Journal Renewable Energy & Mechanics (REM)
DOI: 10.25299/rem.2026.27065
Received 2026-01-21; Revised: 2026-03-10; Accepted 2026-03-31

Vol. 09 No.01 2026
E-ISSN: 2614-8315
P-ISSN: 2714-621X

Manual Hydraulic Briquetting Machine for Sustainable Fuel Production from Biomass and Charcoal Dust

Saminu Umar[1*], Hauwa'u Umar[2]

[1]*Department of Mathematics and Statistics, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria*
[2]*Department of Science Laboratory Technology, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria*
*Corresponding author: saminu.umar@gmail.com

ABSTRACT

Access to reliable and affordable energy remains a significant challenge in rural communities, where reliance on firewood, charcoal and kerosene contributes to environmental degradation and health risks. This study reports the design, fabrication and testing of a manual hydraulic briquetting machine capable of converting locally available biomass and charcoal dust into dense, uniform briquettes. The machine was constructed from mild steel and a hydraulic bottle jack, allowing operation without electricity and simple maintenance using local tools. Briquette production involved mixing biomass with cassava starch as a binder, then manually compressing and air-drying. Compressive strength tests showed that charcoal dust produced the strongest briquettes (1.30 KNm^{-2}), followed by rice husk (1.10 KNm^{-2}) and sawdust (1.03 KNm^{-2}), indicating that feedstock properties influence briquette performance. The results indicate that the machine provides a low-cost, sustainable fuel option while promoting effective utilisation of biomass and charcoal by-products.

Keywords: Biomass, Briquetting, Charcoal, Strength, Waste Utilisation

1. INTRODUCTION

Reliable and affordable energy remains a major challenge across many sub-Saharan African countries, where large numbers of households and small enterprises still lack dependable energy sources for cooking, heating and productive activities (World Bank, 2023). Nigeria reflects this situation, as rural communities continue to experience weak infrastructure, limited access to electricity, and high connection costs that place modern energy services out of reach for many households, leading the majority of rural families to rely on firewood, charcoal, kerosene, and small diesel generators (Abubakar et al., 2024). These fuels are expensive, cause indoor air pollution, contribute to deforestation and expose users to serious health risks, including stroke, chronic obstructive pulmonary disease and lung cancer, associated with prolonged smoke inhalation (World Health Organisation, 2024).

Nigeria also produces significant quantities of agricultural and biodegradable residues from key crops such as rice, maize, millet, sorghum and groundnut (Odejobi et al, 2024). Waste materials, including rice husk, sawdust, charcoal dust, rice husks and wastepaper, are generated in large volumes across farms, sawmills, markets and processing centres. In many cases, these materials are disposed of through open burning or indiscriminate dumping, practices that degrade the environment and increase greenhouse gas emissions (Aduba et al., 2024). Converting this abundant biomass into a useful energy source offers a sustainable solution to both waste management and energy scarcity. Briquetting technology transforms loose biomass into compact fuel blocks that burn efficiently, produce less smoke and have improved thermal stability compared with traditional fuels such as firewood and charcoal (Yunusa et al., 2024). Briquetting has also been shown to enhance combustion characteristics and reduce the release of sulphur and nitrogen oxides during burning relative to untreated biomass, indicating improved fuel performance and lower pollutant emissions (Qi et al., 2021). Converting agricultural residues into briquettes can simultaneously mitigate environmental pollution, address energy scarcity, reduce pressure on forest resources and support sustainable household energy systems.

For briquetting to be widely adopted in rural Nigerian settings, machines must be simple, durable, economical and compatible with the types of agricultural residues available. Many commercially imported machines require electricity, advanced mechanical components, or specialised spare parts that rural users cannot easily access or maintain (Onyegirim et al., 2025). Electric or complex briquetting systems often require continuous power supply and regular maintenance to prevent wear and performance degradation, which can pose challenges for rural deployment (Onyegirim et al., 2025). These limitations create a strong need for locally fabricated briquetting machines suitable for community-level use. A manual hydraulic briquetting machine is a suitable option because it operates without electricity, is constructed from locally sourced materials, and can be maintained by local artisans. Such technology supports clean energy access, promotes small-scale enterprise development and provides opportunities for training and employment in local fabrication workshops (Onyegirim et al., 2025).

This study focuses on the design and fabrication of a manual hydraulic briquetting machine tailored to the needs of Nigerian communities. The goal is to convert locally available agricultural residues into clean-burning briquettes that can reduce household energy costs, promote effective waste utilization and contribute to environmental protection. By offering a low-cost, user-friendly solution, the machine serves as a step toward sustainable, community-driven energy improvements. However, many manual hydraulic briquetting machines on the market have limitations, such as low production capacity, limited compaction pressure, and slow operating cycles, compared to mechanical or screw press systems. These issues can lead to lower briquette density, reduced durability and inconsistent quality during large-scale production, while also requiring significant human effort (Onyegirim et al., 2025).

