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Ultimate Analysis of Charcoal Briquette Produced using Banana and Locust Bean Peels as Binders

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ABSTRACT

This study aims to evaluate the ultimate analysis of charcoal dust briquette (CCD), banana peels (BNP) and locust bean peels (LBP) as sustainable alternatives to conventional fuels. The objective of this work is to analyse the ultimate (composition) of the briquettes. The study involved producing charcoal dust briquettes with varying concentrations of BNP and LBP as binders, followed by detailed analysis of their composition. The methodology entailed the preparation of the briquettes from charcoal dust (CCD) with BNP and LBP as binders in different ratios. The ultimate analysis assessed elemental composition including the percentage of carbon, hydrogen, nitrogen, oxygen, and sulphur content and their average values are: 57.4% ± 3.9% (BNP) and 58.6% ± 1.8% (LBP), 5.4% ± 0.7% (BNP) and 4.7% ± 1.7% (LBP), 4.1% ± 1.3% (BNP) and 4.8% ± 1.6% (LBP), 26.9% ± 4.2 % (BNP) and 26.2% ± 4.2% (LBP) and 6.1% ± 2.5% (BNP) and 5.7% ± 3.0% (LBP) respectively. The ultimate analysis revealed higher carbon content and energy potential in LBP briquettes, making them a more viable alternative for energy production. LBP-based briquettes demonstrate significant advantages over BNP-based briquettes in terms of energy content and performance. The produced samples are not suitable for domestic application but rather industrial usage were sulphur and Nitrogen capture mechanism as in place to reduce the release of such oxides to the atmosphere. The study recommends prioritizing LBP in briquette production and further optimizing the briquette manufacturing process to enhance quality and efficiency. There is a need for further studies on the cause of high sulphur and nitrogen content and the variation of pressure, particle size distribution, and densification temperature.

1. Introduction

A briquette comprises of compressing carbonised biomass, coal, or charcoal dust to produce alternative fuel for domestic and medium scale enterprises applications. Briquetting is a process that involves subjecting the carbonised biomass, charcoal dust and other carbonaceous materials to high pressure at temperature necessary to improve the strength of the briquette. The temperature of briquetting depends on the type of technology used. In some briquetting techniques, the materials are compressed with or without the addition of adhesive. The adhesive materials are added to assist in holding the particles of the base material together. Research in briquetting has focused on the production of smokeless alternative fuel from charcoal, coal and/or agricultural wastes. The pressure is necessary to overcome the springiness of these base materials (Abodenyi and Yakmut, 2020).

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Energy for domestic application can either be renewable and non-renewable depending on the source, type, availability and ability to re-produce the fuel at a sustainable period. Renewable energy is an infinite energy source obtained from a continuing or repetitive energy source occurring in natural environment. These energy sources include biomass, solar energy and wind energy etc. While non-renewable energy are finite, exhaustible and cannot be re-placed. These are type of energy obtained from static stores of energy that remain bound unless released by human interventions. These non-renewable energies include fossil fuel, petroleum, coal, natural gases and nuclear fuels (Garkuwa, 2023).

Charcoal briquettes are type of briquette that uses charcoal, carbonised biomass or its dust to produce a solid fuel that contain high carbon content, have a high heating value, and can ignite for a long time. Briquettes that are currently mass produced are usually from coal as base material, whose raw materials are natural resources that cannot be renewed. While bio-briquettes derived from crop residues or waste residues have not been fully explored (Djuanda and Mantra, 2019). Rice husk as an example is formed as a by-product of rice milling in the agro–based biomass industry. About 30% husk is produced in the process on a dry weight basis but it cannot be used effectively as fuel due to its higher humidity and lower mass and energy density. Generally, the residual rice husk has low moisture content (10-12%) withe small amounts of alkaline minerals are found in its ash. To overcome these problems, making briquettes is an effective way to improve its carbon as well as energy density and environmental deprivation (Usman, *et al.*, 2025).

Energy availability is essential for the development of any country around the world. The use of fossil fuel such as firewood as energy source has negative impact on both human health and the ecosystem. These cause deforestation which results to soil erosion, desert encroachment, atmospheric pollution and global warming. Nigeria is one of the countries bestowed with abundant agricultural activities leading to abundant agro-residues which are inefficiently used, causing extensive pollution to the environment (Senchi and Kofa, 2020).

The major source of energy for many urban and rural household activities such as cooking and heating is the burning of woods, charcoal, and other agricultural by-products. As more and more people rely on dwindling sources of flammable materials (fossil fuels and wood) for cooking and heating, these materials will eventually become scarce unless urgent steps are taken to reverse this trend. Biomass charcoal briquettes are an efficient way to use than these existing resources. Briquetting involves collecting combustible waste that cannot be efficiently used because it's less density and compressing it into a convenient form of solid fuel that can be burned like wood.

