

Aquatic Weed Densification: A Systematic Abridged Review

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Abstract

The astronomical increase in population has posed continuous energy demand, of which non-renewable energy sources such as fossil fuel has been unable to upset. An effective method of using biomass as a fuel and energy source in this situation is briquetting, which reduces bulkiness, increases density, and enhances the specific energy content that may be obtained from biomass by reducing volatile content. It reduces the costs related to storage and logistics of biomass energy as well as curb the polluting and other negative effects posed by aquatic weeds and biomass in general in the environment. This review present various technologies utilized in briquette production, process and feedstock parameters for optimization of briquette production, binders, categories of biomass materials etc. The mean goal is to create awareness to exploit the potentials of biomass briquetting to ensure a sustainable fuel and energy supply.

Keywords: Biomass, aquatic weeds, energy, briquette, binder.

Introduction

Continuous price increases, declining oil reserves, and greenhouse gas emissions make it more difficult to rely on fossil fuels. The utilization of renewable energy resources, such as solar, wind, biomass, geothermal, and agricultural wastes, which may be used repeatedly to generate electricity, has been spurred by the predicted crisis of rising energy demand and environmental concerns (Islam et al., 2008; Day-Vines et al., 2020). These energy sources are referred to be alternative energy sources since they are locally accessible. Because of problems with handling, shipping, storage, and burning, this pure, limitless energy source is currently underutilized despite its potential to reduce environmental pollution (Matiru, 2007).

Briquetting technology is one of the possible solutions to the issues associated with underutilized agricultural residues (Tariebi & Davies, 2024). It is a densification technique that maximizes biomass's volumetric calorific value and raw material handling capabilities (Oladeji, 2010; Ogunsanwo, 2001). Numerous networks of rivers and creeks define the Nigerian Niger Delta region. Aquatic weeds, like water hyacinth, blossom profusely and clog drainage systems,

rivers, and creeks. This hinders hydropower plant operations, fishing, river navigation, and other activities. Physical, chemical, or biological methods have not been successful in controlling these aquatic weeds. Its quick growth rate in comparison to other agricultural plants may be the cause of this. However, this rapidity of growth of water hyacinth can be capitalize on to ensure sustainable production of fuel briquettes, which will open up employment opportunities to those mostly affected by them, and absorb the shock from hike in price of energy accessibility and firewood scarcity for heating applications on the low income earners (Tariebi & Davies, 2024).

Methodology

General Preamble on Aquatic plants

Unchecked plants known as aquatic weeds grow and complete their life cycles in water, endangering the aquatic environment and the associated ecosystem. Water is one of the most important natural resources since it is the basis of all life on Earth. For this reason, proper management of water—from its source to its use—is essential to maintaining life as

usual. It has a big impact on how natural resources are managed. Over the course of the last thirty years, aquatic plants, such as hypha grass, water lily, duck weed, water hyacinth, and water lettuce, have proliferated across the rivers, creeks, lakes, and reservoirs of the Niger Delta (Tariebi & Davies, 2024). Previous research has demonstrated that the presence of these sufficient weeds has serious negative effects on human health because they impede social and economic activities such as fishing, netting, ship passage, and the

reduction of water bodies' ability to produce fish. They also harbor insect pests, which in turn host pathogens. Other issues caused by aquatic plants are decreased water supply for nearby populations, impaired navigation, and issues preventing power plant pumps and turbines from operating as intended (Ogaga & Bestman, 2022). Plate 1. to Plate 3., illustrate some of the challenges created by the presence of aquatic weeds in streams, lakes, Rivers etc.