2. MATERIALS AND METHODS

2.1 Materials and Machine Description

The briquetting machine was fabricated using locally available mild steel materials and hydraulic components suitable for small-scale and rural workshop environments. The main structural members were mild-steel square pipes measuring 50 mm × 50 mm × 3 mm and flat bars measuring 50 mm × 6 mm, while steel plates of 5 mm, 8 mm, and 10 mm thickness were used for the compression chamber, mould assembly, and piston components. All permanent joints were formed using arc welding with standard welding electrodes. A 10-ton manually operated hydraulic bottle jack mounted at the upper section of the frame provided the compressive force required for briquette formation.

The machine comprises a rigid steel frame supporting a hydraulic jack, a compression chamber, a piston, a detachable mould assembly, a base plate, and an ejector plate. During operation, manual pumping of the hydraulic jack generates a compressive force that is transmitted through a closely fitted steel piston to compact the biomass material within the mould cavities. The mould assembly consists of three rectangular cavities, each measuring 70 mm × 70 mm × 80 mm (length × width × height), enabling the simultaneous production of three briquettes per compression cycle. The moulds were fabricated from 5 mm-thick steel plates and mounted on a common base plate to ensure dimensional stability during compaction.

Agricultural biomass residues used in this study were rice husk, sawdust and charcoal dust obtained from local processing centres. Cassava starch was employed as a binder due to its availability, low cost and effective binding characteristics.

2.2 Design Considerations and Fabrication

The machine was designed with emphasis on simplicity, structural strength, safety and ease of operation. Particular attention was given to ensuring that the system could operate without electricity, utilise locally sourced materials and allow maintenance using basic workshop tools. Portability and low operational noise were also considered to make the machine suitable for household- and community-level briquette production.

The structural members were dimensioned to withstand the compressive load from the hydraulic jack. The compressive force applied during briquetting is expressed as

$$F = P \times A \tag{1}$$

where F is the compressive force in newtons, P is the pressure applied by the hydraulic jack, and A is the cross-sectional area of the piston.

The compression chamber was fabricated from 5 mm-thick steel plates, while the pressing piston consisted of a 10 mm-thick steel plate connected to the hydraulic jack ram. The piston plate was sized to fully cover the mould assembly, thereby distributing pressure uniformly during compaction. The frame dimensions were selected to provide adequate rigidity during loading while allowing convenient manual feeding and removal of biomass materials.

2.3 Biomass Preparation and Briquetting Procedure

Rice husk, sawdust, and charcoal dust were prepared for briquetting by sieving through a 3 mm mesh screen to remove oversized particles and foreign matter, thereby achieving a uniform particle size distribution. Cassava starch was used as a binder, mixed with each biomass at a 100:15 weight ratio, and water was added gradually during mixing to obtain a homogeneous mixture without forming a slurry. Care was taken to avoid excess water, as high moisture content negatively affects briquette strength and durability.

The prepared biomass mixture was poured into the mould, which was positioned inside the compression chamber. Prior to compaction, a small amount of water was added to the biomass and binder mixture to achieve an optimum moisture content of about 10 per cent by weight, which helps activate the cassava starch binder and improve particle bonding during compression. Manual pumping of the hydraulic bottle jack drove the piston downward, applying compressive force to the biomass within the mould cavities. The applied pressure caused particle rearrangement, interlocking, and binder-assisted bonding, resulting in compact briquettes. After reaching the required compression level, the pressure was released, and the briquettes were ejected using the ejector plate. The briquettes were then air-dried under ambient conditions for 3 to 5 days until the moisture content reduced to about 6 to 8 per cent, thereby improving their mechanical strength, durability, and combustion characteristics.

2.4 Compressive Strength Testing

Compressive strength tests were carried out on the produced briquettes using a hydraulic compression testing machine. Each briquette sample was positioned between two parallel loading plates, and load was applied gradually until visible cracking or failure was observed. The maximum load at failure was recorded and the compressive strength was calculated using

$$\sigma = \frac{F}{A} \quad (2)$$

where σ is the compressive strength, F is the failure load and A is the loaded surface area of the briquette. Multiple samples were tested for each biomass material, and the average compressive strength values were computed for analysis and comparison.

2.5 Burning Rate Measurement

The burning rate of the briquettes was calculated using Eq. (3):

$$BR = \frac{M_i - M_f}{t_c} \quad (3)$$

where BR is the burning rate of the briquette in g/min, M_i is the initial mass before combustion in g, M_f is the final mass after complete combustion in g, and t_c is the time taken for complete combustion in minutes.

Each briquette sample was tested three times, and the mean ± standard deviation was reported.

