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Design and Fabrication of Tapered Screw Briquetting Machine

Yahaya U. JAURO[1], Danladi D. USMAN[2], Lawan G. ABUBAKAR[3], Yusuf G. SHIMBURA[4], Aminu MOHAMMED[5]

[1]Department of Agricultural and Bioenvironmental Engineering, Federal Polytechnic Bali, Taraba State, Nigeria
[2*,3,4,5]Department of Agricultural and Bioresource Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria

[1]omarjyahya@gmail.com, [2*]ddusman@atbu.edu.ng, [3]lgabubakar@atbu.edu.ng, [4]yusufgarsama@gmail.com, [5]aminu@atbu.edu.ng

Abstract
Briquettes produced from waste materials present a sustainable energy alternative that can mitigate environmental impacts, forest degradation, and deforestation. The compaction of biomass residues, termed briquetting, transforms this waste into an efficient and viable clean energy source suitable for rural and suburban communities. The primary objective of this research was to design, fabricate and testing of a tapered screw-type briquetting machine for briquette. The machine was designed and fabricated using mild steel, and was tested for production, the machine was powered by a 1 hp (746 W) single-phase electric motor integrated with a gearbox. Key parameters were a hopper capacity of 151.68kg, a 450 mm screw length, a 400 mm extrusion barrel, a 39 mm extruder diameter, and a 700 mm drive belt. The efficiency of the machine and throughput capacity were computed to be 89% and 135 kg/h while the material has a maximum density of 840 kg/m^3 and relax density of 326.17 kg/m^3. This development proved effective in converting common agricultural residues such as rice husk, sawdust, and sugarcane peels into dense, combustible briquettes suitable for both domestic and industrial heating applications.

Keywords: *Design, fabrication, biomass, briquettes, tapered screw.*

1.0 Introduction

The global reliance on conventional energy sources such as firewood, charcoal, and fossil fuels contribute to environmental degradation, climate change, and public health challenges, particularly in some regions of developing countries (Kpalo *et al*., 2020). In sub-Saharan Africa, over 80% of rural households depend on biomass for cooking and heating, contributing significantly to deforestation and indoor air pollution (IEA, 2021). This unsustainable energy model has led to the search for renewable, cleaner, and more efficient alternatives capable of addressing both energy, poverty and ecological preservation. To provide solutions, biomass briquetting technology has gained recognition as a viable waste-to-energy strategy that converts agricultural and other forms of solid waste forestry, and municipal residues into uniform, high-density solid fuels known as briquettes (Kaliyan and Morey, 2009). The briquetting process typically involves drying, shredding, and compacting loose biomass under high pressure with or without binders to produce briquettes with improved handling, storage, and combustion properties compared to raw biomass (Grover and Mishra, 1996). The technological evolution of briquetting has seen the development of various types of briquettes press, including piston (hydraulic/mechanical), screw extrusion press, and roller press, each with distinct operational and output characteristics (Maji *et al*., 2017). While piston presses are noted for high pressure and durability, screw presses are praised for continuous operation and the production of centrally hollow briquettes that enhance combustion efficiency (Yaman *et al*., 2001). Despite these advances, the adoption of briquetting, especially in rural and peri-urban contexts, remains constrained by challenges related to machine cost, energy input, maintenance requirements, and the availability of suitable feedstock (Jekayinfa and Scholz, 2009).

The widespread stalks offer a cleaner, more efficient, and environmentally friendly solid fuel. It serves as a vital renewable and sustainable alternative energy source particularly in places that heavily depend on traditional biomass and fossil fuels. As an alternative source of energy, briquettes transform low-value biomass waste into high-density, uniform solid fuels with improved combustion properties (Njenga *et al*., 2019), reduce of deforestation and carbon emissions by substituting charcoal and firewood and can significantly reduce greenhouse gas emissions compared to traditional wood fuels (Kpalo *et al*., 2020)., and enhanced environmental and health outcomes because it generally produce less smoke and particulate matter during combustion compared to charcoal and firewood, contributing to improved indoor air quality and reduced respiratory health risks (WHO, 2022).

Despite the recognized potential of briquette technology as a sustainable alternative energy source, a significant research gap exists in the localized design and optimization of tapered screw briquetting presses (Chin *et al.,* 2000). Existing studies primarily focus on performance evaluation of commercial or imported machines, often overlooking critical design parameters tailored to specific feedstock, such as the common agricultural residues in developing countries. This has resulted in a reliance on costly, imported machines that are frequently ill-suited to local material properties and maintenance capacities, limiting their adoption and effectiveness (Obi *et*

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al, 2013). Consequently, there is a pressing need for applied research that designs, fabricates, and tests a cost-effective tapered screw briquette press that balances performance, affordability, and ease of maintenance, thereby bridging the gap between laboratory-scale innovation and field-level implementation.

