Project Proposal

on

Transforming Agricultural Waste into Renewable Energy: A Semi-Mechanized Biomass Briquetting Plant to Minimize Human Drudgery and Promote Sustainable Development

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1. INTRODUCTION

1.1 Background of Study

The utilization of agricultural residue as solid fuel is often difficult due to the variation in their physical and combustion characteristics. If the wastes are densified, they become compact to transport in addition to giving them regular shape and sizes. The dense biomass can also be tailored for efficient combustion. One of the methods of compacting biomass into a product of higher density than the original raw material is known as briquetting.

Briquetting, or biomass densification, refers to a group of techniques used to convert biomass into fuel. In order to reduce volume and agglomerate loose biomass materials, it usually entails compacting them under pressure. This keeps the product in the compressed state, where it has a greater compactness, consistent form, reduced moisture level, and enhanced calorific value (Sunday *et al*., 2020; Kaur *et al*., 2017).

Densification process referred to as briquetting is employed to upgrade solid biomass into final products with consistent properties. Briquetting is a process that converts low bulk density biomass into high density, energy-rich fuel in order to improve its density, burning time, and calorific value per unit volume (Mwampamba *et al*., 2018; Surendra *et al*., 2017). This transformation makes biomass easier to handle, store, and transport (Ngusale *et al*., 2018).

Arowosafe *et al*. (2021), noted that briquetting is the enhancing of biomass into uniform solid fuel by mechanical process to accomplish higher density, increased calorific value and less moisture content when the solid fuel is compared to its initial raw biomass material. This is achieved by applying mechanical pressure that compact the particles and forms inter-particle bonds. However, the quality of densified biomass is largely determined by the strength and stability of the particle bonds, which in turn are influenced by several process variables such as die diameter, die temperature, applied pressure, type of binder, and pre-heating of the biomass mixture (Tumuluru *et al*., 2011).

The output of the densification process is known as briquette, which is referred to as a compressed block of organic waste material (Oladeji, 2015). Briquettes can be made from combustible materials obtained from agricultural waste, sawdust or other types of biomass. Briquette has attracted much attention as an alternative fuel for domestic (cooking, heating, barbequing) and industrial purposes (agro-industries, food processing) in both rural and urban areas as it pose no harmful threat to the society while in use because it is eco-friendly, environmentally acceptable and can be domestically produced.

In Nigeria, the densification of biomass for briquette production has experienced major setbacks due to the fact that the conversion technologies are somewhat complex, rigorous and requires a lot of human effort and labour to complete the production process. Many researchers have worked on the development of various Biomass briquette conversion technologies in Nigeria at different levels. Arowosafe *et al*. (2021) developed a screw press briquetting machine principally for converting agro-residues into briquettes; they reported that the machine is capable of producing briquettes in continuous operation. Ejiroghene *et al*. (2017) designed and fabricated a low cost manually operated biomass briquetting machine for local use in Nigeria.

Inegbenebor (2002) developed a five tonnes capacity briquetting machine for compressing agricultural and wood waste that can produce six briquettes at a time. Mainza (2017) designed and fabricated a ten tonnes manual briquetting machine capable of producing twenty briquettes at a time. Ajikashile *et al.* (2021) designed and fabricated a hydraulic piston press biomass briquetting machine for hollow-briquettes.

Researches done so far have been able to design and fabricate machines for briquette production that have several processes i.e. separate machines were used to carbonize, crush and to mix before getting to the final stage of briquetting. Although work has been substantially successful however, none of the machines has been automated which has made the efforts laborious, time consuming and unfit for commercial purpose. Therefore, this research seeks to develop a semi-mechanized biomass briquetting plant which will combine all the processes of briquette production in a single plant assembly thereby eliminating individual machines (for carbonizing, crushing, milling and briquetting machine). The great savings in space and efficiency can be realized while maintaining an output quality with low cost.

1.2 Aim and Objectives

The aim of this research is to develop a semi-mechanized biomass briquetting plant assembly that can efficiently convert biomass waste into briquettes.

