ACCEPTABILITY OF BRIQUETTE PRODUCTS: A PANACEA TO SUSTAINABLE ENERGY GENERATION IN NIGERIA

Omole, A. O.[1], Areo, O. S.[2*], Adejoba, A. L.[2], Aguda, O. L.[2] and Afolabi, S. O.[1]
[1]Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria
[2]Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria, Ibadan, Nigeria.
*Corresponding Author: areosola73@gmail.com, +2348101820261

ABSTRACT

The transition from fossil fuels to biomass energy has been identified as a major approach to lowering carbon dioxide (CO_2) and other greenhouse gas emissions in Nigeria. Briquette is a solid biofuel made from compressed biomass residues, which could be used as a source of energy in domestic cooking and heating. Renewable energy from briquettes has relatively low pollution emissions and huge potential for utilisation. Biomass briquettes provide minimal heating costs; have increased storage ability and high portability. Although, Nigeria has a sizable supply of biomass for briquetting, the marketability and technology are incredibly underdeveloped. This article highlights the acceptability of briquette products as possible alternative energy sources to the present high-cost and irregular heating energy sources currently available in the country. This review paper considered briquette as a viable and sustainable option for meeting the energy needs of Nigerian households. It discusses the need to promote briquette utilization among government, private sector and civil society organizations. In addition, there is need for the development of low cost technology that will enhance its acceptability.

Keywords: Biomass residues, Briquette utilization, Renewable energy.

INTRODUCTION

In developing countries, a large percentage of the population depend on conventional sources of energy like fuel-wood and charcoal. The exponential growth in human population and industrial expansion, have caused an ever increasing need for energy for residential use and other purposes (Bagabo *et al*., 2014). Unfortunately, there is limited availability of reliable and affordable clean energy. In Nigeria, local demand for energy is met through the use of fuelwood, charcoal, kerosene, liquefied gas and electricity.

Electricity and Liquefied Petroleum Gas (LPG) are expensive and not accessible to many low-income, rural communities (Kpalo *et al.*, 2022). The price of power from electricity has increased astronomically in recent years, with a rise from ₦30.23 to ₦62.33 per kWh (NERC, 2020). The average cost of LPG increased from ₦4,565.56 in December 2022 to ₦4,588.75 in January 2023 for a 5 kg gas cylinder. The cost of a litre of kerosene rose from ₦397.34 in July 2021 to 789.75 in July 2022 (NBS, 2022). Charcoal cost ₦4,500 per bag, with regional variations resulting in higher pricing. Except for the already-refined gasoline, no subsidies or other incentives are provided for the consumption of energy from these sources.

Nigeria was one of the top producer of wood fuel in 2020, along with Ethiopia, India, China, Brazil, and other countries (FAO 2020). Unfortunately, Nigeria's current capacity for power is about 13,000 MW,

which is inadequate judging by the country's current demand for electricity from over 200 million people, (approximately 98,000 MW). The real output is between 3,500 MW to 5000MW, leaving over 90,000 MW demand gap across the country (Ichu *et al*., 2019; Adoghe *et al.,* 2023).

Biomass is the third largest global energy resource for heating and cooking (Tumuluru *et al*., 2011; Baqir *et al*., 2018). In Nigeria, over 78% of the energy needs are met by traditional biomass combustion (Mugabi and Kisakye, 2021). Majority of the wood originate from forests, and are either directly burned in open fires or initially turned into charcoal before use. Unfortunately, charcoal production, open burning, and indiscriminate fuelwood collection are inefficient and unsustainable practices. These activities result in environmental problems such as deforestation, soil erosion, land degradation, and air pollution (Shaaban and Petinrin, 2014).

Biomass briquette production has been suggested as a process which converts wood waste and plant residues into high density solid substances. Pressure is applied to the biomass waste which is mixed with binders, during the production of briquettes. The briquette is used for cooking, heating dwellings, roasting fish, and providing energy in homesteads (Ndindeng *et al*., 2015). The use of renewable energy from briquettes could increase energy security, boosts economic growth and community welfare, while reducing environmental degradation.