2.0 Materials and Methods/Methodology

2.1 Material Selection

The following materials were selected based on their mechanical strength as regards the type of forces such compression force, frictional force, shear force and hopper flow force acting on the machine members, its operational environment, cost of the material and its availability.

Table 1. Technical Parameters of the Machine

S/N	Machine Component	Function	Material	Specification
1	Frame	Design to support briquetting barrel and screw assembly	Angle iron	2mm/5mm
2	Hopper	This is a channel for easy passage of feedstock into the screw of the system.	Mild steel sheet	2mm
3	main pulley	Pulleys are connected with belt which transmit motion and power to the shaft	Cast iron	180mm/25mm (external and internal diameter)
4	Motor pulley	Pulleys are connected with belt which transmit motion and power to the shaft	Cast iron	100mm/20mm (external and internal diameter)
5	Transmission belt	The belt transfers the mechanical power and torque generated by the electric motor.	Fiber reinforced synthetic rubber	700mm (length)
6	prime mover (electric motor)	Provide the initial rotation power	Cast iron outer casing	1Hp
7	Auger (shaft)	Compress and extrude material continuously using rotating auger	Mild steel round rod	25mm
8	Auger carrier	The carrier housed the auger	Mild steel sheet metal	3mm
9	Extruding barrel	The outlet to which the compressed briquettes come out.	Mild steel sheet metal	3mm

A single phase one horsepower electric motor with attached gearbox was used to power the machine with a power requirement of 746 watts (W), other important parameters such a hopper has 151.68kg capacity, screw length is 450mm, length of extruding barrel 400mm, extruder diameter is 39mm, and the length of belt is 700mm respectively. The designed methodology applied include design and Planning, which defined specifications, required forces, machine drawings, and prepared bill of materials. This was followed by the cutting and fabrication of components to shape, and the welding of the frame, compression barrel, screw, hopper, and power transmission parts. Assembly included mounting the compression system**,** installing the drive mechanism, attaching the hopper, and adding safety features. Testing and Calibration were then performed to conduct dry and wet runs, adjust speed and moisture of briquette. Finally, documentation and finalization were carried out to record adjustments**,** paint the machine, and prepare operating guidelines.

2.2 Design Consideration

The following factors were considered in the machine design.

- Machine with minimum loss of material during operation.
- Machine that can improve the timeliness of operation.
- Hopper size and shape to be suitable for handling bulk materials.
- Selecting standard parts of the machine to be free from corrosion and withstand the operational conditions.
- Design simplicity such that faulty components can be constructed and replaced by local artisan.

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- Ergonomics factors such as operator's safety
- Economic aspect and overall cost of the machine
- Attraction and acceptability to the farmers

2.3 Design Concept

The briquetting machine designed was a tapered screw press. Its main components parts are the power cable, electric motor, pulleys and belts, screw, compression chamber, frame and briquette die. Power is transmitted through pulleys and belts from the motor to the screw. After starting the motor, raw material are fed through the hopper into the compression chamber and extrude it through the die. Design considerations were based on forces required to drive the shaft, diameter of the screw shaft, the dynamic load on the bearing transmitted by the screw shaft, power required to compact pulverized feedstock as well as extrude the resultant briquette from the die. Other considerations include determination of dimensions and shapes of components for smooth operation.

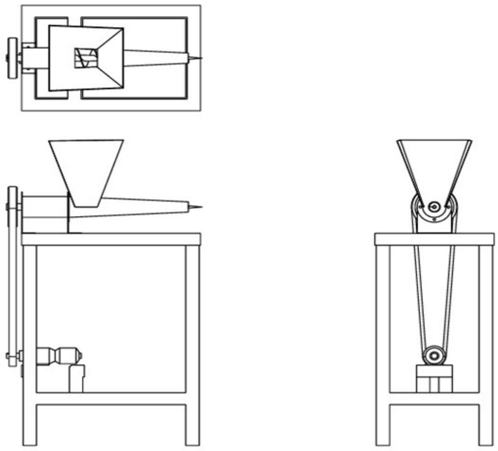

Figure 1: Design Concept

2.4 Design Calculation

Design of hopper

The volume of hopper was calculated using Equation (1) as stated by Ikubanni *et al* (2020).

