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EVALUATION OF SOME PHYSICAL AND COMBUSTION PROPERTIES OF BIOMASS BRIQUETTES PRODUCED FROM DIFFERENT AGRICULTURAL WASTE MATERIALS AND THEIR BLENDS

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ABSTRACT

This study evaluated some physical and combustion properties of briquettes produced from rice offal, sawdust, groundnut shell, and their blends to determine their suitability for clean energy and the benefits of blending. Biomass materials underwent size reduction, sieving (1 mm), moisture adjustment (8%), cassava starch binding (8%), uniform mixing, moulding, hydraulic compaction, and sun dried. Briquette quality was assessed using density, moisture content, ash content, calorific value, compressive strength, and burning rate. Results showed that rice offal briquettes had the highest ash content (22.73%) and lowest calorific value (14.15 MJ/kg), while groundnut shell briquettes recorded the highest energy value (18.89 MJ/kg) with moderate ash (5.23%). Sawdust briquettes exhibited the lowest ash content (2.40%) but the weakest compressive strength (0.06 N/mm²). Blending improved performance significantly: the ternary blend achieved the highest compressive strength (0.88 N/mm²) and stable density (0.58 g/cm³), while the groundnut shell–sawdust blend showed high calorific value (17.82 MJ/kg) and efficient combustion making it best for clean energy performance. ANOVA and Duncan Multiple Range Test (DMRT) indicated significant effects of feedstock on most parameters. The study demonstrates that agricultural residues can be converted into high-quality briquettes, with blending enhancing overall fuel performance for sustainable energy applications.

Keywords: Briquettes; Groundnut shell; Sawdust; Rice offal; Blends

1.0 INTRODUCTION

Global energy demand is increasing rapidly due to industrialization, urbanization, and population growth, with projections indicating a 25% rise by 2040, particularly in developing countries (Fazendeiro and Simões, 2021). Despite this growth, fossil fuels still account for over 70% of global energy supply, contributing significantly to greenhouse gas emissions, air pollution, and climate change (Siddik *et al.*, 2021). This situation has intensified the search for cleaner and more sustainable energy alternatives. Biomass energy, especially from agricultural residues, has gained attention as a viable renewable option due to its abundance, renewability, and environmental benefits (Kalak, 2023). Globally, more than 3 billion tonnes of agricultural residues are generated annually, yet a large portion is inefficiently managed through open burning or left to decay, leading to environmental pollution and loss of potential energy resources (Lackner and Besharati, 2025). Nigeria possesses vast biomass resources as a result of its agrarian economy, where agriculture contributes about 24% to GDP and employs nearly 70% of the rural population (Eweka *et al.*, 2022). Agricultural residues such as groundnut shells, rice husks, sawdust, maize stalks, and cassava peels are produced in large quantities each year. The country's biomass energy potential is estimated at approximately 2.33 EJ annually, with agricultural residues contributing about 1.09 EJ (Olanrewaju *et al.*, 2019). However, despite this abundance, these residues are largely underutilized, contributing to environmental challenges and inefficient waste management. At the same time, widespread reliance on fuelwood and charcoal for domestic energy continues to drive deforestation and indoor air pollution, leading to serious health and environmental concerns.

Briquetting presents an effective solution by converting low-density biomass into compact, high-energy solid fuels with improved handling, storage, and combustion characteristics (Awulu *et al*., 2015; Kebede *et al.*, 2022). Among the available technologies, hydraulic press briquetting is widely used due to its ability to produce dense and durable briquettes suitable for domestic and industrial applications. Studies have shown that briquettes produced from agricultural residues can achieve calorific values in the range of 14–20 MJ/kg, making them comparable to traditional fuels such as firewood and even some grades of coal (Awulu *et al*., 2015; Bereziuk *et al*., 2025). However, the performance of briquettes largely depends on the type and composition of feedstock materials, as variations in physical and combustion properties can significantly influence density, strength, burning rate, and energy output (Achebe *et al.*, 2018). This creates a need for systematic evaluation of different biomass materials and their combinations to determine the most suitable feedstock for efficient briquette production. Therefore, this study evaluates the physical and combustion properties of briquettes produced from selected agricultural residues; groundnut shells, sawdust, and rice offal using a hydraulic press machine. The findings are expected to promote better utilization of agricultural waste, support sustainable energy development, and provide practical insights for farmers, energy producers, and policymakers in enhancing energy security and reducing environmental impact in Nigeria.

