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Bamboo Charcoal - An Opportunity for Livelihood Needs

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Abstract: ***Bamboo charcoal is a kind of environmentally functional material having properties beneficial to environment. Charcoal made from bamboo has good properties, similar to wood and other ligno - cellulosic material in terms of high carbon content and calorific value. Due to the special microstructures, bamboo possessed extreme absorbing and other special characters after carbonization. It was the fuel of choice of the people in early nineteenth century for its use in iron making and smelting. Charcoal is the solid residue produced when bamboo is burned or carbonized in a confined space with limited air supply. The temperature of pyrolysis ranges from around 350^0 C to 700^{0}C and the products are vapours, char and bio - oil which can further decompose into tar material. In this study, review of related literature is carried out to assess the suitable method of bamboo charcoal production, its application and how the utilization of forest resources such as bamboo, could help in improving the livelihoods of rural communities.***

Keywords: Bamboo Charcoal, Calorific value, Pyrolysis, Carbonization

1. Introduction

Bamboo, the evergreen versatile plant is intrinsically associated with humans since decades. It is the fastest growing plant and is estimated to cover 8.96 million ha of the total 63.3 million ha forest of India (Yengkopam, 2013). The North - East India harbors about 43% of the total bamboo wealth of India. Especially in the rural areas it plays a key role in the life of the people. Bamboo is grown widely in the North Eastern Region, and is used for making diversified utility products. Besides the various uses of bamboo, it finds large scale use as fuel / charcoal in place of traditional wood. The diminishing forest resources in the country welcome substituting wood development as an intervention. From the many renewable resources identified, bamboo is found to be the most promising material substitute for wood around the world. Since northeastern region of India is rich in bamboo flora (Biswas, 1988) with a report of more than eighty species of bamboo, plays a vital role in conservation of forest as well as fulfill the basic needs of people of this region. The versatility of bamboo is unique and unparalleled by any other timber being used for making items from cradles to coffins. Though **b**amboo is a multipurpose, eco - friendly crop abundantly available, yet an under - utilized natural resource needs to be managed and exploited for sustainable use. Bamboo is conceived as the thrust area in the industrial development of NE India and for economic and ecological security of people. This precious resource needs to be fully tapped as an industrial raw material, as substitute for wood in rural/urban housing, engineering works, handicrafts, furniture through appropriate value addition. People are continuously exploring newer avenues for use of bamboo.

Bamboo has now emerged as an alternative source of raw material for charcoal making, as it matures in a very short duration of 3 - 4 years and does not put any pressure on tree resources. It is reported that about 100 million fringe / forest dwellers and other 275 million people depend on forests, directly or indirectly in India (Malik and Dhanda, 2003). In India many people living in or near the forest, use huge amount of wood as fuel for their domestic purpose or for commerce. In almost all areas wood charcoal is prepared from the forest biomass, consequently decimating large areas of forest. With the increase in human population the requirement for fuel - wood is also increased. To meet the demand for fuel wood there is significant amount of decline of natural forest cover. Wanton destruction of forest for wood charcoal preparation will lead to climate change, soil erosion, loss of soil fertility, scarcity of water, reduction in carbon sequestration as well as habitat loss to flora and fauna. Bamboo is the only alternative to trounce this state of affairs. Also the properties of wood and bamboo are similar albeit with small differences here and there. Bamboo shares a number of desirable fuel characteristics with certain other bioenergy feedstocks, such as low ash content and alkali index. The heating value of bamboo is lower than many other woody biomass feedstocks; however, it is higher than most agricultural residues, grasses and straws. Although non - fuel applications of bamboo biomass may be more profitable than energy recovery, there may also be potential for co - production of bioenergy together with other bamboo processing (Scurlock *et al*, 2000). Besides, bamboo biomass seems to be an attractive alternative for inexorable supplies of biofuels, a potential and promising green alternative to avoid the global instability and environmental crises that arise from dependence on petroleum, which in turn cutting down the credence on fossil fuel resources. It plays an important role to mitigate global warming and to conserve fossil fuels. Charcoal made from bamboo is similar to wood and other materials in terms of high carbon content and calorific value (~ 6900 – 7000 k cal/kg). Being of special microstructures, bamboo possesses extreme adsorbent capacity for many toxins, gases and drugs without any specific action and other special characters after carbonization (Moe thu et al, 2010). Bamboo charcoal has an extra - ordinarily large surface area and pore volume that gives it a unique adsorption capacity (Baker et. al, 1992). Bamboo charcoal has four times more cavities than wood charcoal, surface area bamboo charcoal is about 300m^2/g,