The specific objectives include:

i. Design and fabricate different units of the biomass production plant.

ii. To integrate the various assembly units to work simultaneously and to test the machine.

1.3 Statement of the Problem

Research on briquetting technologies in Nigeria is still ongoing as many of the indigenous briquetting machines produce solid briquettes which are characterized by more or less laborious production process. These set of technologies are mostly manually operated and are solely dependent on human strength for direct operation and application of pressure for biomass crushing, carbonizing, milling and densification which result in poor quality briquettes and low production capacities making them unprofitable for commercial use in the Nigerian market.

However, several researches have been carried out to develop a more sustainable technology for production of briquette but none of them have been able to combine the different units involved in the production as most of the processes involved are still manually independent and very laborious consequently, resulting in long hour of production. This research seeks to develop a semi-automated briquetting machine which will not only reduce human labour and enhance briquette production but will also produce high quality briquettes.

2. METHODOLOGY

This research will be divided into two parts. The first part will involve the development of a semi-mechanized biomass briquetting plant while the second part will involve biomass briquette production.

2.1 Development of a Semi-Mechanized Briquetting Plant

The briquette production plant will consist of a biomass dryer, carbonizing kiln, hammer mill, biomass mixer, screw extruder, and a briquette dryer. Each component of the plant assembly will be designed with careful consideration of cost-effectiveness, ease of operation, serviceability, and long-term durability. The overall process flow chart of the briquetting production system is illustrated in Figure 1.

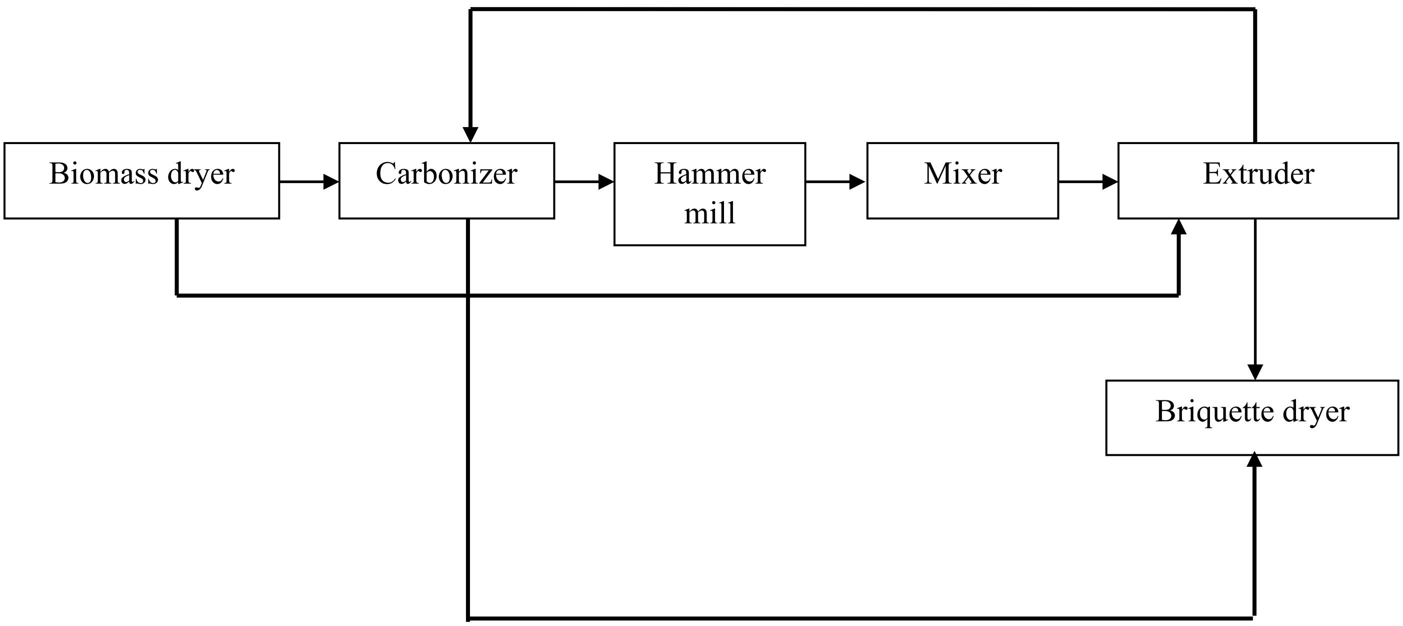

Fig. 1: Process flow chart for briquetting plant assembly

Key:

Sawdust briquette

Agro residue briquette

2.1.1 Biomass Dryer

A tunnel biomass dryer will be developed to ensure that biomass materials are dried quickly and efficiently before further processing. The drying process works by passing hot air through the biomass, reducing its moisture content to the desired moisture level. The operation will begin by feeding the biomass into a cylindrical tunnel equipped with internal paddles or agitators, which steadily move the material along the chamber. As the material advances, it is exposed to a continuous stream of hot air generated by a combustion chamber. To withstand the high temperatures involved, the chamber will be lined with refractory material for durability and safety. The hot air flows through the biomass at high velocity, causing rapid evaporation of moisture. An exhaust system will carry the evaporated moisture out of the chamber, while the dried biomass is discharged at the outlet, ready for densification.

2.1.2 Crusher

Crushing is a critical step in biomass preparation, as it increases the bulk density of the material and enhances its flow during the densification process. To achieve this, the briquetting plant assembly will include a hammer mill for crushing biomass into fine particle sizes. This stage is essential prior to briquetting because it not only improves handling but also partially breaks down the lignin content of the biomass. The breakdown of lignin, combined with the increased surface area, facilitates stronger inter-particle bonding, which ultimately improves the strength and quality of the briquettes.

2.1.3 Mixer

The addition of binders to biomass feedstock is a well-established co-processing practice that enhances densification and improves the mechanical and thermal properties of the final product. Certain types of biomass, particularly when processed under low-pressure compaction, require the use of binders to achieve proper agglomeration. To address this, the proposed system will incorporate a sigma mixer designed specifically for binder integration. This mixer will be fitted with paddles set at varying angles, ensuring thorough agitation and uniform blending of the milled biomass with the binder. The result will be a homogeneous mixture that supports efficient densification and produces briquettes of consistent quality.

2.1.4 Biomass Extruder

A screw press consisting of a screw extruder and a die will be developed, designed to follow the single-screw press extrusion principle. The machine will be composed of key components including the screw, barrel, die, electric motor, pulley, and belt system, frame, and hopper. Drawing insights from literature, several assumptions will guide the design process. These assumptions will account for factors such as the forces required to drive the shaft, the expected throughput capacity, the screw shaft diameter, and the dynamic load on the bearings transmitted by the screw shaft. Additionally, the design will consider the power rating of the electric motor needed both to compact the pulverized biomass and to extrude the briquette through the die. Design acceptability and efficiency will also serve as critical benchmarks in the development of the screw press.

2.1.5 Briquette Dryer

To ensure proper drying of the briquettes, a tunnel dryer will be developed. In this system, the freshly produced briquettes will be conveyed into the drying chamber using a conveyor belt. The dryer will consist of a long, tunnel-shaped chamber through which the conveyor belt will move at a controlled speed. As the briquettes travel through the tunnel, they will be exposed to circulating hot air, which will gradually remove excess moisture. This drying process is critical, as it reduces the briquettes' moisture content to the desired level, thereby enhancing their strength, making them easier to handle and store, and significantly improving their combustion efficiency.

2.1.6 Working mechanism of the briquette production plant assembly

The biomass dryer will first reduce the moisture content of the feedstock to the required level. Once dried, the material will be transferred via a screw conveyor to the burr mill, where it will be crushed and reduced to fine particle size. From the burr mill, another screw conveyor will feed the material into the mixer, where it will be thoroughly blended with a binder to form a homogeneous mixture. The premixed biomass will then be directed into the screw extruder for densification.