$$V = \frac{1}{3} \times h\ (A_1 + A_2\sqrt{A_1 \times A_2}) \quad (1)$$

Were

V = volume of the hopper in (m³); A_1 = area of the top in (m³); A_2 = area of the hopper base in (m³) and h = hopper height (m)

Shaft Design

The size of the shaft to was determined using Equation (2) as given by (Khurmi and Gupta 2012).

$$d^3 = \frac{16}{\pi\tau_{max}}[(K_b M_B)^2 + (K_t M_t)^2]^{\frac{1}{2}} \quad (2)$$

where;

d = diameter of the shaft, m, τ_{max} = allowable stress NM/m², M_t = torsional moment Nm

M_B = bending moment Nm, k_b = combine shock and fatigue factor applied to bending moment

k_t = combine shock and fatigue factor applied to torsional moment

Note: For the gradually applied load condition, Kb and Kt are taken to be 1.5 and 1.0 respectively.

Pitch Diameter

$$(P.D) = \frac{P \times N}{\pi} \quad (3)$$

where: PD = pitch diameter, P = pitch distance between two adjacent teeth, n = total number of teeth on the gear,

The Length of Belt

The length of belt (L) was determine using Equation (4) as reported by (Khurmi & Gupta, 2005)

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x} \quad (4)$$

where;
d_1 = diameter of driving pulley, m, d_2 = diameter of driven pulley, m, x = distance between the centers of the pulleys

Power Requirement

The power requirement of the machine was computed from Equation (5) as stated by Adeshina *et al,* (2021)

$$P = fv(n + 1)/\beta\epsilon \quad (5)$$

where: F is the briquetting force (N), β is the thread efficiency (%), ε the belt drive efficiency (%), n the frictional loss efficiency (%), V is the velocity of the worm (m/s), and P the total power requirement (W).

Frame Design

The design of the frame involves the determination of the correct size of the section which support all the components of the machine under the operating condition. The weight of the components of the frame of the briquetting machine was determined using equation (6) as given by (Khurmi & Gupta, 2005)

$$W = \rho \times V \times g \quad (6)$$

Where;

W is Weight of components, N
ρ is density of material to be used for construction of component, kg/m^3
V is volume of material to be used for construction of components, m^3
g is acceleration due to gravity ($9.81\ m/s^2$)

Maximum and Relax Density

The maximum (compressed) and relaxed densities of the manufactured briquettes were established in accordance with the methods described by Namadi *et al*, (2024).

$$Density \frac{\boldsymbol{mass\ (m)}}{\boldsymbol{volume\ (v)}} \quad (7)$$

$$v = \pi r^2 h \quad (8)$$

where; r and h are the radius and height of the briquette respectively.