2.0 MATERIALS AND METHODOLOGY

2.1 Materials

Groundnut shells, sawdust, and rice offal were used as feedstocks for briquette production. These materials were selected based on local availability, energy potential, and distinct physical characteristics. Groundnut shells were obtained from peanut oil processing mills, sawdust from timber sawmills and carpentry workshops, and rice offal (rice husk and bran) from rice milling plants in Makurdi, respectively. All materials were sun dried and stored prior to use. Cassava starch was used as binder and a manual hydraulic press briquetting machine was used for moulding.

2.2 Hydraulic Press Briquetting Machine

Briquettes were produced using a manual hydraulic press briquetting machine equipped with a hydraulic cylinder, compression chamber, die, piston, and control valve system. The biomass was compacted to form solid briquettes through mechanical interlocking and activation of natural binders. During operation, the prepared biomass is fed into the compression chamber, and pressure is applied through the hydraulic piston to compact the material into solid briquettes. The high hydraulic pressure causes the particles to bond together through mechanical interlocking and the activation of natural binders such as lignin, starch or other binders. The hydraulic press (Fig. 1) was selected for its ability to produce dense, uniform, and durable briquettes with controlled pressure and compaction time, making it suitable for laboratory-scale briquetting.

Fig 1: Hydraulic press machine

2.3 Methodology

2.3.1 Sample Preparation

The agricultural residues (rice offal, sawdust, and groundnut shells) were prepared before briquetting to achieve suitable particle size, moisture content, and binder uniformity. The feedstocks (Fig. 2) were first manually cleaned to remove foreign materials such as stones and sand, followed by size reduction using a hammer mill. The ground materials were sieved to obtain uniform particle sizes of 8 mm and subsequently sun-dried to adjust the moisture content to approximately 8% (wet basis), which is optimal for briquette strength and combustion performance. Moisture content was verified using the oven-drying method, as excessive moisture can cause briquette cracking during compaction, while very low moisture reduces bonding efficiency (Yunusa *et al.*, 2025). A cassava starch binder was prepared by extracting starch from fresh cassava tubers through washing, grating, filtration, settling, and drying to 8% moisture content. The dried starch was mixed with hot water to form a viscous paste, which was added to each feedstock at 8% by weight of dry biomass (Fig. 3). The uniformly blended mixtures were manually mixed to ensure uniform distribution of binder, moisture and the feedstocks.

Fig. 2: Mixing feedstock with the starch

The homogenized biomass was fed into cylindrical moulds lightly lubricated with oil and compacted using a hydraulic press briquetting machine. Compression was applied for a dwell time of 30 seconds to produce dense and uniform briquettes. The freshly formed briquettes were then air-dried under shade for three days to reduce residual moisture, improve mechanical stability, and prevent mold growth. After drying, the briquettes were stored in airtight polythene bags prior to laboratory analysis.

Fig 3: Produced Briquettes

2.4.1 Experimental Design

The experimental design followed a comparative framework. Each type of agricultural waste (groundnut shell, sawdust, rice offal) was processed into briquettes separately under identical operating conditions to facilitate accurate comparisons. The study focused on evaluating the physical, combustion, and handling properties of the resulting briquettes. Three production batches per feedstock were created to ensure reproducibility and statistical reliability.

2.5 Briquette Quality Evaluation Parameters

The produced briquettes were assessed based on several critical parameters to determine their suitability for practical energy applications. The focus was on physical strength, combustion performance, and storage durability, which together influence how well the briquettes can perform as an alternative fuel source. The briquette quality parameters were tested in three replications to ensure consistency in data collection, facilitate comparative analysis among different feedstocks, and support clear presentation of findings.