which is 10 times more than wood charcoal and the ell wall of bamboo mainly consists of cellulose, hemicellulose and lignin (Ye C Y, 1989). It is an environmentally functional material featuring excellent absorption properties which protects environment by reducing pollutant residue (Zhou et al, 2011). Higher adsorptivity and very high specific surface area, about 150 - 400 m2/ g, which is 2 - 3 times bigger than wood charcoal, bamboo charcoal can be used for a wide range of different purification and absorption applications, such as purifying drinking water, in air filters, gas masks, mattresses and pillow and for certain industrial purification uses (Zhang et al, 2011). That is why many advanced countries now prefer bamboo charcoal for various uses.

A bamboo charcoal is light, black, porous material with about 80 - 85 per cent carbon (NMBA, 2008). It is the solid residue produced when bamboo is burned or pyrolysis in a confined space with limited air supply. Pyrolysis is the chemical decomposition of organic materials by heating in the absence of oxygen or any other reagent, except steam, whereas; in some cases catalysts are used to enhance the efficiency. The temperature of pyrolysis ranges from around 350^0 C to 700^0C and the products are vapours, char and bio - oil which can further decompose into tar material**.** The moisture content of raw material also plays an important role during coal making as much of the energy is utilized in drying of the material during the carbonization process (Trossero *et al.,* 2008). Charcoal is usually found in the form of raw (lump) charcoal and briquette (densified powdered charcoal) charcoal consisting of carbon - 44.40 %, Hydrogen - 5.17 %, Oxygen - 43.00 % and others - 7.43 %. The quality of charcoal depends on both the species of material used and application of carbonization technology (Trossero *et al*., 2008). Charcoal made from bamboo has good properties, similar to wood and other ligno - cellulosic material in terms of high carbon content and calorific value.

The production of bamboo charcoal will promote the sustainable development of economy save further destruction of forests. The forest needs about 100 years, or more, to recover naturally, so the only alternative to support the people depending on wood charcoal immediate is bamboo. As per the projection of the SFD, Govt. of Meghalaya, (Shillong Times, 11th Sept.2008) various industries, especially Ferro - alloy industries, located in Meghalaya needs 71.724 metric ton of charcoal annually to run at full potential, but the requirement is not fulfilled due to absence of coordinated approach in production and supply of charcoal (Shillong Times, 11th Sept.2008)

Production Process:

Bamboo, like any biomass, can be converted to heat and power, to liquid, solid or gaseous fuels and other chemical products through a variety of conversion processes. The three major factors which influence the conversion yield are:

a) The moisture content of the raw material at the time of carbonization
b) Type of carbonizing equipment used
c) The care with which the process is carried out

In charcoal production process, the most important step is the carbonization stage. This production process can be divided into four stages according to the change of temperature:

Methods of Bamboo Charcoal Production:

For carbonization of Bamboo a properly control environment with precise temperatures and timing is required. There are different methods of carbonization and activation process of bamboo. The methods are:

(i) Traditional Method
(ii) Mechanical furnace Method

Mechanical furnace is commonly used to manufacture bamboo briquette charcoal, which is first formed into bamboo particle sticks made of bamboo processing residues, bamboo tips and then pyrolyzing into product in a mechanical furnace

Different traditional methods of bamboo charcoal production:

In traditional process, generally different types of Carbonization "Kilns" are used for production of Bamboo charcoal.