In the past, technologies that increased the harnessing of energy from coal and crude oil revealed that the biomas energy was of low economic value (Van and Fouquet, 2017). However, increased environmental degradation and particularly climate change have shifted the focus back to biomass energy. Fuel briquettes are easy to produce and they are affordable, with the possibility of customization under a wide range of settings. This article presents the acceptability of briquettes and its utilization as an alternative source of energy in Nigeria.

BRIQUETTE PRODUCTION

The quality and dimensions of briquettes depend on the manufacturing processes, mold, and raw materials used. The sizes range from 10 to 400 mm in length and 25 to 100 mm in diameter, while shapes include cylinders, rectangles, squares, and polygons (Wang *et al*., 2017). Briquetting is a technique that increases the bulk density of biomass from 150 kg/m^3 to as high as 1300 kg/m^3 (Ujjinappa and Sreepath, 2018). These densely packed solid biomass release stored energy when burned (Oladeji, 2015). The briquetting technology is the process of compacting or densifying residue into products with a higher density than the raw materials (Mwampamba *et al.,* 2013; Kaur *et al*, 2017). The technique includes drying, grinding, sieving, compacting, and cooling (Kpalo *et al.,* 2020). Some types of briquetting machines include roller presses, screw press extruders, and mechanical or hydraulic piston presses (Kaur *et al.,* 2017). These devices can be operated manually or by using an automated system, depending on whether the approach is low or high compaction pressure. Briquettes can be prepared with or without binders such as

starch, gum Arabic, or clay soil. The raw material, compaction pressure and speed influence the type of binder employed (Pallavi *et al.*, 2013). The briquetting technology has struggled to obtain solid footing in Nigeria, due to technical limitations, and insufficient knowledge on how to adapt the technology to local conditions (Dairo *et al.*, 2018).

CHARACTERISTICS OF BRIQUETTES

Briquette properties are assessed based on their physical, mechanical, and thermal qualities. These determine how briquettes are handled, transported, stored, and burned. The effectiveness of the densification process is shown by the quality of the briquettes, which also affects how well they can withstand specific impacts (Tumuluru *et al*., 2010). The kind of feedstock material and the briquetting process also affect their quality (Stolarski *et al*., 2013). Hence, a good briquette should have low moisture content, high crushing strength, high density, moderate flame propagation, and a high calorific value (Arewa *et al*., 2016).

Biomass Feed Stock for Briquette Production in Nigeria

Large volumes of biomass residues are produced as by-products in forestry based industries, agriculture, and industrial sectors (Table 1) (Njenga *et al*., 2009; Sugumaran and Seshadri, 2010). These are residues are either burned in the open air or allowed to degrade naturally. These release greenhouse gases (GHG) and cause environmental problems. For instance, the forestry and agricultural industries produce up to 1000 million tonnes (Mt) and 140 Mt of waste, respectively, on an annual basis (Dasappa, 2011). These residues however, could be used for briquette production. About 45% of the wood used to make furniture and 52% of the wood processed to lumber in sawmills are left over as residues. Less than 80% of the trees that are harvested are removed from the forest during logging, leaving behind approximately 20% as residue (Ogunrinde and Owoyemi, 2016).

TYPES OF BRIQUETTES

Briquettes can be divided into charcoal and biomass briquettes. They could also be binderless or additive briquettes, depending on the technology adopted (Adegoke *et al*., 2018; Lamido *et al*., 2018).

The carbonized briquettes have their biomass converted into carbon through pyrolysis (Amer and Elwardany, 2020). Pyrolysis is the process of heating any carbon or hydrocarbon containing substance in the absence of oxygen. The elimination of water and other elements allows the briquette to burn at a higher temperature for pyrolised biomass (Ajith *et al.*, 2020). When compared to unprocessed biomass, which has a calorific value of approximately 15 MJ/kg, bio-char has a calorific value of 25 to 30 MJ/kg, about double the energy content per unit of weight. The terms "charcoal briquettes" or "biocoal" refer to briquettes that have a charcoal-like look (Mwampamba *et al*., 2013).