2.6 Physical Properties

2.6.1 Density

Density is an important property that affects energy content per unit volume, handling, transportation, and combustion efficiency of the briquettes. It was determined using the equation 1:

$$\text{Density (g/cm}^3\text{)} = \frac{Mass\ of\ Briquettes\ (g)}{Volume\ of\ Briquettes\ (cm^3)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The mass of each briquette was measured using an electronic weighing balance, while the volume was calculated based on geometric measurements (Major, intermediate and minor diameters) using a Vernier caliper.

2.6.2 Moisture Content

Moisture content significantly affects briquette ignition, burning efficiency, and storage life. The moisture content was measured using the oven-drying method, where samples were dried in an oven at 105°C for 24 hours, and the loss in weight was recorded. Moisture content was calculated using equation 2:

$$\text{Moisture Content (\%)} = \left(\frac{Initial\ mass - Dry\ mass}{Initial\ mass}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

2.7 Combustion Properties

2.7.1 Calorific Value

The calorific value, or Higher Heating Value (HHV), represents the energy content of the briquettes. It was determined using a bomb calorimeter, following ASTM standards. The calorimeter automatically calculates the HHV in Mega joules per kilogram (MJ/kg), based on the heat released during complete combustion of a known mass of briquette. A calorific value above

14 MJ/kg is generally considered desirable for efficient energy use in biomass fuel applications (Kamruzzaman *et al*., 2025).

2.7.2 Ash Content

Ash content was measured by combusting a known mass of briquette until complete burning is achieved, leaving only ash. Ash content was calculated using equation 3:

$$\text{Ash Content (\%)} = \left(\frac{Mass\ of\ ash\ residue}{Initial\ mass\ of\ Briquette}\right) \times 100 \quad \text{......................(3)}$$

2.8 Data Analysis

All experimental data were collected systematically and entered into Microsoft Excel for preliminary processing. A one-way ANOVA and DMAT was conducted using the data generated to determine the statistical significance of the different feedstocks and blends on the measured briquette properties at $p \leq 0.05$.

3.0 RESULTS AND DISCUSSION

The results of the physical and combustion properties of briquettes produced from the different feedstocks and their blends used for the study is shown on Table 1 while Table 2 shows the analysis of variance result. Figure 1 is a visualization of the comparative of the produced briquettes properties across the selected feed-stocks and their blends.

Table 1: The results of the Physical and Combustion Properties of Briquettes Produced from Different Feedstocks and their Blends in three replications

Feed Stock	Replication	Density (g/cm^3)	Moisture content (%)	Calorific Value (MJ/kg)	Ash content (%)	Compressive Strength (N/mm^2)	Burning Rate (g/min)
Rice Offal (R)	1	0.58	8	18.85	22.80	0.26	2.66
	2	0.61	8	18.90	22.70	0.24	2.71
	3	0.58	8	18.92	22.70	0.25	2.66
	Average	**0.59**	**8.00**	**18.89**	**22.73**	**0.25**	**2.68**
Saw Dust (S)	1	0.48	8	16.80	2.40	0.07	3.43
	2	0.44	8	16.75	2.40	0.06	3.55
	3	0.45	8	16.70	2.40	0.06	3.49
	Average	**0.46**	**8.00**	**16.75**	**2.40**	**0.06**	**3.49**
Groundnut Shell (G)	1	0.50	8	14.20	5.30	0.13	2.56
	2	0.52	8	14.10	5.20	0.14	2.63
	3	0.50	8	14.15	5.20	0.13	2.60
	Average	**0.51**	**8.00**	**14.15**	**5.23**	**0.13**	**2.60**
Groundnut Shell (G) + Rice Offal R)	1	0.49	8	16.52	15.30	0.12	1.54
	2	0.52	8	16.52	15.20	0.13	1.56
	3	0.50	8	16.52	15.20	0.13	1.57
	Average	0.50	8.00	16.52	15.23	0.13	1.56
	1	0.59	8	15.45	11.40	0.52	1.69

