite briquette samples' heating capability is illustrated in Figures 7 and 8. The maximal density is 680 kg/m3, as shown in Figure 7. Figure 8 indicates that the maximum heat value is 21000 kJ/kg. The density influences storage capacity and transportation effectiveness, while the higher heating values suggest a greater energy potential per unit mass.

The calorific value is a measure of the amount of thermal energy that a substance possesses. Data from Figure 8 demonstrated that the composite briquette has the maximum average calorific value at 21,000 kCal/kg. The briquette samples that were produced had a high thermal value that was suitable for residential use and small-scale industrial applications.

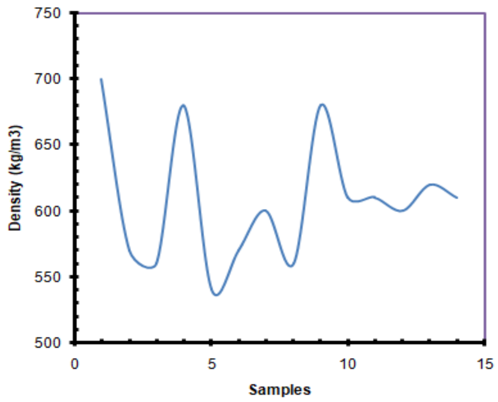


Figure 7 Profile of Density of Composite Briquette versus Samples/Runs

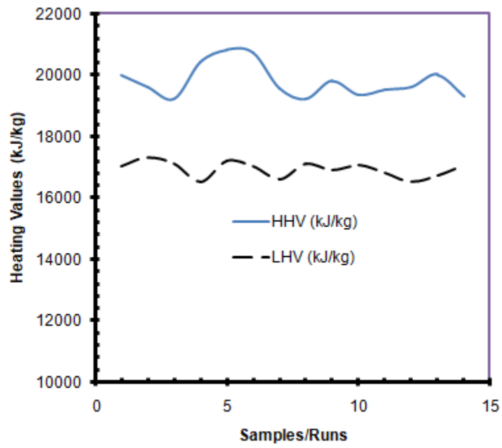
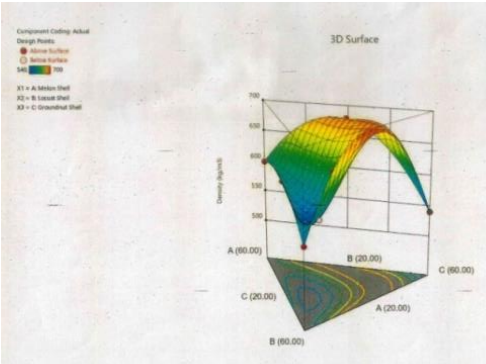
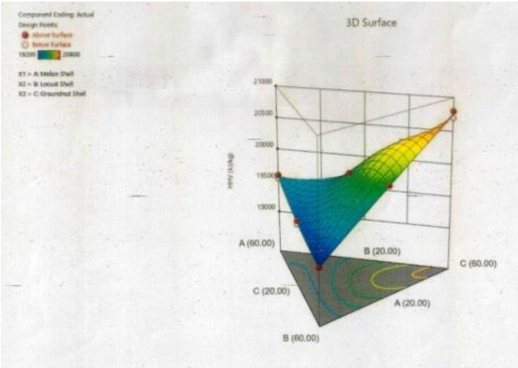


Figure 8 Profiles of Heating Values of Composite Briquette versus Samples

Figures 9 illustrate the three-dimensional surface depicting responses related to ash content, density, higher heating value, and lower heating value. The figure indicated that an increase in ash content often diminishes heating values, while briquettes with increased density are likely to possess elevated heating values. The ideal region in the chart indicates places with balanced ash concentration and density for superior heating performance. It indicates that briquette optimization necessitates guidance on material composition and density adjustments to enhance energy efficiency, aiming to increase heating values for industrial, food, and beverage or heating applications while minimizing ash content to mitigate emissions.