Biomass contains natural structural binders or stabilizing substances, like lignin and proteins which are released and activated when biomass is compressed at relatively high temperatures and pressures (Oyelaran *et al.*, 2015). This promotes biomass briquette

structural particle bonding. The piston presses as well as the screw press are two examples of technology used in producing briquettes without binders. The majority of the machines are of the reciprocating kind, in which a reciprocating ram applies high pressure to a die to squeeze the biomass. The lignin component of the biomass act as a natural binder as they are constantly extruded by a screw through a heated taper die in a screw extruder press (Ravina *et al.*, 2016). Additional binders may be used to increase the densification, hardness and durability of briquettes (Obi *et al.*, 2022). Binders such as cassava flour, molasses, wheat flour, fine clay, red soil are used to join granular particles for agglomeration in the additive technology method, which is manually operated. However, briquettes made using this method have low densities (Adegoke *et al*., 2018). The selection of binders depend on parameters, such as the desired bonding strength, low emissions, the effect on briquette combustion performance, environmental friendliness, sustainability and economic availability (Obi *et al.*, 2022).

Table 1. Potential sources of biomass for briquette production

Biomass sources	**Residues**
Tree	Sawdust, leaves, and wood shavings
Coconut	Husks and shell
Oil Palm	Empty bunches, shells and fibers
Cassava	Stalks and Peels
Groundnut	Shells or husks
Maize	Stalks and cobs
Sorghum	Straws
Plantain	Stem and peels
Sugarcane	Bagasse and straws
Rice	Husks
Wheat	Husk, straw and brown
Aquatic	Marine or freshwater algae, seaweed, kelp, lake weed, water hyacinth

Source: Dasappa (2011)

BENEFITS OF BRIQUETTE UTILIZATION

Mitigation of deforestation

Charcoal and firewood production depend solely on felling trees from the forest. For instance, Adebayo *et al.* (2019), reported that majority of the residents in charcoal producing communities in Oyo State attested to the fact that charcoal production is a major cause of deforestation. Briquette is made from wood residues and agricultural wastes (Ibrahim *et al,* 2020). This will help in reducing the rate of deforestation and promote sustainable utilization of forest products.

Alleviation of energy crisis

Due to the current energy crisis, traditional wood and coal charcoal are expensive. Biomass briquettes are potential alternative fuel for cooking and heating (Mahoro *et al*., 2017). Briquettes produce less smoke and burn with close to 98% efficiency, when energy-saving stoves are used. It could still provide 76% efficiency when the stove is not energy saving (Ali *et al.,* 2019). This is higher than charcoal and firewood, whose efficiency range of 60-68%. They also produce less ash because they only burn 5% of their initial weight (Mitchell *et al.,* 2020).

Resource recovery and reuse

The technology utilizes organic wastes, which pollute metropolitan areas, particularly informal settlements with poor waste management infrastructure. Municipalities spend less on transportation and landfill management when waste is recycled (Ugwu *et al.,* 2021). Briquette ash contains calcium and magnesium, which could neutralize soil acidity (Wang *et al.*, 2016).

Cheaper energy for cooking and heating

Briquettes are affordable and a renewable source of energy as opposed to oil, coal, or lignite. They contain less of sulfur, which prevents pollution of the environment. The higher calorific value and low ash content are beneficial to the environment. In addition, their combustion is more uniform, and they are easier to transport (Ifa, *et al*., 2019; Cheerag, 2022).

LIMITATIONS OF BRIQUETTE UTILIZATION

In most developing countries, biomass energy has the potential to be the primary solution for satisfying rural heating energy needs (Obi *et al.,* 2022). However, its use in many of this developed country is limited (Ericsson and Werner, 2016). Most of the rural people's heating energy are provided by direct burning of wood and other loose biomass in three-stone fires and other low-efficiency stoves.