Plate 1: water lettuce (*Pistia stratiotes*): (Researcher's field Trip, 2025)



Plate 2: water hyacinth (*Eichhornia crassipes*): (Researcher's field Trip, 2025)



Plate 3: water lily (*Nymphaea spp*): (Researcher's field Trip, 2025)

Bioenergy

Fuel made from biomass, which includes wood, garbage, plants, animals, (hydrogen) gas, and alcohol fuels, is known as bioenergy. The ability to produce biomass energy in liquid (alcohol), solid (charcoal and briquettes), and gaseous (gas and biogas) forms makes it one of the most adaptable renewable energy sources. Biomass is any renewable organic material with a wide range of properties that can be used as fuels, including plant materials, animal products and manure, food processing and forestry byproducts, urban waste, etc. When it comes to promoting energy recovery in renewable energy, biomass energy is the best option for taking a comprehensive strategy. Compared to fossil fuels, biomass has a lower heating value per unit mass due to its higher oxygen content and lower carbon content. This suggests that more biomass fuel must be

handled and processed to provide an equivalent amount of usable energy. Additionally, there are drawbacks to burning biomass directly because of its inherent characteristics, which include high moisture content, poor density, and low calorific value per unit volume. Therefore, it's critical to create plans for turning biomass into secondary fuels that are superior to the primary material, which is what briquetting does (Ajit et al., 2017). The use of biomass as fuel offsets the harmful effects of carbon dioxide in the atmosphere, and it is inexpensive and readily available. This is because, throughout the process of biomass development, carbon dioxide created during combustion is eliminated by photosynthesis, leaving the atmosphere neutral with regard to the opposing effects of carbon-dioxide.

Biomass categorization

Energy crops

A growing part of agricultural diversification and sustainable development is the use of high yield crops cultivated especially for energy uses. Right now, miscanthus and short-rotation coppice (SRC) are the two primary energy crops utilized to generate electricity. Additional crops cultivated for specific purposes are utilized to generate biogas and transport biofuels. Crops raised expressly for fuel production, which yield large biomass yields per hectare at low input energy, are the source of plant energy (Stewart, 1987).

Industrial and food Wastes

For energy purposes, families, businesses, and industries can also utilize the biomass found in wastes and residues. Municipal waste is part of this. The biomass energy derived from waste is the second greatest source. Waste energy is primarily produced by manufacturing waste, landfill gas, and municipal solid waste (MSW). It is predicted that between 2000 and 2020, biomass energy will become the United States' greatest renewable electricity source that isn't hydroelectric (EIA, 2009).

Wood and its residues

In both home and commercial contexts, wood remains a significant energy source, particularly in the forestry, paper, pulp, and other associated industries. Almost 10% of Austria's primary energy consumption comes from woody biomass, which is also the predominant energy source in most developing countries, mainly for space heating and cooking (Grover & Mishra, 1996).

Sewage Gas.

The biogas created at waste water treatment facilities when sewage sludge is broken down and burned is known as sewage gas. Sewage sludge is subjected to anaerobic digestion by fermenting it in tanks for approximately 25 days at a temperature of 32 to 36°C (EIA, 2009).

Agricultural/forest Waste

Animal dung, agricultural leftovers, and dead animals are examples of the wastes typically connected to the farming, feedlot, ranching, range, and forest industries that produce and process food and fiber. Agricultural residue amounts to billions of tons

annually in both developing and wealthy nations. A significant quantity of energy and raw materials can be produced from this volume of biodegradable wastes (Ebo & Jaromira, 2012).

General Procedure of biomass densification.

The briquetting process begins with the raw materials being collected, then the materials are dried, size reduced, and compacted using a press or extruder. It can be produced with or without binders. Presses and drying equipment that are complex and expensive are needed for binder-less briquetting (Tabil, 1996). Unwanted items are first separated or sieved through a wire mesh to guarantee that all of the feedstock is the proper size. For improved workability and compactness, large feed stocks such as groundnut waste, bagasse, barley, wheat straws, and maize straw are chopped into little pieces. Mixing is done when using many feed stocks to maximize the fuel's burning properties. For the feedstock to be loose and easy to deal with, water is typically added. A few days of soaking in water are necessary for certain biomass products before they become sufficiently soft to work with (Musa, 2007). At this point, the feedstock is prepared for manual or mechanical compaction. After observing a certain amount of dwell time, the next step will be ejection from the mold (Oladeji, 2011). It takes up to a week for the briquettes to be dried and ready for use (Wilaipon, 2008).