Biomass briquette forming compresses large amounts of agricultural waste with or without binders to produce compact solids under pressure to increase it carbon and energy densities. Briquettes are products that are physically and mechanically transformed from dry, granular, fine-grained material into a solid state characterized by the correct shape, with or without the addition of additives. Briquettes are mainly used for thermal purposes (steam production, metal smelting, space heating, ovens, tea making, etc.) and for power generation through gasification of biomass briquettes, as well as for domestic and commercial applications (Inegbedion, *et al.*, 2023).

The composition of the ash-free organic solid fuel from biomass is relatively cheap and efficient for household's applications. The major components of briquettes are carbon, oxygen, and hydrogen. Most biomass also contains a small proportion of nitrogen and sulphur. The resulting composition of biomass as well as the briquettes it produce affects the combustion characteristics. Nitrogen and sulphur are significant in the formation of harmful emissions and have an effect on reactions forming ash. The sulphur and Nitrogen contents of below 1% is a welcome development which consequently reduce the release of sulphur and nitrogen oxides into the atmosphere, thereby decreasing the polluting effect of the briquettes as a whole, (Jittabut, 2015).

Among the different types of briquettes widely used in many countries include biomass briquettes, coal briquettes and charcoal briquettes etc. However, blending coal with agro waste (Rice chaff, maize cob, and saw dust) with binder gives rise to briquettes with better combustion characteristics and better pollution as compared to the conventional coal briquettes. These briquettes are called bio-coal briquettes (Tiwari, 2011). According to Raju, *et al.* (2014) sawdust or wood dust are by-products of cutting, grinding, drilling, sanding of wood, or otherwise pulverizing wood. Saw or wood dusts are the main components of particleboard with a variety of other practical applications, including serving as mulch, as an alternative to clay cat litter, or as a fuel as reported by Dass, *et al.* (2019).

The technology of producing smokeless fuel is an essential technique for energy renewal. It is a form of recycling agricultural waste into a useful source of energy (Ikella, *et al.*, 2014). Study shows that large quantity of forest and agricultural residues are generated but are not utilized optimally to add value especially in developing countries. Generally, this forest residue are converted to charcoal for daily energy usage. Nigerians currently are shifting towards using charcoal as the major source of energy in semi-arid and rural areas which left behind abundant charcoal dust un-utilised. The charcoal dust has high carbon content in loose form which cannot be conveniently use as fuel which lead to its abundance and discarded in landfill or on the streets of the charcoal vendors. Therefore, current study exploits the use of abundant charcoal dust in the study area together with banana and locust bean peels as binders to produce briquettes.

2. Materials and method

The raw materials used in this work include charcoal dust, banana and locust bean peels. Charcoal dust was used as base material, while locust bean peels and banana peels were used as binders. Foreign materials such as stones and sand metal chips from the surrounding are remove from the raw samples by sorting picking and sieving. The banana and locust bean peels were sundried for five (5) days. After drying, the peels were grinded with a grinding machine to produce the required fine particles for proper densification process. The pulverized samples were screened and passed through 1.18 mm ASTM sieve sizes ASTM D3865-12, (2000). They were sieved using 1.18 mm sieve size each separately. The pulverized charcoal dust and banana and locust bean peels were dissolved separately with boil water in the ratio of 3:1 for all the samples with the boil water. Charcoal briquettes were formulated using different percentages of charcoal dust and binders (banana peels and locust beans peels) as shown in Table 1. Uniform distribution of binding materials in charcoal dust particle is a critical requirement for the proper binding action. Binders were manually mixed with charcoal dust particles. Boiled water was added to the mixture as a medium to facilitate good mixing. The mixing procedure was adopted from Ajimotokan, *et al.* (2019).

Table 1: Formulation for the briquette production

Levels	Granulated charcoal (wt %)	Banana peels (wt %)	Locust Beans peels (wt %)
1	85	15	0
2	80	20	0
3	75	25	0
4	70	30	0
5	85	0	15
6	80	0	20
7	75	0	25
8	70	0	30

2.1 Ultimate Analysis Test

Estimation of important chemical elements that make up biomass, namely carbon, hydrogen, oxygen, nitrogen and sulphur was determined through ultimate analysis. The ultimate analyses process to determine these elements were analytical methods prescribed by (Jittabut, 2015). The ultimate analysis was carried out at Public Health Engineering Laboratory of Civil Engineering Department in Abubakar Tafawa Balewa University (ATBU) Bauchi. The ultimate analysis of briquettes made from banana peel (BNP) and locust bean peel (LBP), focusing on the elemental composition: carbon (C), hydrogen (H_2), nitrogen (N), oxygen (O_2) and sulphur (S). The result is crucial for assessing the energy content, combustion characteristics, and environmental impact of the briquettes.