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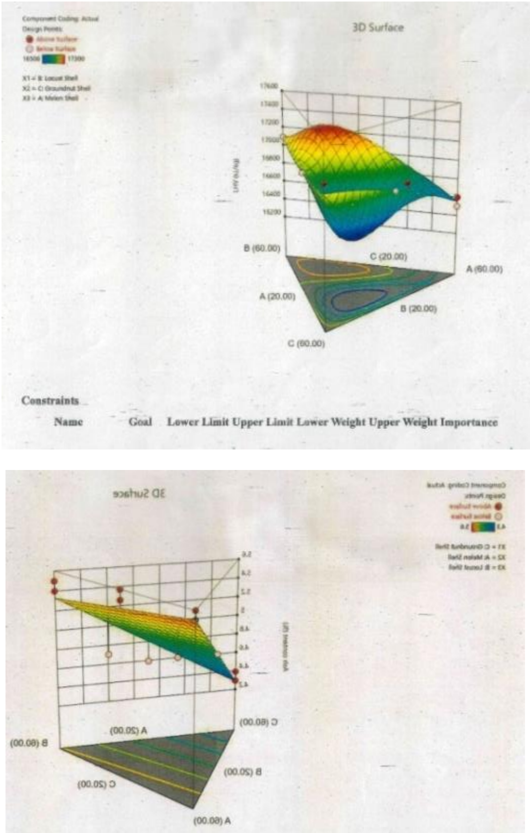
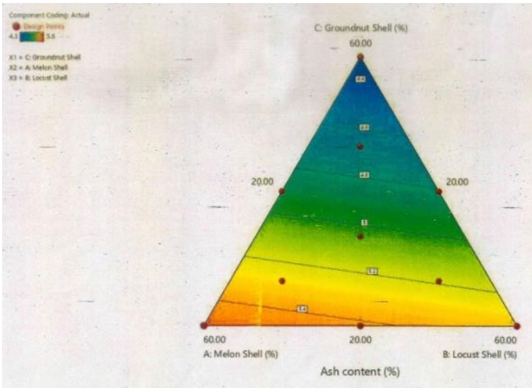


Figure 9: The 3-D surface with responses on ash content, density, higher heating value, and lower heating value

The red zone represents the area of highest reactions, the blue zone denotes the area of least responses, and the green zone signifies the practicable region, as illustrated in Fig. 10. Figure 10 provides insights into Designate red zones for optimal heating efficiency, blue zones indicate constraints and green zones provide adaptability. It suggests the optimization of material composition and density, the maximization of heating values, and the specification of production parameter settings.



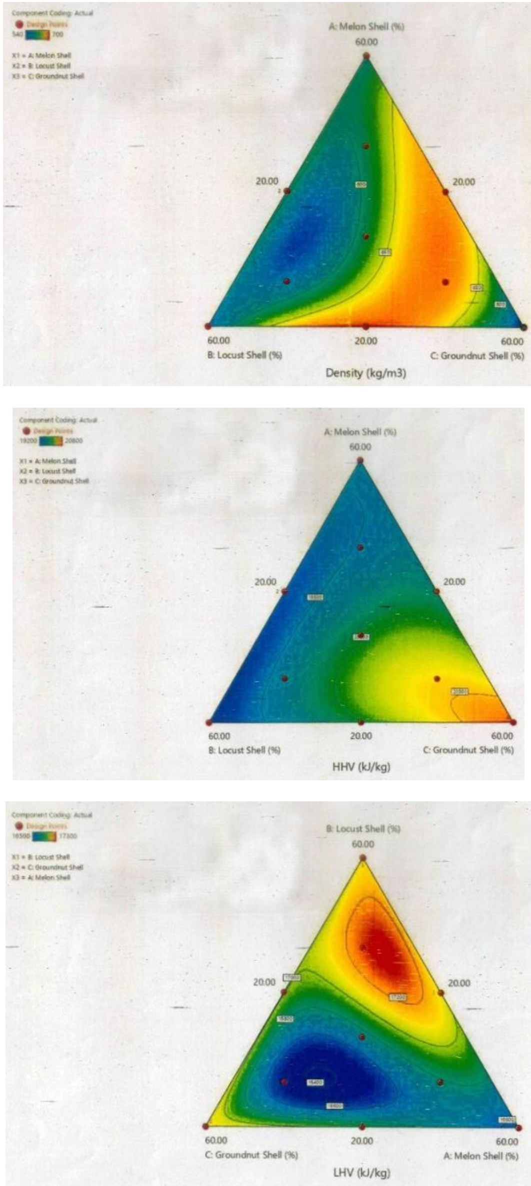


Fig. 10: The contour of responses shown as the red zone indicates maximum region responses

Conclusion

This study developed composite briquettes from melon, locust, and groundnut shells, and investigated the combustion characteristics of the composite briquettes The combustion parameters evaluated from the produced briquettes demonstrate their appropriateness for home and small-scale industrial applications. The biomass composite briquette possesses the capacity to serve as an effective biofuel, providing a sustainable substitute for conventional fossil fuels while utilizing agricultural residue. This study demonstrated the potential to improve the combustion efficiency and energy yield of composite briquettes composed of melon shells, locust shells, and groundnut shells through the optimization of their fuel characteristics. Future studies should focus on the cost-effectiveness and sustainability of biofuel production, along with the long-term combustion performance,

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environmental impact, and possible scalability for industrial applications.