Rice Offal (R)+ Saw Dust (S)	2	0.54	8	15.45	11.40	0.52	1.72
	3	0.55	8	15.45	11.40	0.51	1.70
	Average	**0.56**	**8.00**	**15.45**	**11.40**	**0.52**	**1.70**
Groundnut Shell (G) + Saw Dust (S)	1	0.61	8	17.82	7.20	0.15	2.44
	2	0.57	8	17.82	7.20	0.18	2.54
	3	0.58	8	17.82	7.20	0.20	2.47
	Average	**0.59**	**8.00**	**17.82**	**7.20**	**0.18**	**2.48**
Rice Offal (R)+ Groundnut Shell (G) + Saw Dust (S)	1	0.59	8	16.60	12.90	0.89	0.91
	2	0.56	8	16.60	12.90	0.84	0.81
	3	0.58	8	16.60	12.90	0.91	0.82
	Average	**0.58**	**8.00**	**16.60**	**12.90**	**0.88**	**0.85**

Table 2: The ANOVA of the effect of feedstocks on the responses

Tests of Between-Subjects Effects						
Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Feedstock	Density	.047	6	.008	22.450	.000
	Moisture content	.000	6	.000	.	.
	Calorific value	42.259	6	7.043	7825.746	.000
	Ash content	843.046	6	140.508	98355.333	.000
	Compressive strength	1.544	6	.257	831.241	.000
	Burning rate	13.862	6	2.310	1370.543	.000
Error	Density	.005	14	.000		
	Moisture content	.000	14	.000		
	Calorific value	.013	14	.001		
	Ash content	.020	14	.001		
	Compressive strength	.004	14	.000		
	Burning rate	.024	14	.002		
a. R Squared = .906 (Adjusted R Squared = .866)						
b. R Squared = .965 (Adjusted R Squared = .958)						
c. R Squared = 1.000 (Adjusted R Squared = 1.000)						
d. R Squared = 1.000 (Adjusted R Squared = 1.000)						
e. R Squared = .997 (Adjusted R Squared = .996)						
f. R Squared = .998 (Adjusted R Squared = .998)						