2.1.1 Determination of carbon and hydrogen by Liebig method

The carbon and hydrogen contents value were determined (Liebig method) based on ASTM-D3178 standards. As reported in Adekunle (2015) and Jittabut (2015), 2 g of peels and charcoal samples was place in to a platinum crucible and burned in excess oxygen at a temperature of about 1300°C. The combustion product flew over a heated copper oxide and lead chromate into the absorption train. The CuO ensures complete combustion of the carbon and hydrogen while the lead chromate absorbs the oxides of sulphur in the samples. The pre weight absorbers absorbed water and carbon dioxide and the percentage carbon and hydrogen in the sample were calculated from the gain in weight of absorbers. The carbon as carbon dioxide and hydrogen as water was calculated from the increase in weight of the absorbents which was used to collect the water and carbon dioxide as shown in equation 1 and 2 (Adekunle, 2015; Jittabut, 2015).

$$\%\,Carbon\ = \frac{12 \times mass\ of\ CO_2}{44 \times mass\ of\ sample}\ X\ 100\% \qquad (1)$$

$$\%\,Hydrogen\ = \frac{2 \times mass\ of\ H_2O}{18 \times mass\ of\ sample}\ X\ 100\% \qquad (2)$$

An oxide of sulphur which was released in significant amount was removed from the combustion gases by passage over silver at about 600°C while nitrogen dioxide was removed by lead chromate (Adekunle, 2015; Jittabut, 2015).

2.1.2 Determination of nitrogen content by Kjeldahl method

The nitrogen content was determined using ASTM- D3179 (2002) standard as describe in Adekunle (2015) and Jittabut (2015). The process involves adding 2 g of the sample into a Kjeldahl digestion flask. Also, 20 ml sulphuric acid, 1 g each of copper sulphate and potassium sulphate as catalysts were added into the flask. The flask was heated gently until boiling and the mixture was then diluted with 100 ml of distilled water and allowed to cool at room temperature. After cooling, the flask was connected to the Kjeldahl distillation apparatus and sodium hydroxide solution was added to the mixture and then heated to boiling again. The ammonia gas was condensing into the receiving flask contain 2% boric acid. Bromocresol green and methyl red indicator was added (drop wise) and alkaline distillate was titrated against 0.1 m hydrochloric acid. The procedure was repeated using the set up apparatus shown in Figure 1. The percentage of nitrogen (%N) was calculated using equation 3 (Adekunle, 2015; Jittabut, 2015).

$$\%N = \frac{[(VH_2SO_4) - (VBK \times NNaOH) - (VNaOH \times NNaOH)]}{1.4007 \times W} \times 100\% \qquad (3)$$

Where: VH_2SO_4 is the mL standard H_2SO_4 pipette into flask for sample, *VNaOH* is the mL standard NaOH used to titrate sample, NH_2SO_4 is the Normality of H_2SO_4, N NaOH is the Normality of NaOH, *VBK* is the mL standard NaOH used to titrate1ml standard H_2SO_4 minus B, *B* is the mL standard NaOH used to titratereagent blank distilled into H_2SO_4, 1.4007 is the milliequivalent weight of nitrogen x100 and *W* is the Sample weigh.

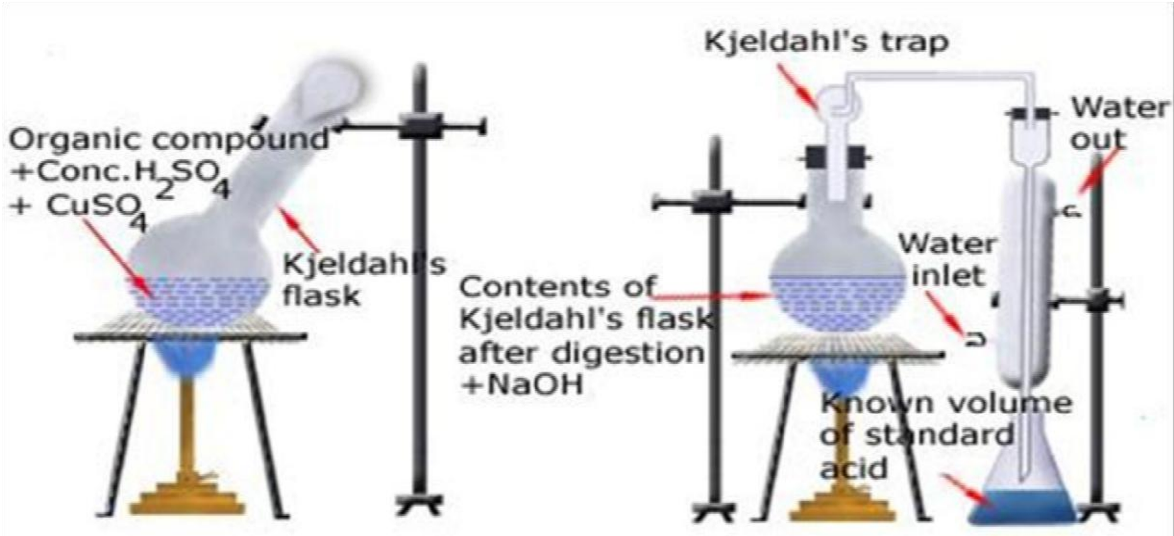

Figure 1: Kjeldahl's Method Apparatus for Estimating Nitrogen content (www.Chemistry World, 2015)