1) Pit kiln:

It is the most primitive type of kiln, which is used even now - a - days in many parts of the country by rural charcoal producers. In this process bamboo materials are placed in a pit and covered with a layer of grass and the construction is sealed with soil. Two small openings allow ignition and release of smoke. The carbonising process takes about two (2) to ten (10) days depending on the size of the pit. It is cheap and easy to make but less useful due to low quality and efficiency (8% - 15%). Also most of the volatiles (gases, liquids, tars, etc) are driven off and burned by this method and therefore resulting in energy loss. Apart from labour and raw material (feed stock), there is not much capital involved in mound and pit kilning technology. Improved kilning techniques do involve substantial investments.

This method of biomass carbonization is remarkably slow, unpredictable and inefficient which is used widely in developing countries causing widespread deforestation (Antal et al, 2003; Hassan and Mohmed, 2000) and pollution (Sofialidis *et al* 2005).

Loading

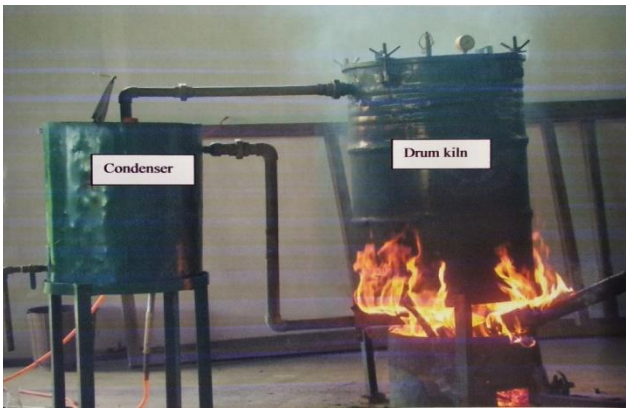
Igniting

Covering of Pit kiln with soil

2) Metal or Drum kiln:

A drum kiln can be made from empty oil barrels. The height of oil drum can vary from 80 cm. to 100 cm. and diameter of drum may be between 50 cm. to 70 cm. The intact top cover of drum should be removed by cutter and separate lid of G. I. sheet should be fabricated to open and close the drum as and when required. This type of kiln is very effective to produce bamboo vinegar. Experiment conducted at RFRI resulted in 66.96 kg of *Bambusa tulda* producing 32.5% good quality charcoal and 2.5 liter of vinegar and un quantified amount of syn gas/flu gas which was burnt for 4 hours and 40 minutes. Bamboo biomass, under pressure, may be converted to charcoal using flash carbonization method in less than 30 minutes. However, the work was carried out in laboratory condition and no further report on its application is available (Antal *et. al*, 2003)

Loading of the Drum



Ignition of Drum kiln Collection of Bamboo Vinegar (Bi - Product)

3) Brick kiln:

A properly made brick kiln is the most effective methods of charcoal production. It is cheaper, moderate in labour requirements and capable of giving good yields of quality charcoal if operated by skilled hands. Brick kiln is simple to construct, relatively unaffected by thermal stresses in heating up and cooling and strong enough to withstand the mechanical stress of loading and unloading and allow control of the entry of air. It is reasonably light weight construction to allow cooling and provide good thermal insulation for the wood/bamboo undergoing carbonization. The ability of the brick kiln to conserve the heat of carbonization is an important factor in its high conversion efficiency of biomass into charcoal. Formation of cold spots due to wind impact on the kiln walls may prevent proper burning of the charcoal and result in low yields.

The brick kiln is a dome shaped structure constructed with bricks and mud mortar. It has a rectangular opening at the bottom for loading and unloading of bamboo and several other openings along the wall for release of smoke. After ignition, these openings are systematically closed to create a closed environment. The temperature inside the kiln raises in between 300°c to 800°c and whole carbonization and cooling process may take up to three (3) to Five (5) days. In this process maximum 39% charcoal yield is recorded at Rain Forest Research Institute, Jorhat, Assam.