Process variables as factors influencing biomass briquetting

Temperature:

The durability of briquettes and the material's resistance to an applied load are impacted when raw materials are heated to high temperatures (PES forum, 2009). The temperature of the die affects a number of biomass briquette properties, including bulk density and durability. For a given moisture content, adding heat to the die increases strength and moisture stability while decreasing the pressure needed to achieve a certain biomass density (Hall & Hall, 1968).

Pressure:

The pressure used to create biomass briquettes has a significant impact on their quality. Density is greatly increased by pressure (Yank *et al.*, 2016). Although it should be chosen at an optimal ratio that affects the briquette's mechanical strength by increasing plastic deformation, biomass briquettes are more durable under high pressure (Yaman *et al.*, 2000).

Die Geometry:

The shape and size of the die can have a significant impact on the volume of biomass that can be briquetted. According to Tabil & Yusuf, (1996) briquette durability improves, when a small die with a larger length or diameter used. The durability of briquettes and pellets made on lower die sizes is higher, according to (Heffier & Pfost's, 1973) evaluation of the impact of mould's dimensions.

Binder to Biomass Ratio

The ratio of binder to biomass has an impact on briquette quality, particularly on durability. A study on briquette manufacture by Pineland Eco scientists (PES forum, 2009) revealed that briquettes dispersed readily without binders. The briquettes burned more slowly, produced more heat, were more durable, and had higher densities when binders with a 2:1 biomass to binder ratio were added. As the binder ratio level rises, the density of the uncompressed biomass mixture combination increases (Enweremadu et al., 2004). Additionally, they came to the conclusion from their research that as the binder ratio rises, there is greater resistance to compression.

Dwell time

According to Junior Maimou, (2024) the amount of relaxation that takes place when the briquette is taken out of the die is also influenced by the hold time during the compression. According to Chin *et al.*, (2000) briquettes with the least amount of relaxation can be obtained by generally using a dwell length of 20–40 seconds. Subsequent research has demonstrated that the necessary duration for certain materials is notably shorter. For instance, O'Dogherty, (1989) discovered that in straw, relaxation rose only during a 10-second dwell period, with no discernible increase noted at longer times. It's evident that selecting a stay period longer than what's necessary for lowest relaxation doesn't negatively impact the relaxation's ultimate properties. To produce briquettes with a consistent density, selecting a hold period longer than 40 seconds implies that additional stringent control over this variable—such as timing—is not required. Interestingly, Faborode & O'Callaghan, (1987) discovered that the final relaxed density of the briquette changed very little when the same (final) pressure was applied repeatedly to the compacted material.

Variables of the feedstock that influence the briquetting of biomass

Important considerations for choosing biomass include the availability of feedstock in large numbers, its low moisture content when compressed, its uniform size and granularity to allow for easy flow in storage silos and bunkers, and more (Dusan et al., 2018; Moral & Rahman, 2001).

Size of Particle:

Materials must have an even distribution of particle sizes in order to pass through the die and stay solid. The rate at which the material flows is affected by this. Because coarsely comminuted materials can leave fixtures in the briquettes, which break quickly, they tend to produce briquettes that are less durable (Dusan et al, 2018). However, a very fine particle size makes the machine more capable since it allows the material to flow through the die more easily, which results in a low flow rate in the die (Dusan *et al*, 2018). Nonetheless, the parameters of the briquetting process must be created to fit a certain biomass. Particle sizes must so be lowered to the required size reduction could be accomplished with a hammer mill. The expense of shrinking in size should also be taken into account. Reducing the raw biomass's size allows for improved product characteristics through briquetting, mixing, and drying (Mani et al., 2006). Kaliyan & Morey, (2009) recommends the use of biomass material that is 6–8 mm in size and contains 10–20% powdery component for optimal effects. However, coarse particles need more compacting force and produce poor stability and uniformity.