2.1.3 Determination of sulphur by the Eschka method

Sulphur content was determined using ASTM-D 3177 (1997) standard as reported in Adekunle (2015) and Jittabut (2015). For this experiment, 1 g of the sample was put into a crucible and mixed with 3 g of Eschka mixture and finally covered with 1 g of Eschka mixture. The crucibles containing the mixtures were then put in a cold muffle furnace and heated gradually to a temperature of 800°C and allowed to stay for 60 minutes. Digestions were carried out in hot water for 45 minutes with intermittent stirring. The solution in each beaker was decanted using a no. 540 Watman filter paper into a 400 ml beaker. Three drops of methyl orange indicator were added (drop wise) until colour turned just neutral. Then, 1 ml of hydrochloric acid was added, after which 25 ml of potassium sulphate solution was also added. The sample was thereafter heated to boiling and 10 ml of 10% of barium chloride solution was gradually added while stirring. The solution was boiled for 30 minutes and filtered with no. 42 Watman filter paper after cooling down. The trapped residue was washed thoroughly with hot water. The total sulphur content was calculated using the formula shown in equation 4.

$$Total\ sulphur = \frac{A-B\times 13.738}{C} \quad (4)$$

Where A is the mass of barium sulphate from the sample, B is the mass of barium sulphate from the blank and C is the mass of sample

2.1.4 Determination of oxygen content

The oxygen content in the ultimate analysis can be calculated by deducting the percentages of carbon, hydrogen, nitrogen, and sulphur from hundred as reported by Speight (2005) in equation 5.

$$\%O = 100 - (C + H + N + S)\% \quad (5)$$

Where O is the oxygen content in wt% dry basis, C is the carbon content in wt% dry basis, H is the hydrogen content in wt% dry basis, and S is the sulphur content in wt% dry basis

3. Results and discussions

3.1 Carbon Content

The carbon content in BNP briquettes ranges from 52.19% to 60.67%, with an average of 57.42%, whereas LBP briquettes have carbon content ranging from 56.76% to 60.78%, averaging 58.64% as shown in figure 2. Higher carbon content is indicative of higher energy density and better combustion performance. The carbon content in both types of briquettes is relatively high, which aligns with findings from Abdulkareem, *et al.* (2018), who emphasize that higher carbon content contributes to more efficient energy release during combustion. This makes both BNP and LBP briquettes effective in generating heat, but the slight variation between the two materials suggests that LBP briquettes may offer marginally better performance.

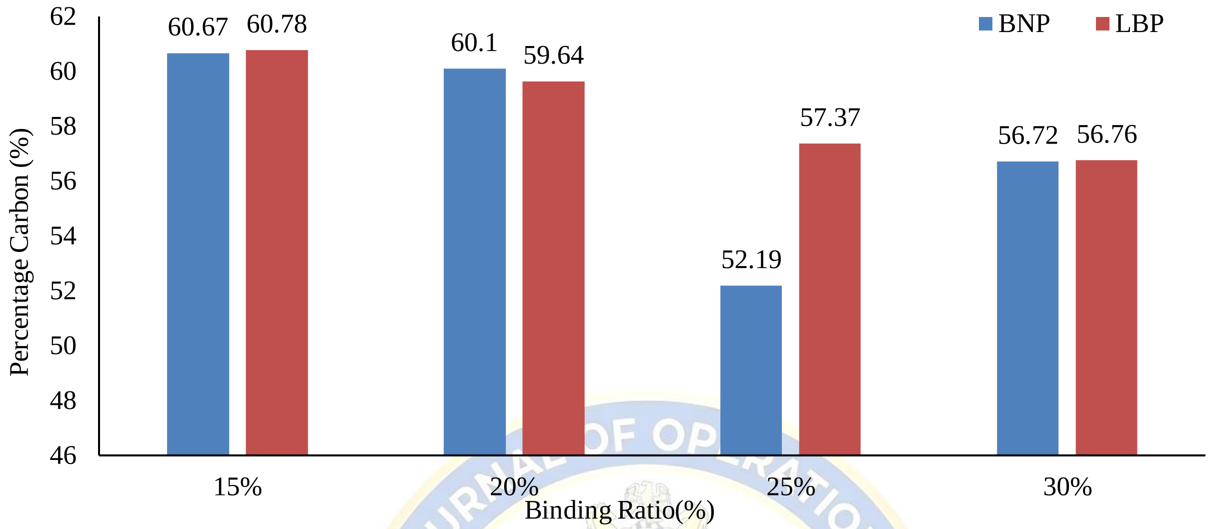

Figure 2: Carbon content of the produced briquettes

3.2 Hydrogen Content

The hydrogen content for BNP briquettes ranges from 4.58% to 6.36%, with an average of 5.38%, while LBP briquettes hydrogen content ranges from 3.52% to 7.26%, with an average 4.68% as can be seen in Figure 3. Hydrogen contributes to the calorific value of the briquettes by enhancing the energy content during combustion (Babajo, *et al.*, 2026). The higher hydrogen content in BNP briquettes could potentially contribute to a higher calorific value and better combustion efficiency, though the difference between BNP and LBP briquettes is not substantial.