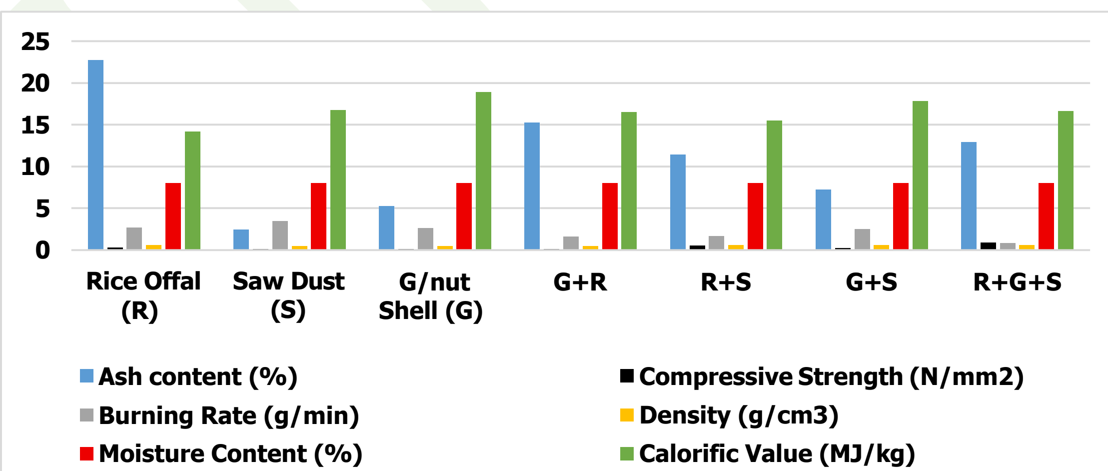

Fig 4: Comparing Briquette Properties across Feed-stocks and Blends

3.1 Ash Content

The ash content of the briquettes varied considerably depending on the type of feedstock used. Rice offal recorded the highest average ash content of 22.73%, followed by groundnut shell with 5.23%, while sawdust had the lowest ash content of 2.40%. For the blended briquettes, the average ash contents were 15.23% for G+R, 11.40% for R+S, 7.20% for G+S, and 12.90% for R+G+S. These findings agree with those of Akpenpuun *et al.* (2020) and Nurek *et al. (*2023). Rice offal briquettes exhibited high ash content due to their silica and mineral composition, while sawdust had low ash (0.5–2.5%) and cleaner combustion; groundnut shell also showed relatively low ash, indicating higher combustible matter (Akpenpuun *et al.,* 2020; Sarker *et al*., 2024). Blending reduced overall ash content, especially in rice offal mixtures, demonstrating improved combustion quality. Low ash is desirable as it enhances heating value and minimizes issues like clinker formation and ash buildup (Obi *et al.,* 2022).

3.2 Compressive Strength

Compressive strength varied widely, with sawdust briquettes recording the lowest (0.06 N/mm²) and the R+G+S blend the highest (0.88 N/mm²), while rice offal (0.25 N/mm²) and groundnut shell (0.13 N/mm²) were intermediate, consistent with Mandala et al. (2023) and Ajiboye et al. (2016). The superior strength of blended briquettes, particularly R+G+S, is due to improved particle interlocking and cohesion, whereas sawdust's fibrous structure limits bonding. Higher compressive strength enhances durability during handling and storage, making blended briquettes more suitable for large-scale applications.

3.3 Burning Rate

Burning rate varied across samples, with sawdust briquettes burning fastest (3.49 g/min), followed by rice offal (2.68 g/min) and groundnut shell (2.60 g/min), while blends burned more slowly G+R (1.56 g/min), R+S (1.70 g/min), G+S (2.48 g/min), and R+G+S (0.85 g/min) consistent with Akpenpuun *et al*. (2020). The slower rates in blends, especially R+G+S, are due to higher density and compactness limiting oxygen flow, whereas sawdust's porous structure promotes rapid combustion. Lower burning rates favour sustained heat applications. An inverse relationship exists between density and burning rate; thus, R+G+S is suitable for prolonged use, while sawdust is better for quick, high-intensity combustion.

3.4 Density

Density ranged from 0.46–0.59 g/cm³, with sawdust recording the lowest (0.46 g/cm³) and rice offal and R+G+S blends the highest (0.59 g/cm³), while other blends were intermediate. Variations are attributed to feedstock structure and particle size; sawdust's fibrous nature leads to lower compaction, whereas rice offal and groundnut shell form denser, less porous briquettes, consistent with Namaswa *et al.* (2022). Higher density enhances burning duration, heat output, and mechanical strength, making the R+G+S blend the most stable and durable.

3.5 Moisture Content

The briquettes had an average moisture content of ~8%, within the recommended 6–10% range for quality fuels (Sanchez *et al*., 2022). This level supports efficient combustion and prevents issues associated with excess or insufficient moisture. The uniform moisture content across samples indicates effective drying control, enabling reliable comparison of properties, while also enhancing briquette strength, binding, and burning efficiency.

3.6 Calorific Value (Higher Heating Value, HHV)

The calorific value, also known as the higher heating value (HHV) indicates the energy potential of the briquettes and is one of the most critical parameters for evaluating fuel quality. The pure feedstock briquettes exhibited HHVs of 18.89 MJ/kg for groundnut shell, 16.75 MJ/kg for sawdust, and 14.15 MJ/kg for rice offal. The blended briquettes recorded intermediate values: G+R (16.52 MJ/kg), R+S (15.45 MJ/kg), G+S (17.82 MJ/kg), and R+G+S (16.60 MJ/kg). Research by Sekyere *et al.* (2025) also had similar findings. Groundnut shell briquettes exhibited high calorific value due to higher carbon content, lower ash, and elevated lignin levels (Awulu *et al.*, 2018; Akpenpuun *et al.*, 2020). Sawdust showed moderate values from its balanced composition, while rice offal had the lowest due to high silica and ash content. Blending improved the calorific value of rice offal briquettes through synergistic effects, enhancing energy density and combustion efficiency, consistent with findings by Ajiboye *et al.* (2022). Overall, the calorific values (14–20 MJ/kg) fall within the acceptable range for biomass briquettes, indicating their suitability as alternatives to conventional fuels like firewood and charcoal.

