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USE OF BAMBOO BIOMASS FOR THE PRODUCTION OF SOLID BIOFUELS

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Abstract: Bamboo is a versatile, fast-growing plant that is found in abundance, especially in Asian countries. Bamboo is also a plant that fits perfectly with many of the UN's goals of sustainable development, increasing the use of energy from renewable sources, combating poverty, or even reducing the effects of climate change and soil erosion. Precisely because of this abundance in recent decades, the fields in which bamboo is used have become increasingly diverse. Due to the high values of caloric power, volatile substance content and low ash and moisture content, bamboo is a suitable crop for bioenergy production. As the cultivation of bamboo does not require large investments, it can also be grown by individual producers. Due to its many benefits, this species is an ideal crop, especially for part of the population of some developing countries. This is used in agriculture, furniture, food and pharmaceuticals and cosmetics. The processing of bamboo results in a significant amount of plant residues that can be transformed into biomass. In addition to the use of bamboo biomass for energy production after obtaining and using pellets, briquettes or even coal, it can also be used as mulch to increase the yield of agricultural crops. Globally, the consumption of natural resources in addition to depleting the planet's reserves, generating numerous pollutant emissions, should be monitored to detect especially the causes that cause its increase, in order to reduce the danger of extinction of life on the planet. This paper presents a brief summary of some uses of bamboo biomass for the production of solid biofuels such as staves, briquettes and coal.

Keywords: bamboo, biomass, pellets, briquettes, charcoal

INTRODUCTION

Bamboo is part of a large family of herbaceous plants, the family Poaceae, characterized by a fast pace, which can be grown sustainably in various parts of the world. Thus, plants in this family are found in various geographical areas, located in Africa, Asia, Australia, India and America (Newell, J (2004).

Bamboo is a sustainable resource, which can grow in different climatic conditions, preferring especially tropical areas. This species contributes substantially to the improvement of air quality, as it releases approx. 35% more oxygen and absorbs approx. 40% more carbon dioxide than trees. Planting bamboo is also beneficial for fixing carbon, against soil erosion and purifying the environment. (Bamboos Market Size, 2019).

Bamboo forests cover an estimated area of 37 million hectares (ha), equivalent to almost 4% of the total forest area in the world (FAO 2014) (Food and Agriculture Organization of the United Nations. Improving the socio-economic benefits of forests. The state of the world forests 2014. Rome Italy 2014). There are also some varieties of this species that grow successfully in mild temperate areas in Europe and North America (INBAR 2015a).

As the cultivation of bamboo does not require large investments, it can also be grown by individual producers. Due to its many benefits, this species is an ideal crop, especially for part of the population of some developing countries.

Bamboo is also a plant that fits perfectly with many of the UN's goals of sustainable development, increasing the use of energy from renewable sources, combating poverty, or even reducing the effects of climate change and soil erosion.

Compared to the chemical composition of wood, the cellulose content of bamboo is lower, being similar to that of softwood. Also, the lignin content is between that of softwood and that of hardwood. The ash content of bamboo is 3 to 4 times higher than that of wood. (Ye CY, et al. 1989).

Due to the high values of caloric power, volatile substance content and low ash and moisture content, bamboo is a suitable crop for bioenergy production. (Kumar R. and Chandrashekar N., 2014).

Biomass, by definition, consists of the biodegradable part of plant material, which is the most abundant renewable resource on the planet. (T.C. Maria, et. Al.2011). It can be said that biomass is the first form of energy used by man, with the discovery of fire.

Globally, the consumption of natural resources in addition to depleting the planet's reserves, generating numerous pollutant emissions, should be monitored to detect especially the causes that cause its increase, in order to reduce the danger of extinction of life on the planet (Darie, Silviu 2020).

Out of the desire to find an alternative source of energy to replace fossil fuels, which are depletable sources, the possibility of using bamboo residues (plant residues) as biomass for biofuel production was studied (Pongthornpruek S. and Sasitharanuwat A., 2019).

Thus, in addition to the use of bamboo biomass for energy production after obtaining and using pellets, briquettes or even coal, it can also be used as mulch to increase the yield of agricultural crops. (Usio, N., et. Al. 2021).

MATERIALS AND METHODS

— Bamboo pellets

Biomass pellets are one of the products developed as an alternative to new energy sources used as fuel. So pellets are

a biofuel produced from wood waste, agricultural residues, energy crops, which come in the form of cylindrical granules, characterized by certain standard sizes. Thus the diameter is between 5 ... 8 mm, and the length has variable dimensions, reaching up to approx. 50 mm. (Gageanu I., et. al. 2016). The technology of obtaining the pellets (Figure 1) consists in introducing the ground biomass from a feed hopper in a compaction chamber, from where it is directed and forced to pass through a cylindrical hole, at very high pressures, in certain suitable conditions (possibly of high temperature and a certain humidity), so that the raw material can be transformed into a compact solid mass of cylindrical shape. (Gageanu I., et. al. 2016, Vlăduț V. et.al. 2012).