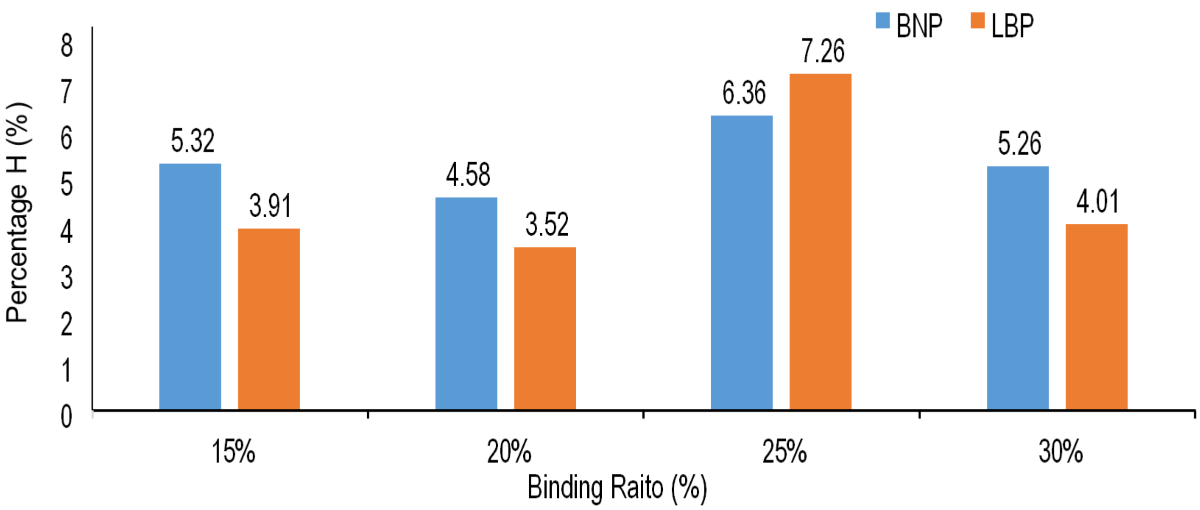

Figure 3: Hydrogen content of the produced briquette

3.3 Nitrogen Content

The nitrogen content in BNP briquettes ranges from 2.92% to 5.85%, with an average of 4.06%, while LBP briquettes nitrogen content range from 2.43% to 6.21%, with an average value of 4.81%

as as can be seen in Figure 4. Nitrogen content is less critical for energy output but is relevant for understanding potential emissions. High nitrogen levels can lead to increased nitrogen oxides (NOx) emissions during combustion, which is a concern for air quality (Garkuwa, *et al.*, 2022). Both BNP and LBP briquettes have similar nitrogen levels, indicating comparable potential negative environmental impacts of emissions to the atmosphere.