2.6 Proximate and Calorific Analyses

Moisture content, volatile matter, fixed carbon and ash content were determined according to ASTM standards D3173, D3175 and D3174. Calorific value was measured using a bomb calorimeter in accordance with ASTM D5865.

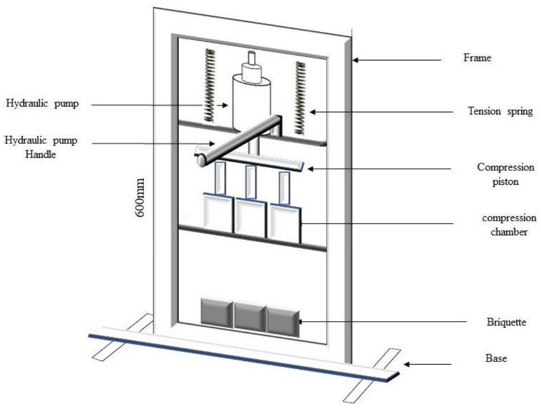

Figure 1: Schematic diagram of the manual hydraulic briquetting machine.

The configuration of the fabricated briquetting machine is illustrated in Figure 1, showing the hydraulic jack, compression chamber, piston, mould assembly and supporting frame.

2. RESULTS AND DISCUSSION

The fabricated briquetting machine is presented in Figure 2. The machine operated reliably under repeated loading cycles, maintaining structural integrity and consistent performance throughout briquette production. No mechanical failure, excessive vibration, or loss of alignment was observed during operation, indicating that the applied compressive forces were adequately sustained by the fabricated structure. This observation was based on visual monitoring of the machine during repeated compression cycles, including inspection of the frame stability, welded joints and the vertical movement of the piston within the compression chamber to ensure that no structural deformation, abnormal vibration, or misalignment occurred during operation.

Figure 2: Fabricated manual hydraulic briquetting machine.

(a) (b) (c)

Figure 3: Briquette samples produced from charcoal dust, sawdust and rice husk

Figure 3 presents the briquettes produced from different materials, with charcoal dust, rice husk and sawdust samples shown in panels A, B and C, respectively. The briquettes were uniform in shape and size, with clearly formed edges and intact surfaces after ejection from the mould.

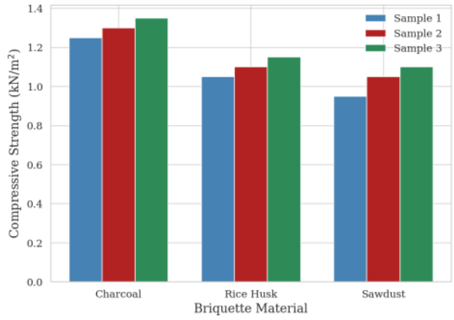

Figure 4: Compressive strength comparison of briquettes produced from different materials

The variation in compressive strength among the materials is illustrated in Figure 4. The results indicate a clear performance ranking among the tested materials, with charcoal-dust briquettes demonstrating superior strength under identical processing conditions. Charcoal briquettes recorded compressive strength values ranging from 1.25 to 1.35 kN m^{-2}, while rice husk briquettes showed moderate values between 1.05 and 1.15 kN m^{-2}. Sawdust briquettes exhibited the lowest strength values, ranging from 0.95 to 1.10 kN m^{-2}. The consistent trend across the three samples indicates that the type of biomass material strongly influences briquette strength. The higher strength observed for charcoal briquettes may be associated with their finer particle size and better particle packing during compression, which enhances interparticle bonding and briquette density.

Table 1 presents the proximate composition of the briquettes produced from charcoal dust, sawdust and rice husk, expressed in percentage on a weight basis. Charcoal dust briquettes recorded a moisture content of 10.2 ± 0.5, volatile matter of 68.3 ± 1.2, fixed carbon of 17.0 ± 0.8 and ash content of 4.5 ± 0.3. Sawdust briquettes showed slightly higher moisture content (12.0 ± 0.4) and volatile matter (70.1 ± 1.0), with lower fixed carbon (15.0 ± 0.5) and ash content (3.0 ± 0.2). Rice husk briquettes recorded moisture content of 9.5 ± 0.3, volatile matter of 66.0 ± 0.7, fixed carbon of 18.0 ± 0.6 and the highest ash content (6.5 ± 0.4). The relatively higher fixed carbon observed in charcoal dust and rice husk briquettes suggests better energy retention during combustion, while the higher volatile matter in sawdust briquettes indicates faster ignition and combustion behaviour.