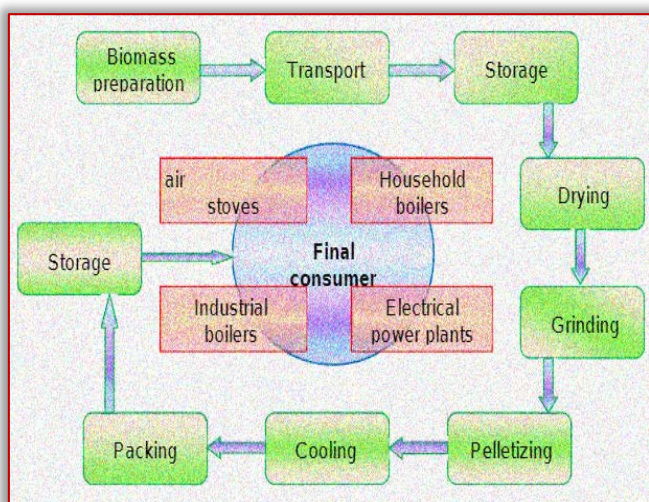


Figure 1. The stages of the technological process of pellet manufacturing (Vlăduț V. et.al. 2012)

Biomass raw materials that can be transformed into pellets are numerous, the most commonly used being: wood, branches, sawdust, wood chips, peanut shell, sunflower peel, sugar residue, yeast, coconut shell, coffee grounds, corrugated cardboard, straw, cotton swab, tobacco waste, mustard stalk, jute waste, rice husk, bamboo chips, bamboo dust, tea waste, wheat stalk, palm fruit husk, soybean bran or other forest or agricultural waste (Figure 2).



Figure 2. Biomass raw materials (Source: www.bestbriquettepress.com)

The manufacturing process of bamboo pellets is the same as for pellets obtained from other types of biomass. The raw

materials are ground into powder before being pressed, obtaining pellets with diameters between 6 and 12 mm. Bamboo pellets can be made from stems, leaves or even powders that come from making various objects (www.bestbriquettepress.com). Bamboo pellets have satisfactory burning characteristics and high mechanical strength (Jacky Michael Pah, et.al., 2019).

— Stages of the process of obtaining bamboo pellets

- ≡ Grinding and drying bamboo is done to turn the raw material into powder, usually using a hammer mill. Before starting the grinding process, dust and any foreign matter must be removed from the raw material. After crushing, the raw material is dried using a rotary dryer, so that the humidity of the resulting pellets is reduced, below 10%.
- ≡ Manufacture of pellets, consists in compressing the dry powder into pellets, at high pressure and speed using a press, also known as a bamboo pellet machine.
- ≡ Cooling and storage of pellets is done immediately after the pelletizing process by lowering the temperature, to improve quality and durability. Then the pellets are stored in places free of moisture. (<http://www.gcmec.com>).

— Bamboo biomass briquettes

The materials from which the briquettes can be obtained are the same as in the case of pellets. Lighters are considered to be the best way to replace firewood. Since the late 90s, the demand for lighters used for heating the house, either for fireplaces or stoves, has increased, being still on an upward slope (Martha Andreia Brand et. 2019).

The process of obtaining bamboo briquettes is similar to that of obtaining pellets, namely: first the raw material is crushed using a hammer or roller crusher. After chopping, the raw material is dried, then placed in a press to obtain the actual briquettes, which are then dried to be stored at the end.

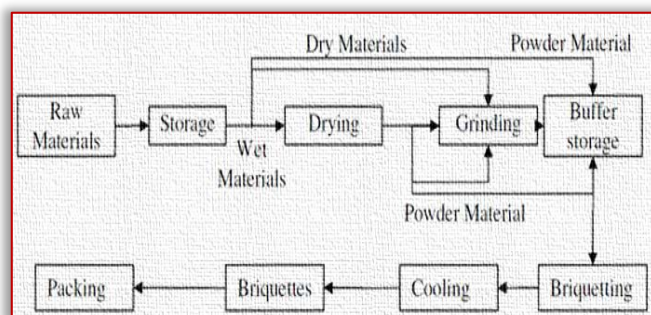


Figure 3. Scheme of the biomass briquetting process (Source: www.bestbriquettepress.com)

— Bamboo charcoal

By definition, bamboo charcoal is the product obtained by subjecting bamboo to the process of pyrolysis. Bamboo charcoal can be classified into raw bamboo charcoal and bamboo lighter charcoal, depending on the raw material used (https://en.wikipedia.org/wiki/Bamboo_charcoal). Bamboo charcoal (Figure 4) has a micro-porous structure with countless small cavities. Compared to charcoal, bamboo charcoal has about four times more cavities and a larger specific surface area.