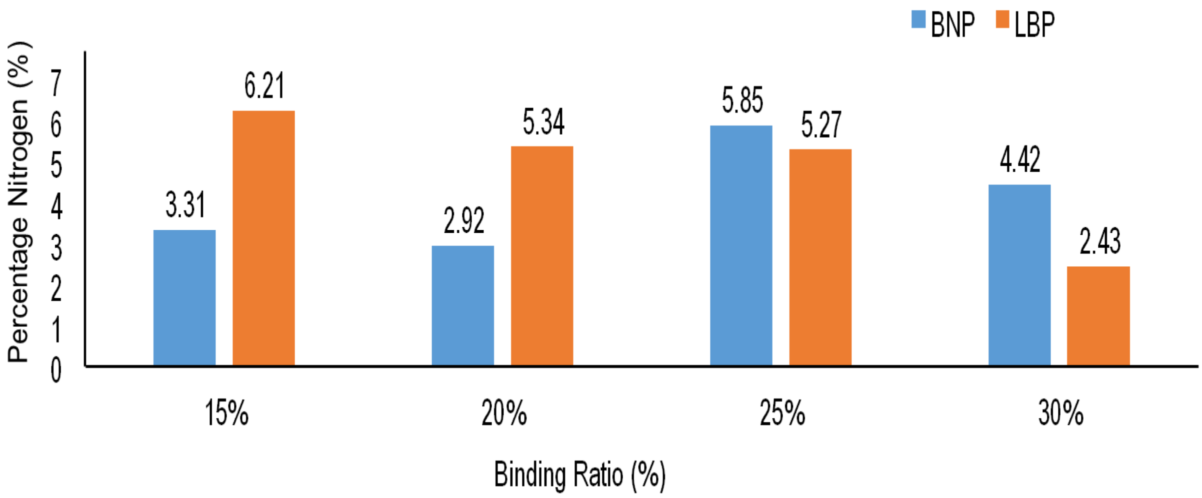

Figure 4: Nitrogen content of the produced briquette

3.4 Oxygen Content

The oxygen content in BNP briquettes ranges from 21.10% to 30%, averaging 26.73%, while LP briquettes oxygen content range from 20.70% to 30.00%, averaging 26.20% as shown in Figure 5. Oxygen content influences the combustion efficiency, as higher oxygen can support more complete combustion (Ahmed, *et al.*, 2014; Adekunle, *et al.*, 2015). The comparable oxygen levels in both types of briquettes suggest similar combustion characteristics, though BNP briquettes might have a slightly higher tendency for complete combustion due to their higher average oxygen content.

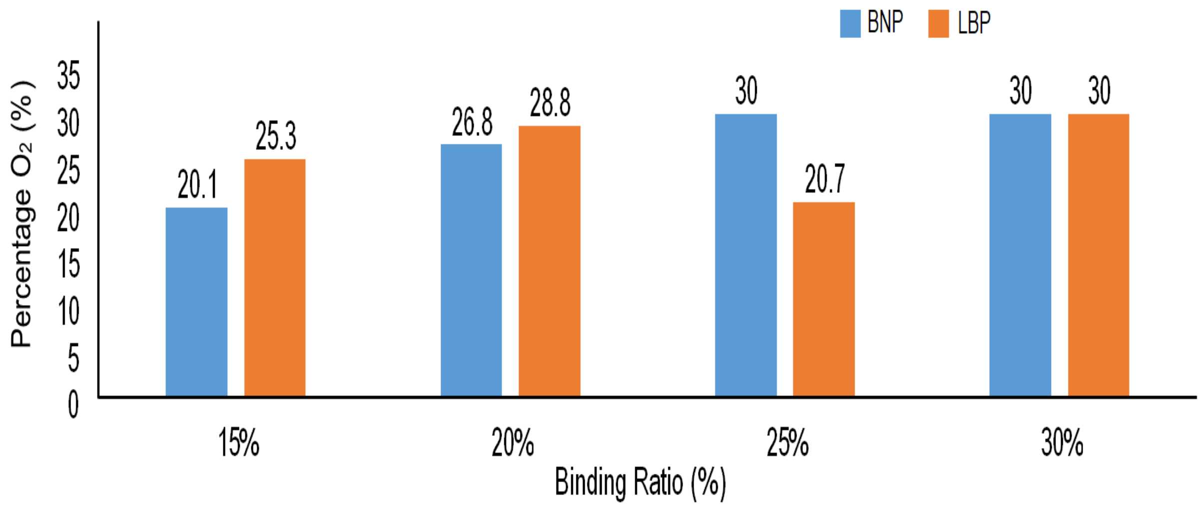

Figure 5: Oxygen content of the produced briquette

3.5 Sulphur Content

Sulphur content in BNP briquettes ranges from 3.60% to 9.60%, with an average of 6.10%, while LBP briquettes range from 2.70% to 9.40%, averaging 5.68% as shown in figure 6. Sulphur content is important for assessing environmental impact, as high sulphur levels can lead to sulphur dioxide (SO_2) emissions, which contribute to acid rain (Adekunle, *et al.*, 2015). The sulphur levels in both briquettes are relatively high but comparable, indicating high and similar environmental concerns related to SO_2 emissions.