Briquette production and utilization may be constrained due to a lack of defined biomass supply chain structures in both agricultural and forestry-related businesses (Liu *et al.*, 2020). The absence of government-backed policies may also limit briquette acceptance in urban and rural areas (Nguyen *et al*., 2021).

Another impediment to biomass briquette production and utilization is a lack of relevant technologies for building bio-economies (Obi *et al.,* 2022). While low-cost briquetting machines have been developed, they frequently lack the capacity for commercial-scale manufacturing and may not match the

quality criteria for commercial briquettes (Dairo *et al.,* 2018). Encouraging and supporting the development and transfer of appropriate technology remains an effective strategy for the rapid development of a bio-economy powered by biomass briquettes. Furthermore, market development and affordable briquetting devices must be followed by commercially accessible improved cook stoves that are culturally relevant, energy efficient, emissions-free, and convenient for the target consumers (Shen *et al.,* 2015; (Mugabi and Kisakye 2021).

Uses of Biomass Briquettes

Any equipment designed to burn wood or coal can be used with briquettes (Table 2). However, the conversion will need to take into account a few changes in operating characteristics, particularly with regard to the distribution of primary and secondary air. Before making changes to the equipment, there is need for a thorough understanding of the unique properties of briquetted biomass. The density of briquettes are twice that of regular fuel wood. Because of the extremely low porosity, combustion char is denser than wood or biomass charcoal. Additionally, screw-pressed briquettes with central holes are said to be superior fuel to coal, wood, and solid briquettes (Mahoro *et al.,* 2022).

Table 2: **Uses of biomass briquette**

S/N	Industry	Possible Application
1	Domestic use	Cooking, water heating and space heating
2	Commercial and institutional catering	Cooking, water heating, grilling
3	Hospitality	Cooking, water heating, space heating (outdoor dining areas)
4	Industrial boilers	Generation of heat and steam
5	Food processing	Distilleries, bakeries, canteens, restaurants, drying
6	Textiles	Dyeing bleaching
7	Crop processing	Tobacco curing, tea drying, oil milling
8	Ceramic production	Brick kilns, tile making, pot firing etc.
9	Gasification	Fuel for gasifiers to produce electricity
10	Charcoal production	Initiating pyrolysis to make charcoal production more efficient
11	Poultry	Incubation and heating of chicks

Source: Kpalo *et al.* (2022)

Acceptability of Briquettes Products in Nigeria

In Nigeria and across the globe, the demand for alternative energy sources has increased the use of charcoal and firewood, whose prices have been on the increase. Briquettes are created from ingredients that can be cheaply sourced, making them an economically feasible fuel alternative and a source of income (Lamido *et al*., 2018).

Since there is no centralized organization in charge of biomass briquette utilisation, which spans multiple ministries as well as the

Federal, State, and Local levels of governance, there is limited information on biomass projects or businesses engaged in the briquette production. Although many extremely small-scale initiatives are being suggested, any estimates of the total volume are only speculations (Ichu *et al*., 2020). Nigeria not only has a large supply of bioenergy feedstock (Ben-Iwo *et al.*, 2016). Biomass briquettes have the potential to replace conventional fuels used for cooking and industrial process heat (Ichu *et al*., 2020). Biomass energy utilisation will further benefit the environment, public health, and national economy (Rather *et al.*, 2022).

Conclusion

Biomass briquette is a potential alternative source of energy, if properly harnessed. The large volume of biomass residues produced as a byproducts of forestry based industries, agriculture, and industrial sectors could be converted to good use. However, there is need for the development of low cost technology that would support the biomass briquette industry in Nigeria. There is also a need for relevant policies that will ensure its growth. This would have a long term effect in the reduction of deforestation and improved waste management in the urban areas.

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