Depending on the end use, the quality of the coal can be measured and specified in various ways. Normally, the amount of heat obtained by burning coal and the yield of the object to be heated to which the appropriate combustion equipment is added are the main criteria for assessing the maximum coal yield. (James G. Speight, 2020).

Two processes are used for carbonization: one of combustion that takes place directly in an oven, the other being a mechanical process (Pei-Hsing Huang et. Al. 2014).



(a)



(b)



(c)

Figure 4. Bamboo charcoal (a) www.pining.com; (b) <https://yo-holding.com/bamboo-coal>; (c) <https://yo-holding.com/bamboo-coal>

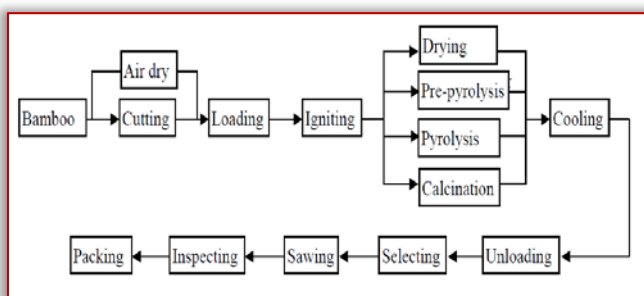


Figure 5. The process of bamboo charcoal production (J. Shenxue 2004)

In the 1990s, a carbonization chamber built in the ground was used to produce bamboo charcoal. However, this method does not ensure the obtaining of quality coal, in addition, not being at all in accordance with the rules of environmental protection. Therefore, after more than ten years of

experiments and improvements in bamboo charcoal manufacturing technology, the use of pear (brick) kilns has been used. A mechanical kiln is used to produce bamboo charcoal briquettes. The bamboo charcoal production process is shown in Figure 5.

RESULTS

— Equipment used for processing bamboo biomass

Figure 6 shows a pellet manufacturing plant produced in China by Zhengzhou Leabon Machinery Equipment Co., Ltd. It consists of machinery that performs the steps of the manufacturing process presented above. This plant is designed to turn bamboo biomass into pellets. Depending on the chosen model, the working capacity can be between 400 – 1000 Kg / h, and the drive can be provided by an electric motor, a diesel engine or a tractor (<https://www.zzleabon.com>).

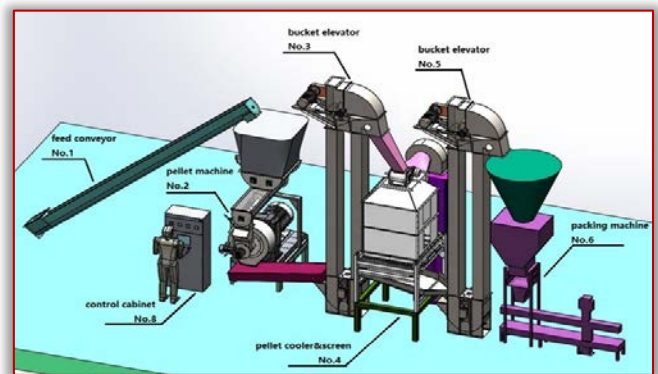


Figure 6. Agro Waste Pellet Mill Installation (Source: <https://www.zzleabon.com>) Gemco (China) produces several types of equipment for the manufacture of pellets (Figure7). The operation of the equipment can be ensured by: electric motor, diesel engine, gasoline engine or a tractor, the equipment being classified according to this criterion. Equipment can also be classified according to the field of use of the pellets: for burning (energy production) or for animal feed (<http://www.gemco-energy.com>)

The main element of this machine is the granulation chamber, where the material loaded by the feeding system is compressed between the roller press and the mold. With the help of the knife, the pellets coming out of the holes of the flat mold are cut, being then collected in a container of dimensions and subsequently, stored.



Figure 7. ZLSP 420 Wood Pellet Mill Machine (Source: <http://www.gemco-energy.com>)

HENAN RICHY MACHINERY CO., LTD (China) produces the MZLH pelletizer, this being a new type of machine for the production of biomass pellets, with high efficiency. The raw material consists mainly of various wastes and bamboo chips. The feeding system ensures a uniform supply with the crushed raw material, centrifuged by the rotation of the mold ring. The material is then subjected to an extrusion process, being pressed and molded into the mold. The process is continuous, and the product discharged from the mold, having a columnar shape is dimensioned to a certain length, by a cutting system.



Figure 8. MZLH pelletizer (Source: <https://www.pellet-richi.com>)

The equipment for the manufacture of bamboo biomass briquettes is very varied, being represented by the models of manual presses (Figure9) up to the fully automated ones.