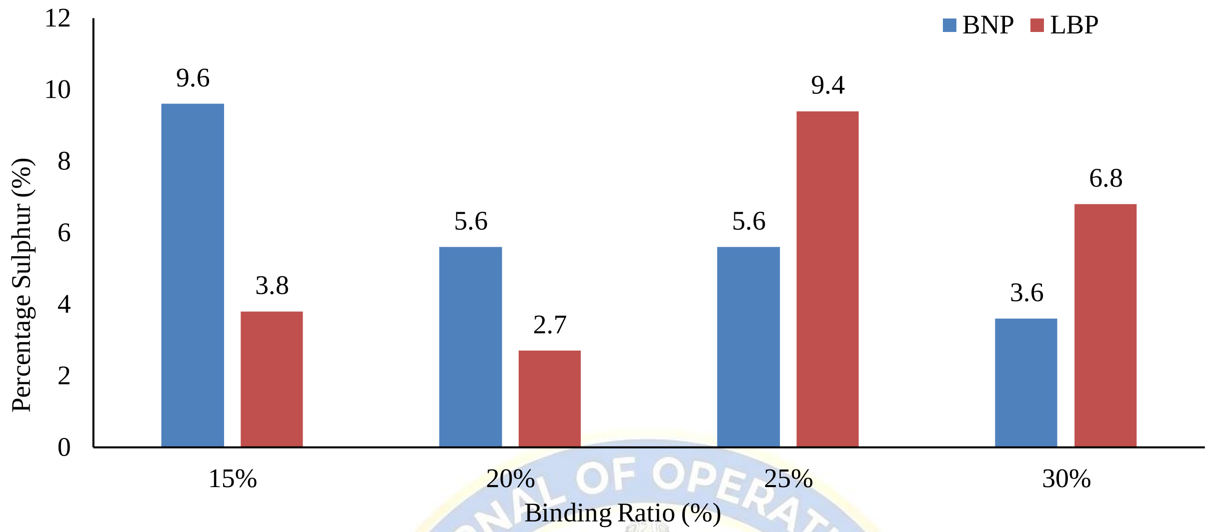

Figure 6: Sulphur content of the produced briquettes

The statistical analysis and T-Test shows that the ultimate (elemental) parameters have significant differences (f (4, 35) =632.63; P=0.000; P<0.05), indicating that the elemental composition of the briquettes varies significantly based on the type of binder. However, there is no significant effect of the sample binders (P>0.05) and concentrations (P>0.05) on the elemental composition. This suggests that while the overall elemental composition differs, the specific binder type and concentration do not significantly alter the content of carbon, hydrogen, nitrogen, oxygen, or sulphur in the briquettes.

4. Conclusion

The average percentages of carbon and hydrogen content are (57.40% for BNP, 58.6% for LBP) and (5.40% for BNP, 4.7% for LBP) respectively and the results showed that the briquettes contain a high carbon and moderate hydrogen content which are directly related to energy content and combustion efficiency. The average nitrogen (4.10% for BNP, 4.80% for LBP), sulphur content (6.10% for BNP, 5.70% for LBP) were found to be high which influence the potential environmental impact or emissions from the produced sample. The average oxygen content is (26.90 for BNP, 26.20% for LBP) which influence the stability and ignition properties of the fuel.

The briquettes produced in this work were well suited for domestic applications. Additionally, the study contributes to reduced dependence on non-renewable energy and focuses on renewable energy thereby promoting the use of agricultural waste products in energy production which in turn lead to cleaner environment. The findings show that the potential of utilizing LP as a key component in briquette production to enhance fuel quality and sustainability. The better overall performance of LP briquettes suggest that they offer a more reliable and environmentally friendly alternative to traditional fuels. Additionally, the study's results support the broader adoption of LP briquettes in various applications, contributing to reduced dependence on non-renewable resources and promoting the use of agricultural waste products in energy production. Thus, the study demonstrates that briquettes made from LP provide a viable and advantageous option for fuel production, offering improved energy efficiency and performance.

From the environment friendliness point of view, the produced samples are not suitable for domestic application but can be used for industrial application where Sulphur and Nitrogen capture mechanism or absorbent are used to reduce the release of such oxides to the atmosphere.

Recommendation

Upon successful completion of the experiment, it is recommended that:

i. The high sulphur and nitrogen contents of the produced samples will cause a greater risk of producing large quantity of SO_x and NOx to the atmosphere leading to pollution and acid rain when reacted with moisture from the atmosphere. Therefore, there is a need to further explore the course of high sulphur content from the charcoal dust, locust bean and banana peels from the study area

ii. Also it is recommended that the binding pressure, particle size distribution, and densification temperature be varied for future trials.

Reference

Abdulkareem, S., Hakeem, B. A., Ahmed, S. I. Ajiboye, T., Adebisi, J. A. and Yahaya, T., (2018). Combustion characteristics of bio-degradable biomass briquettes. *Journal of Engineering Science and Technology*, 13(9), 2779-2791.

Abodenyi, V. A. and Yakmut, S., (2020). Comparative Study of the Burning Rate of Briquettes Made from Agricultural Waste, *African Scholar Journal of Agriculture and Agricultural Tech (JAAT)*, 18(1), 219-226.

Adekunle J. O., Ibrahim, J. S. and Kucha, E. I., (2015). Proximate and Ultimate Analyses of Bio coal Briquettes of Nigerian's Ogboyaga and Okaba sub-bituminous Coal, *British Journal of Applied Science and Technology*, 7(1), 114-123.

Ahmed, S., Kumari, A. and Mandavgane, K. (2014). A review on briquettes as an alternative fuel. *International Journal of Innovations in Engineering and Technology*, 3(4), 139-144.