3.7 Analysis of the Effect of the Feedstocks on the Briquette Properties

ANOVA results indicated that feedstock type (Rice Offal, Sawdust, and Groundnut Shell) had a significant effect ($p < 0.05$) on density, calorific value, ash content, compressive strength, and burning rate, while moisture content was not significantly affected, confirming effective pre-drying. Rice offal briquettes showed the highest density (0.5900 g/cm³), whereas sawdust had the lowest (0.4567 g/cm³), attributed to differences in particle packing and structure. The highest calorific value was recorded for rice offal (18.89 MJ/kg), while groundnut shell had the lowest (14.15 MJ/kg); blended feedstocks exhibited improved intermediate values, indicating synergistic effects. Sawdust briquettes had the lowest ash content (2.40%), while rice offal recorded the highest (22.73%), reflecting its higher mineral content. Blends reduced ash-related limitations. The R+G+S blend produced the highest compressive strength (0.88 MPa), while sawdust had the lowest (0.063 MPa), demonstrating enhanced bonding in mixed feedstocks. Sawdust burned fastest (3.49 g/min), whereas the R+G+S blend burned slowest (0.8467 g/min), indicating more sustained combustion in blends. High R^2 values (0.906–1.000) confirm that feedstock composition strongly influenced briquette properties and validates the model.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The study demonstrated that briquettes can be successfully produced from groundnut shells, sawdust, rice offal, and their blends using a hydraulic press, with feedstocks properly prepared and bonded using cassava starch. The resulting briquettes exhibited good physical and combustion properties, with densities of 0.46–0.59 g/cm³, calorific values of 14.15–18.89 MJ/kg, and stable moisture content at 8%, indicating suitability for domestic and industrial energy use. Performance varied among materials, with groundnut shells showing the highest energy value, sawdust the lowest ash content, and rice offal the highest ash content, while the blended R+G+S briquettes showed the best overall performance in terms of strength, energy, and combustion efficiency. Statistical analysis confirmed that feedstock composition significantly affected most properties except moisture content. This study concludes that converting agricultural residues into briquettes is a viable and sustainable solution for energy production, waste management, and rural development.

4.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

i. Blending agricultural residues is recommended for commercial briquette production due to improved strength, lower ash, and better combustion performance.

ii. Groundnut shell and sawdust briquettes are best suited for domestic energy use because of their higher calorific value and cleaner combustion.

iii. Rice offal briquettes are more appropriate for industrial applications with ash management systems due to higher ash content.

iv. Hydraulic press machines should be adopted by small-scale producers for producing dense, uniform, and durable briquettes.

v. Proper control of particle size, moisture content, binder distribution, and drying is essential for high-quality briquettes.

vi. Government and NGOs should support briquette production through training, subsidies, and extension services to promote clean energy and reduce waste burning.

vii. Further studies should examine storage stability, emissions, economic feasibility, and process optimization for large-scale production.

REFERENCES

Achebe, CH., Umeji, A.C., and Chukwuneke, J.L. (2018). Energy evaluation of various compositions of biomass waste briquettes. *Advances in Research*, 13(6), 1-11.

Ajiboye, T.K., Abdulkareem, A.S., and Afolabi, A.S. (2022). Performance evaluation of composite biomass briquettes from agro-residues. *Renewable Energy Focus*, 41, 1–9.

Ajiboye, T.K., Abdulkareem, A.S., and Anibijuwon, A.O. (2016). Investigation of briquettes produced from agro-residues. *Journal of Energy Technologies and Policy*, 6(6), 1–8.

Akpenpuun, T.D., Salau, R.A., Adebayo, A.O., Adebayo, O.M., Salawu, J., and Durotoye, M. (2020). Physical and combustible properties of briquettes produced from a combination of groundnut shell, rice husk, sawdust and wastepaper using starch as a binder. *Journal of Applied Sciences and Environmental Management*, *24*(1), 171-177.