References

1. Agidi G., Efomah A.N. and Alake S.A.,(2015) "Assessment of the Performance of a Disc Actuated Briquette Production Machine Developed at the National Cereals Research Institute, Badeggi," Global Journal of Engineering Science and Research Management, Gbabo., 2(7), 35–40.
2. Chaney J.O., (2010)"Combustion Characteristics of Biomass Briquettes," Fuel Processing Technology, 30(2), 219–230.
3. El-Saeidy, E.A. 2004. "Technological Fundamentals of Briquetting Cotton Stalks as a Bio-fuel". An Unpublished Ph.D. Thesis. Faculty of Agriculture and Horticulture, Humboldt University: Humboldt, Germany.
4. Francis Inegbedion (2022)"Estimation of the moisture content, volatile matter, ash content, fixed carbon and calorific values of sawdust briquettes", MANAS Journal of Engineering, MJEN Volume 10, Issue 1, Pg. 17-20
5. Francis Inegbedion and Emmanuel Ikpoza (2022) "Estimation of the Moisture Content, Volatile Matter, Ash Content, Fixed Carbon and Calorific Values of Rice Husk Briquettes", Proceedings of the 3rd African International Conference on Industrial Engineering and Operations Management University of Nigeria Nsukka, Nigeria, April 5 - 7,
6. Inegbedion F., and T.I. Francis-Akilaki, (2022) "Design and Fabrication of a Briquetting Machine", Journal of Energy Technology and Environment, vol. 4, no. 1, pp. 11 – 20,
7. Inegbedion, F and Erameh A. A. (2023) "Estimation of Combustion Properties of Briquettes Produced from Palm Fruit Shell", International Journal Of Engineering Technologies-IJET, Vol.8, No.1,
8. Jekayinfa, S.O. and O.O. Omisakin. 2005. "The Energy Potentials of Some Agricultural Wastes as Local Fuel Materials in Nigeria". Agricultural Engineering International, the CIGR E-Journal of Scientific Research and Development. Vol. III Manuscript EE 05 003:10.
9. Jekayinfa, S.O. and V. Scholz. 2009. "Potential Availability of Energetically Usable Crop Residues in Nigeria". Energy Sources. Part A (31):687-697.
10. Kaliyan N. and R.V. Morey. 2009. "Factors Affecting Strength and Durability of Densified Biomass Products". Biomass and Bioenergy. 2009(33):337-359.
11. Khadatkar S.B. and Gangwani D., (2016) "Automated Briquetting Machine for Bio Coal Manufacturing," International Journal of Engineering and Technical Research (IJETR), 4(1), 105–111.
12. Kishan B. S., Kumar K., Santhosh T. J., Gangadhar D. A.,(2016.) Design and Fabrication of Low-cost Briquetting Machine and Estimation of Calorific Values of Biomass Briquettes, International Journal of Innovative Research in Science, Engineering, and Technology, vol. 5, no. 7, pp. 12454 – 12461,
13. Kumar S. G., Rao J. C., Madhavi K. S.,(2016) Evaluation of Calorific Value of Bio-Briquette, International Journal of Research in Engineering and Technology, vol. 05, no. 09, pp.124 – 128,
14. Martin F.J., A.M.R. Pineda, A.J. Manaay, A.R.S. Handa, and A.B. Ocreto, (2008) "Design and Development of Charcoal Briquetting Machine", USM R & D, vol. 16, no. 2, pp.85 – 90,
15. Moore W., and Johnson D.,(1999) "Procedures for the Chemical Analysis of Wood and Wood Products," Forest Products Laboratory Department of Agriculture. Madison, U.S.A.
16. Ogwu Y. I., Tembe T. E., Shomkegh A. S.,(2014.) Comparative Analysis of Calorific Value of Briquettes Produced From Sawdust Particles of Daniella oliveri and Afzeliaafricana Combination at Binary and Tertiary Levels with Rice Husk, Journal of Research in Forestry, wildlife and Environmental, vol.6, no. 2, pp.13 – 21,
17. Oladeji, J.T. 2012. "Comparative Study of Briquetting of Few Selected Agro-Residues Commonly Found in Nigeria". Pacific Journal of Science and Technology. 13(2):80-86.
18. Pallavi H.V., Srikantaswamy S., Kiran B.M., Vyshnavi D.R. and Ashwin C.A. (2013), "Briquetting Agricultural Waste as an Energy Source," Journal of Environmental Science, Computer Science and Engineering & Technology, 2(1), 160–172.
19. Romallosa A.R.D. and Kraft E., (2017), "Feasibility of biomass briquette production from municipal waste streams by integrating the informal sector in the Philippines," Resources, 6, 12.
20. Sangotayo, E. O., Itabiyi, O. E., Adedeji, K. A., Adegoke, T., & Elehinafe, O. L. (2017). Characterization of activated carbons produced from some agricultural residues. Journal of Scientific and Engineering Research, 4(6), 132-140
21. Sotannde, A.O. O.A. Oluyege, and B.G Abah, (2010) "Physical and Combustion Properties of Briquettes from Sawdust of Azadirachta indica", Journal of Forestry Research, vol. 21, no. 1, pp.63 – 67,

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