Ajimotokan, H. A., Ehindero, A. O., Ajao, K. S., Adeleke, A. A., Ikubanni, P. P. and Shuaib-Babata, Y. L., (2019). Combustion characteristics of fuel briquettes made from charcoal particles and sawdust agglomerates, *Scientific African*, 6, 1-6

ASTM D3177 (1999): Standard Test Method for Total Sulphur in the Analysis Sample of Coal and Coke. American Society for Testing and Materials (ASTM): Philadelphia, Pennsylvania

ASTM D3177 (2002): Standard Test Method for Total Nitrogen in the Analysis Sample of Coal and Coke. American Society for Testing and Materials (ASTM): Philadelphia, Pennsylvania

ASTM D3865-12, (2000). Standard test method for gross calorific value of coal and coke, American Society for Testing and Materials (ASTM): Philadelphia, Pennsylvania.

Babajo, A. A. Soja, Y. J., Usman, A. M. and Yami A. M. (2026). Proximate and Ultimate Analysis of Hybrid Briquettes Produced from Rice Husk and Corn cob Using Gum Arabic as a Binder, *Journal of the Nigerian Institution of Mechanical Engineers (JNIMechE)*, 14(01), 012-025.

Dass, P. M., Nkafamiya, I. I., Thliza, B. A. and Joseph, J. I., (2019). Proximate Analysis of Biomass and Cotton Stalk Charcoal Briquettes Produced from Biu, Nganzai, and Zabarmari in Borno State using a Locally Fabricated Briquetting Machine, *International Journal of Progressive Sciences and Technologies (IJPSAT)*, 16(2), 83-91.

Djuanda, S. and Mandra, M. A. S., (2019). Characteristics of charcoal briquettes from agricultural waste with compaction pressure and particle size variation as alternative fuel, *International Energy Journal*, 19, 139 – 148.

Garkuwa, Y. A., Usman, A. M., Bello, A. A., Habou, D. (2022). Development of high calorific value blended local sugarcane bagasse–Maiganga coal briquettes for domestic application, *Nigerian Journal of Engineering Science and Technology Research*, *8*(2), 104-112. https://njestr.com.ng/view.php?_folder&_yr=2021&_vl=8&_ish=2

Garkuwa, Y. A., Bello, A. A., Habou, D. and Yahuza, I., (2023). Physicochemical properties and thermal characteristics of biomass briquettes with enhancement from coal additives, *Savannah Journal of Science and Engineering Technology*, 01(01), 01-06.

Ikelle, I., Chukwuma, A. and Ivoms, O. S. P., (2014). The characterization of the heating properties of the briquettes of coal and rice husk, *(IOSR) Journal of applied chemistry*, 7(5), 100-105.

Inegbedion, F. and Erameh, A. A., (2023). Estimation of Combustion Properties of Briquettes Produced from Palm Fruit Shell, *International Journal of Engineering Technologies (ijet), 8(1), 1-10*

Inegbedion, F. and Inegbedion, F. (2024). A Comparative Analysis of Combustion Properties of Briquettes Produced from Sawdust Particles, Palm Fruit Shell and Rice Husk, *Journal of energy technology and environment*, 6(2) 104-112.

Jittabut P., (2015). Physical and Thermal Properties of Briquette Fuels from Rice Straw and Sugarcane Leaves by Mixing Molasses, *International Conference on Alternative Energy in Developing Countries and Emerging Economies*, 1(1), 2-9.

Marquardt, G., Bueter, K. and Motzek, T., (2014). Impact of the Design of the Built Environment on People with Dementia: An Evidence-Based Review. *HERD: Health Environments Research and Design Journal*, 8, 127-157. https://doi.org/10.1177/193758671400800111.

Raju, A. I., Jyothi, R. K., Satya, M. and Praveena, U., (2014). Studies on Development of Fuel Briquettes for Household and Industrial Purpose, *International Journal of research in Engineering and Technology*, 3(2), 55-63.

Speight J. G. (2005). Hand book of Coal Analysis. Chemical Analysis: Series of Monographs on Analytical Chemistry and Applications. Ed. Winefordner. John Wiley and Sons In. Hoboken New Jersey.166:222.

Senchi, D. S and Kofa I. D., (2020). Proximate and Ultimate Analysis of Carbonized Rice Husk Briquettes, *International Journal of Advanced Academic Research (Sciences, Technology and Engineering)*, 6(10), 120-128.

Senchi, D. S. and Kofa, I. D., (2020). Comparative Studies of Water Boiling Test and Ignition Time of Carbonized Rice Husk Using Starch and Gum Arabic as Adhesives, *Iconic Research and Engineering Journals*, 4(1), 2456-8880.

Tiwari, (2011) Producing fuel briquettes from sugarcane waste, *EWB-UK National Research and Education Journal*, 220 550, 39-45.

Usman, A., Dasin, D. Y., Usman, A. M. and Babajo, S. A., (2025). Determination of proximate analysis of charcoal briquette produced using banana and locust bean peels as binders, *Savannah Journal of Science and Engineering Technology*, 3(3), 160-166.