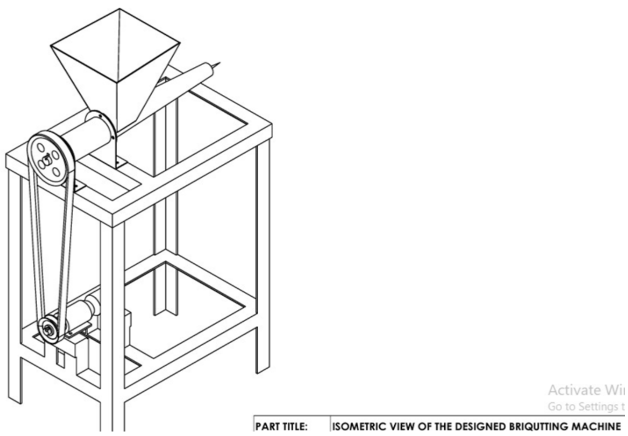

Figure 2. Isometric view of the designed briquette machine

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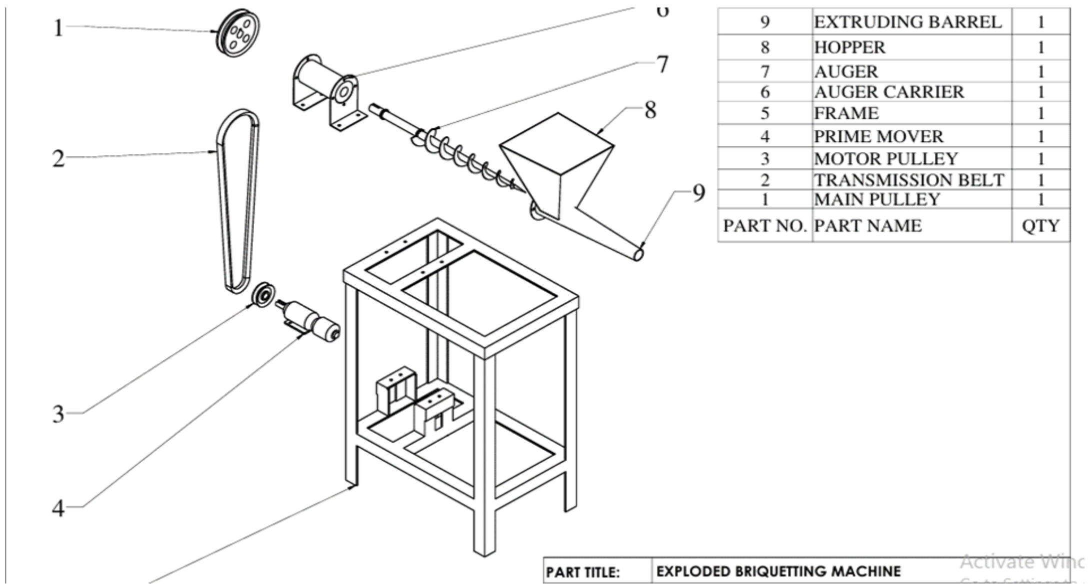

Figure 3. Exploded view of designed briquetting machine

3.0 Results and Discussion

A tapered screw-type briquetting machine was successfully designed and fabricated with all the major components designed with required materials to specification and assemble as stated in table 1 above. Figure 1 above shows a concept proposed design of the machine, figure 2 and figure 3 shows an isometric and exploded view of the already designed machine showing all components. The machine was test run to produce briquettes with all major and minor adjustment take care off for smooth operation while maintaining briquettes quality having a high compressive density of 840.17kg/m³ and a relax density of 326.7 kg/m³ as stated in table 2 above. Also, the machine has a an efficiency of 89% and a throughput capacity of 135kg/h. Similar research on the development of a dually operated biomass briquette press was carried out by Adeshina *et al*, (2020) arrived at a values of 80% efficiency and throughput capacity of 50kg/h of briquette produced from rice husk, research of Ikubanni *et al*, (2020) titled Development and performance assessment of piston-type briquetting machine, recorded a machine efficiency, throughput capacity and material density from saw dust and rice of 85.7%, 68.71kg/h, 870kg/m³ and 860 kg/m³ . Namadi *et al,* (2024) in their research design, construction and performance evaluation of a low-cost portable molder for biofuel briquette production arrived at a value of 962.19kg/m³ and 448.16kg/m³ for maximum and relax density respectively. The result from this study reveals that the machine developed is good for solid biofuel production for cleaner energy and can be utilized in rural and sub-urban areas of developing countries, also physical properties examined for the briquettes produced revealed that the briquettes possessed good physical qualities that could withstand damage during handling and transportation.

Table 2. Technical parameters of the designed machine and briquette properties

S/N	Parameters	Value	S.I Units
1	Capacity of Hooper	151.68	kg
2	Diameter of extruding barrel	35	mm
3	Length of screw	450	Mm
4	Length of barrel	400	Mm
5	Length of belt	700	Mm
6	Motor size	1.0	hp
7	Power requirement	746	Watts
8	Efficiency	89	%
9	Maximum density	840.17	Kg/m³
10	Relax density	326.17	Kg/m³

4.0 Conclusion

Briquetting offers a viable alternative energy source to traditional firewood and charcoal, directly contributing to the reduction of deforestation driven by energy needs, Adeshina et al, (2020) and Okegbile *et al*, (2017). A tapered screw-type briquetting machine was successfully designed and constructed for this purpose. The development proved effective in converting common agricultural residues such as rice husk, sawdust, and sugarcane peels into dense, combustible briquettes suitable for both domestic and industrial heating applications.

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Among other materials, briquettes produced from sugarcane peels and corn cob demonstrated notable potential in supporting a circular waste-to-energy model. This process not only extracts useful energy from otherwise discarded biomass but also significantly reduces the volume of waste sent to landfills. By diverting organic waste from disposal sites, briquetting conserves land and promotes improved environmental sanitation Okegbile *et al*, (2017). The use of agricultural waste mitigates the common issue of agricultural waste accumulating in drains, vacant plots, and along roadsides thereby reducing pollution, discouraging open burning, and supporting cleaner communities.

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Conflict of Interest

Authors have declared that no competing interests exist.

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