Moisture Content

Tumuluru & Wright (2010) claim that throughout the briquette-making process, moisture in the biomass material acts as a natural binder and strengthens bonds through Van der Waal's forces and other forces, expanding the particle's contact area. Certain processes, including fiber solubilization, starch gelatinization, and protein denaturation, are facilitated by the moisture concentration of the biomass material (Tumuluru & Wright, 2010). Moreover, it lubricates the process of briquetting. According to Tumuluru & Wright, (2010) briquettes with less than 4% moisture content quickly become brittle and weak. They said that the reason for this was the environment's moisture absorption. Elevated moisture content presents a challenge for biomass preprocessing since it necessitates significant energy for briquette grinding

and drying. Variations in densification and material composition may be the cause of each feedstock's unique response to varying pressures and moisture concentrations. Tumuluru & Wright, (2010) wrote that depending on the feedstock and operational conditions, there are several ideal moisture contents for densifying biomass.

Binders and categorization

For the biomass particles to create bonds during low pressure briquetting, a binding agent is required. There are three types of binders: chemical binders (pitch water, sodium silicate, and lingsulfonates), matrix binders (coal, petroleum asphalt, and Portland cement), and film binders (tar, petroleum asphalt, and Portland cement) (Ajit et al., 2017). Additionally, these binding agents fall into two major categories, which are: Molasses, coal tar, bitumen, starch, and resin being examples of organic binders; clay, cement, lime, and sulphite liquor being examples of inorganic binders. In order to give the "green" briquettes the necessary strength and stability, they must be cured by (drying, burning, chemical reaction, etc.) following compaction (Tariebi & Davies, 2024).

Technology for Briquetting

Briquetting technologies could be divided into roller presses, screw presses, piston presses, pellet mill machines, and manual presses, according to (FAO, 1990; Singh et al., 2007). Briquetting technologies can be categorized according to the pressure used: low pressure compaction with a binding agent, medium pressure compaction with the aid of a heating device, and high pressure compaction (Wilaipon, 2009).

Screw Press:

A screw extruder compresses biomass residues by applying force through a revolving screw. Biomass particles grow softer and lose their elastic qualities at high temperatures (Grover & Mishra, 1996). The screw's pressure raises the temperature, causing particles to interlock, and forms local bonds.

Piston Press

This machine produces densified biomass fuel (briquettes/pellets) using a piston that is powered by a flywheel or another hydraulic mechanism. When biomass residues are added from the feedstock unit, a piston compresses them toward the die of the appropriate shape, and the briquettes are extruded from

the die's opening face (Manickam et al., 2009, Bhattacharya et al., 2007).

Roller Press

Two rollers that rotate in opposite directions to one another make up the roller mill's main component. A hopper is used to feed the biomass residues. A control system regulates the flow of biomass residual material (Grover & Mishra, 1996). The two rollers that are constantly rotating in opposing directions apply forces to the biomass residue, extruding them in a compacted state as fuel briquettes (Manickam et al., 2009).

Pellet Mill Machine

A machine that turns biomass residues into pellets with a cylindrical shape, with density between 1125 kg/m³ and 1190 kg/m³, and lengths of 13–19 mm and diameters of 6.3–6.4mm (Tulumuru Wright., 2010). This kind of machine has a circular matrix and a roller. The material to be pelletized from the biomass residues is squeezed between the roller mechanism and the circular matrix. There are a lot of orifices in the circular matrix. The orifice's size is preset. The materials of pelletized biomass residues are automatically extruded from these circular matrix orifices.

Conclusion

The process of densifying biomass makes briquettes, commonly known as "smokeless fuel," a high-calorific product that is convenient to transport and store. In terms of calorific value, it is comparable to coal as a solid fuel that emits no pollutants. The method of briquetting, which uses a variety of waste materials, should be widely ratified as a substitute to deal with the energy problems of the current world because it is effective, economical, and simple to replicate. In order for biomass to significantly impact rural populations as fuel, a briquetting equipment that is appropriate for the local communities must be designed.

Recommendations

1. This study gives a general overview of the potential of biomass briquetting, hence further studies should be directed at characterizing, respective aquatic weeds (water hyacinth, water lily, water lettuce etc.) briquettes using locally accessible binders, which will bring about a sustainable solution to the problems created by the presence of these weeds on our creeks, rivers , etc. and as well give birth to

employment opportunities for our teaming population.

2. Also Governmental Authorities, should provide : grants and enabling environment to encourage the development of locally made, affordable briquetting technologies, to make biomass briquetting, an attractive solution: in waste management as well as employment creation.

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