Inside the extruder, the rotating screw will convey, compress, and compact the material against the die. This action generates substantial pressure and friction due to biomass shearing, wall friction along the barrel, and the high rotational speed of the screw. The combined effects lead to a rise in temperature within the closed system, causing the release of lignin (in biomass types such as sawdust), which acts as a natural binder. The heated material will then be forced through the extrusion die to form solid briquettes.

For cases where an external binder is used, the freshly extruded briquettes will be conveyed into the tunnel dryer, where hot air circulation will reduce their moisture content to the desired level.

2.2 Briquette Production Process

2.2.1 The process of briquette production

Figure 2 shows the process flow chart involved for briquette production. The briquettes production will have two technological routes for producing briquettes from waste biomass and residues:

Route 1: The briquetting – carbonization (B-C) option

Here the raw material will first be densified and then carbonized to produce briquettes.

Route 2: The carbonization – briquetting (C-B) option

Here the raw material is first carbonized and crushed if necessary to obtain powdered charcoal, which is then briquetted using a suitable binder.

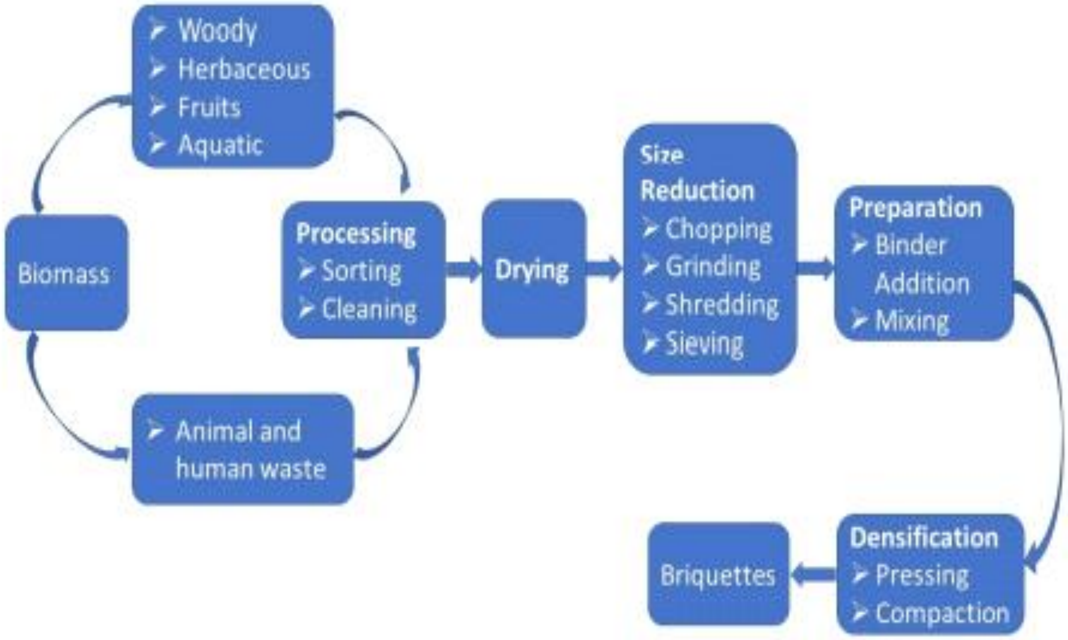

Fig. 2: Flow chart for briquette production

3. BUDGET

S/N	Component	Estimated Cost (₦)
1	Biomass Dryer	2,600,000
2	Carbonizing Kiln	2,500,000
3	Hammer Mill with Cyclone	3,000,000
4	Mixer	2,500,000
5	Screw Extruder	4,000,000
6	Tunnel Briquette Dryer	2,800,000
	Total	**17,400,000**

4. RESEARCH WORK PLAN

S/N	Project Activity	Oct 2025	Nov 2025	Dec 2025	Jan 2026	Feb 2026	Mar 2026	April 2026	May 2026	June 2026
1	Review of Literature									
2	Design and fabrication of dryer									
3	Design and fabrication of carbonizer									
4	Design and fabrication of mixer									
5	Design and fabrication of extruder									
6	Design and fabrication of Tunnel dryer									
8	Design and fabrication of Chiller									
9	Assembling of machine part and testing									

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