Table 1: Proximate Composition of Briquettes

Property	Charcoal dust	Sawdust	Rice husk
Moisture	10.2 ± 0.5	12.0 ± 0.4	9.5 ± 0.3
Volatile Matter	68.3 ± 1.2	70.1 ± 1.0	66.0 ± 0.7
Fixed Carbon	17.0 ± 0.8	15.0 ± 0.5	18.0 ± 0.6
Ash	4.5 ± 0.3	3.0 ± 0.2	6.5 ± 0.4

The burning rate and calorific values of the briquettes are presented in Table 2. Charcoal dust briquettes exhibited the highest calorific value (26.0 MJ/kg) and the lowest burning rate (0.45 g/min), indicating longer combustion duration and higher energy output. Sawdust briquettes showed the highest burning rate (0.70 g/min) with a lower calorific value, suggesting faster fuel consumption. Rice husk briquettes demonstrated intermediate behaviour with moderate burning rate and energy content.

Table 2: Burning Rate and Calorific Values

Material	Burning Rate ((g/min)	Calorific Value (MJ/kg)
Charcoal dust	0.45 ± 0.02	26.0 ± 0.4
Sawdust	0.70 ± 0.03	17.2 ± 0.3
Rice husk	0.55 ± 0.02	20.1 ± 0.5

The variation in compressive strength among the briquette materials is illustrated in Figure 4. The results show a clear ranking among the tested materials, with charcoal dust briquettes recording the highest compressive strength under identical processing conditions. Rice husk briquettes recorded moderate strength values, while sawdust briquettes produced lower strength values. These differences reflect the influence of biomass particle characteristics and packing behaviour during compression on the mechanical integrity of the produced briquettes. The results indicate that charcoal dust is more suitable for producing mechanically stable briquettes under the operating conditions of the fabricated manual hydraulic briquetting machine.

4. CONCLUSION

A manual hydraulic briquetting machine was designed, fabricated and tested to convert charcoal dust, rice husk and sawdust into dense, uniform briquettes. Charcoal dust produced the strongest briquettes, followed by rice husk and sawdust, indicating that feedstock type affects strength. The machine runs without electricity, is simple to build and maintain and produces fuel suitable for household use. Small-scale briquette production offers a low-cost, sustainable, low-emission energy source that uses agricultural residues.

ACKNOWLEDGMENT

The researchers would like to express their gratitude to Dr. Isah Sa’idu. Appreciation is also extended to the authors whose published works contributed to and informed this study.

REFERENCES

Abubakar, I. R., Alola, A. A., Bekun, F. V., & Onifade, S. T. (2024). Investigating the determinants of household energy consumption in Nigeria: insights and implications. *Energy, Sustainability and Society*, *14*(1), 29.

Aduba, J. J., Shimada, K., & Longfor, N. R. (2024). Harnessing biomass waste-to-energy for sustainable electricity generation: prospects, viability and policy implications for low-carbon urban development. *Clean Technologies and Environmental Policy*, 1-22.

Yunusa, S. U., Mensah, E., Preko, K., Narra, S., Saleh, A., & Sanfo, S. (2024). A comprehensive review on the technical aspects of biomass briquetting. *Biomass Conversion and Biorefinery*, *14*(18), 21619-21644.

Onyegirim, S. N., Nwankwo, E. I., Owuama, K. C., & Madukasi, H. A. (2025). Advances in Charcoal Briquetting Machines: A Comprehensive Review of Technologies, Performance and Sustainable Applications. *International Journal of Applied and Natural Sciences*, *3*(2), 35-49.

Dairo, O. U., Adeleke, A. E., Shittu, T., Ibrahim, N. A., & Adeosun, O. J. (2023). *Development and performance evaluation of a low-cost hydraulic-operated biomass briquetting machine*. *FUOYE Journal of Engineering and Technology, 3*(1), 31

Odejobi, O. J., Ajala, O. O., & Osuolale, F. N. (2024). Review on potential of using agricultural, municipal solid and industrial wastes as substrates for biogas production in Nigeria. *Biomass Conversion and Biorefinery*, *14*(2), 1567-1579.

Kpalo, S. Y., Zainuddin, M. F., Manaf, L. A., & Roslan, A. M. (2020). A review of technical and economic aspects of biomass briquetting. *Sustainability*, *12*(11), 4609.

Qi, J., Li, H., Wang, Q., & Han, K. (2021). Combustion characteristics, kinetics, so2 and no release of low-grade biomass materials and briquettes. *Energies*, *14*(9), 2655.

Onyegirim, S. N., Nwankwo, E. I., Owuama, K. C., & Madukasi, H. A. (2025). Advances in Charcoal Briquetting Machines: A Comprehensive Review of Technologies, Performance and Sustainable Applications. *International Journal of Applied and Natural Sciences*, *3*(2), 35-49.

World Bank. (2023, November 21). *Transforming lives through energy access in Eastern and Southern Africa*. https://www.worldbank.org/en/results/2023/11/21/transforming-lives-through-energy-access-afe-1123-in-eastern-and-southern-africa

World Health Organization. (2024, October 16). *Household air pollution and health* (Fact sheet). https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.