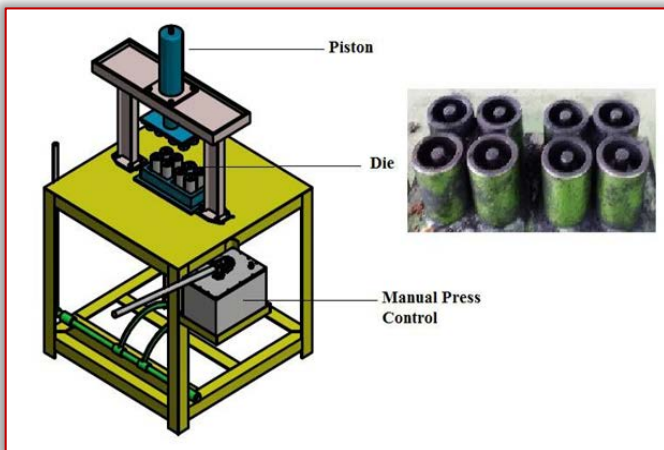
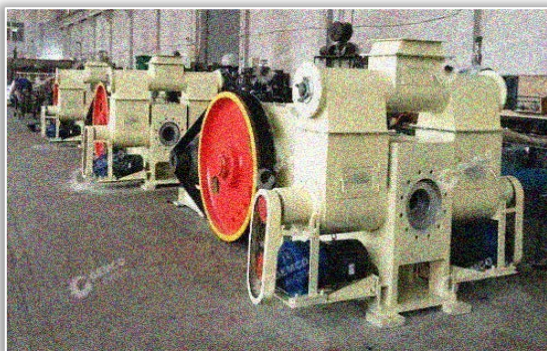


Figure 9. Isometric view of the manual briquetting hydraulic press machine. (Mallika Thabuot et al. 2015)

Gemco Enegy manufactures several types of machines for obtaining bamboo briquettes, classified according to the method of pressing: Biomass briquetting machine by stamping, Screw briquetting machine, as well as a complete biomass production line.



(a)



(b)



(c)

Figure 10. Types of equipment for the manufacture of briquettes (Source: <http://www.gemco-energy.com>)

(a) Biomass briquetting machine with stamping; (b) Screw briquetting machine; (c) Complete biomass processing line

Beston (China) has developed a machine model for the manufacture of bamboo charcoal using One Step Two Fire technology (Figure11). This technology is applied to obtain coal and bamboo by-products (tar and wood vinegar). Four models of this machine are available, classified according to the supply capacity between 0.5 and 5 t / h and the engine power between 45kw / h and 125kw / h.



Figure 11. Beston bamboo charcoal machine (Source: <https://bestonmachinery.com>)

ABC Machinery Co., Ltd. (China) builds a production line of bamboo charcoal making machines, with a production capacity of 2 t / day. The raw materials used to make bamboo charcoal are bamboo chips, bamboo powder, to which wood chips and sawdust are added.

The manufacturing process consists in crushing the raw material, drying, briquetting, carbonizing it, resulting in the

final product – coal. Figure 12 shows the main components of the production line:

1. Crushing system;
2. Drying oven and main pipes;
3. Drying system and evacuation of materials;
4. Screw feeding system;
5. Briquetting system (biomass chopsticks production capacity 500 kg h⁻¹);
6. Carbonization system (with a manufacturing capacity of coal briquettes of 2 tons / day);
7. Cooling system;
8. Air circulation system.

The main advantage of this production line is energy efficiency, because the carbonization process uses the gas recirculation system. Once the carbonization system is turned on, the waste generated can be recycled without adding new fuel to continue production.



Figure 12. Bamboo Charcoal Making Machine Production Line

(Source <http://www.bestbiomassmachine.com/>)

CONCLUSIONS

Both pellets and bamboo briquettes are a source of renewable energy and thus an alternative to traditional fuel sources, achieving a cost reduction of up to 50%.

They have multiple advantages such as:

- ≡ are environmentally friendly, as less than 1% of their contents become ash. They also have very low gas emissions as they burn;
- ≡ has calorific value compared to coal (approximately 4800 kcal) being much more compact;
- ≡ they have a small table, their transport and storage, being done easily.

≡ can serve as fuel for heating, cooking or steam generators. In addition to being used as a fuel, bamboo charcoal has multiple uses in the pharmaceutical and cosmetics industries. Due to its ability to regulate humidity, bamboo charcoal is used in deodorants, soaps or various types of cosmetic creams. In addition, the microporous structure makes it a unique and natural absorption system, like a hard sponge that can catch impurities, harmful materials and gases. This property is recommended for deodorization, purification, moisture control and even for the treatment and treatment of wastewater.

Solid bamboo biofuels are a renewable and energy efficient resource, important for the current context.

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