Stacking of raw material

Closing of Brick kiln

Firing of feedstock in Brick kiln

Extraction of Charcoal

Stages of Bamboo Pyrolysis:

Charcoal is produced by heating biomass under a system of controlled air supply in specially structured brick or metal kilns, which results in removal of water and most of volatile constituents. The making process of bamboo charcoal is the process of heating and resolution, this process can be divided into four stages according to the change of temperature.

a) Drying stage: The temperature in this stage is lower than 120^0C, the resolution is very slow. The water content is evaporating continuously by the heat from outside. But the chemical composition remains unchanged.
b) Pre carbonizing state: The temperature in this stage rises to 150^0 - 300^0C, the heat resolution of bamboo material becomes evident. The chemical composition begins to change and the unstable part of hemicelluloses begins to resolve into CO_2, CO and vinegar.
c) Carbonizing state: The temperature in this stage raises in the range of 260^0C to 450^0C, in this stage the heat resolution develops rapidly, decomposes the bamboo constituents into liquid (vinegar or acetic acid, methanol and tar) and gases (methane and ethane) and charcoal.
d) Calcining stage: The temperature in this stage rises over 450^0C, and from this stage bamboo material is calcined. Residual volatile matter is released, and the content of carbon is increased. Different temperature of carbonization influences the quality and yield of charcoal. It is difficult to demarcate these stages because

of the continuous process contained in a closed environment.

Various byproducts produced during bamboo carbonization processes which are considered to be of great values.

Bamboo vinegar: Bamboo vinegar is a reddish - brown liquid, obtained by condensing the water volatile organic materials released during bamboo pyrolysis. The bamboo vinegar is reported to contain over 200 kind of organic compounds and still others are yet to be identified (Uchimura *et. al.*, 2000; Ikimoto and Ikeshima 2000). Bamboo vinegar has many health benefits and being used in food processing and agriculture (Jain and Chavan, 2013)

Syngas: Syngas or synthesis gas is a gaseous bi - product of bamboo pyrolysis. It mainly consists of Hydrogen and Carbon monoxide. Syn gas is combustible and can be used as a fuel in combustion engine and electricity generators.

Use of bamboo charcoal:
Bamboo charcoal has variety of uses, some of which are very common and some others are advanced utilization in scientific field.

a) **As fuel:**
The most recognized use of bamboo charcoal is as cooking fuel. Many households and well known Restaurants used bamboo charcoal as fuel due to its high calorific value and smokeless property. It is mostly used in the form of briquettes and raw charcoal.
b) **Purifying water:**
Bamboo material possesses excellent absorbing capability after carbonization. Bamboo charcoal can be used to treat drinking water for eliminating organic impurities and offensive smells. It is even better than using chlorine or bleaching powder
c) **Purifying air:**
Due to the presence of micro - porous structure bamboo charcoal can absorb pollutants and harmful gases like Phosphorous Dioxide, Carbon Monoxide, and Hydrogen Sulfide from polluted air.
d) **Absorbing unpleasant odors:**
Bamboo charcoal helps to eliminate unpleasant odors of food in refrigerators. It keeps the food dry and fresh.
e) **Health and beauty:** The charcoal is a natural exfoliate for the skin which removes dead cells, making a person's overall appearance healthier. Regular use of bamboo charcoal based soap or a bath powder is very good for health.
f) **Other uses:**
Bamboo activated charcoal is use to refine coarse sugar. It is also widely used in food and beverage industries to filter out impurities, for water and gas treatment, filling of gas masks, in cigarette filter tips, as filter of ventilation system in atomic reactors to absorb radioactive particles. It can also be used as electrode in electronic equipments.

Advantages of Bamboo Charcoal:
Compared to regular wood charcoal bamboo charcoal has more surface area due to its micro porous structure, having higher absorbing capacity. Bamboo charcoal also burns very efficiently. As for raw materials, bamboo is very abandoned and easily grown plant. It only takes 3 - 5 years to mature and yield, hence it drastically reduces the risks of environmental damage which alternately helps in conservation of biodiversity.

2. Conclusions

Charcoal manufacturing is an extremely viable activity. If cost of bamboo/bamboo waste is taken at rupees 2/kg, cost of manufacturing of charcoal including labour cost is rupees 10/kg, market value of charcoal being around rupees 15/kg and with investment requirement for a rupees 1, 00000 returned back within a period of just 10 months. If market linkages are established, due to its low required investment and potential for employment generation it will uplift the economic condition of bamboo growers at village level.

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