Awulu, J.O., Omale, P.A., and Ameh, J.A. (2018). Comparative analysis of calorific values of selected agricultural waste. Nigerian Journal of Technology (NIJOTECH) Vol. 37, No. 4, October 2018, pp. 1141 – 1146

Awulu, J.O., Audu,J., and Ijabo, O.J. (2015). Effects of Briquettes and Binders on Combustible Properties of Selected Biodegradable Materials. *Asian Academic Research Journal of Multidisciplinary*, *2*(3), 1-11.

Bereziuk, O., Petrov, O., and Vishtak, I. (2025). The Impact of the Parameters of the Briquetting Process Using a Hydraulic Press on the Density Briquettes of Plant Waste. In Design, Simulation, Manufacturing: *The Innovation Exchange* (pp. 83-97). Springer, Cham.

Eweka, E.E., Lopez-Arroyo, E., Medupin, C.O., Oladipo, A., and Campos, L.C. (2022). Energy Landscape and Renewable Energy Resources in Nigeria: A Review. *Energies,* 15(15), 5514.

Fazendeiro, L.M., and Simões, S.G. (2021). Historical variation of IEA energy and CO2 emission projections: implications for future energy modeling. *Sustainability,* 13(13), 7432.

Kalak, T. (2023). Potential use of industrial biomass waste as a sustainable energy source in the future. *Energies*, 16(4), 1783.

Kamruzzaman, M., Bhattacharjya, D.K., Alam, E., Karim, M.R., Nath, B., and Al Hattawi, K. S. (2025). *Thermochemical and physical characterization of agricultural biomass for sustainable energy production*. **Energy Reports, 13**, 1927–1938. https://doi.org/10.1016/j.egyr.2024.11.059

Kebede, T., Berhe, D.T., and Zergaw, Y. (2022). Combustion characteristics of briquette fuel produced from biomass residues and binding materials. *Journal of Energy*, 2022(1), 4222205.

Lackner, M., and Besharati, M. (2025, June). Agricultural Waste: Challenges and Solutions, a Review. *In Waste* (Vol. 3, No. 2, p. 18). MDPI.

Mandala, R., Hegde, G., Kodali, D., and Kode, V.R. (2023). From Waste to Strength: Unveiling the mechanical properties of peanut-shell-based polymer composites. *Journal of Composites Science*, 7(8), 307.

Namaswa, T., Githiomi, J., Oduor, N., and Kitheka, E. (2022). Sustainable biomass energy production and utilization in sub-Saharan Africa: A case study of Kenya. *Journal of Horticulture and Forestry*, 14(4), 56-67.

Nurek, T., Gendek, A., and Roman, K. (2023). Influence of biomass composition on densification and fuel properties. *Scientific Reports*, 13, 46054.

Obi, O. F., Pecenka, R., and Clifford, M.J. (2022). *A review of biomass briquette binders and quality parameters*. **Energies, 15(7), 2426.** https://doi.org/10.3390/en15072426

Olanrewaju, F.O., Andrews, GE., Li, H., and Phylaktou, H. (2019). *Bioenergy potential in Nigeria*. *Chemical Engineering Transactions*, *74*, 61–66.

Sanchez, P.D.C., Aspe, M.M.T., and Sindol, K.N. (2022). An overview on the production of bio-briquettes from agricultural wastes: methods, processes, and quality. *Journal of Agricultural and Food Engineering*, 1, 0036.

Sarker, S., Rahman, M., and Hossain, M. (2024). Effect of ash content on biomass briquette quality and combustion characteristics. *Frontiers in Energy Research*, 12, 1378361.

Siddik, M., Islam, M., Zaman, A.K. M.M., and Hasan, M. (2021). Current status and correlation of fossil fuels consumption and greenhouse gas emissions. Int. J. Energy Environ. Econ, 28, 103-119.

Yunusa, S.U., Mensah, E., Preko, K., Narra, S., Saleh, A., Sanfo, S., and Dembele, F. (2025). Development and optimization of rice husk composite briquettes as a sustainable cooking energy solution in Nigeria. *Next Energy*, *8*, 100360.

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