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Charcoal preparation from jute stick: A new approach for sustainable economy

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Abstract

An investigation had been done to produce quality charcoal at different temperature ranges on a laboratory scale. A proximate analysis had been carried out to determine the percentage of moisture, volatile matter, ash, and fixed carbon in charcoal by standard methods. The jute sticks were carbonized at a range of 250°C to 750°C temperature in an electric muffle furnace. Higher yields, 40-45% were obtained at 250°C, and yields decline (8-10%) with increasing temperature up to 750°C. The yield of charcoal was calculated after the determination of moisture, where the average moisture of jute charcoal is about 9.88%. The carbon purity of jute charcoal is identified from FT-IR analysis. Thermogravimetric analysis revealed that thermal decomposition of the analyzed charcoal occurred in three main phases where the thermal decomposition of the charcoal occurred in the range of 340-550°C where the weight loss was 75% and the rest 1% of inorganic materials become ash.

Keywords: Jute Stick; Muffle furnace; Carbonization; Charcoal; FT-IR; TG

1. Introduction

Charcoal is a fine black powder or black perforated solid carbon which is odorless, tasteless, and is pyrolyzed residue that is obtained by removing water and other volatile elements from animals and plants [1]. Charcoal is also an impure form of graphitic. When carbonaceous materials are burned, or heated without access of air. Coke, carbon black, and dust carbon can be considered as charcoal forms and other forms are often chosen by the name of the material, for example, wood, blood, bone, etc., from which they originated [2-4]. Charcoal is usually obtained from mines and by the carbonization of hardwoods. The carbonization of hardwoods means deforestation as well as the destruction of the green environment, another source is mines which are actually limited. Jute sticks are more suitable sources than hardwood due to it is a renewable crop, abundant, ready availability, and cheapness, and it is anticipated that it will be a more ecological and economical source for making charcoal as well fuel and chemical carbon. Jute is a cash crop of Bangladesh but jute stick is agricultural waste and about 2.5-3 million tons of jute sticks produce every year. It is the central part of the jute plant which is left after the fiber is extracted by retting. Fiber has a huge commercial demand for manufacturing household goods and industrial raw materials. Alternatively, the jute stick has very little commercial importance, though it is twice the amount of jute fiber. Villagers just use jute sticks for their domestic purpose for example making fences for their boundary wall and burns for cooking. Therefore, charcoal could be made from jute sticks. And, we have been successful in utilizing the waste jute stick as a raw material to make charcoal. Charcoal is mainly used for outdoor cooking but a huge amount is used for industrial applications by the activated form that has fine particles and increased surface area. Charcoal has been used for various purposes including art, fuel, and the pharmaceutical industry since ancient times. It is a gastrointestinal decontaminant substance, used to treat those who eat hazardous substances. Charcoal has a large surface area results in it is not absorbed in the gastrointestinal tract or

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metabolized. It absorbs chemicals from the stomach and digestive tract traps them and flushes them out of the body without being absorbed into the blood [5, 6]. In this study, we have focused to prepare pure charcoal by the pyrolyzation of jute sticks at different temperatures for the finding of the optimum temperature by using an electric muffle furnace (Figure 1).

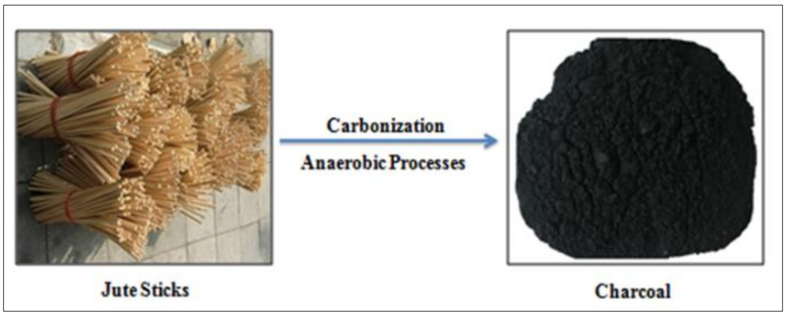

Figure 1 Flow diagram for the preparation of Charcoal from jute sticks

2. Material and methods

Jute sticks were collected from the Head Office of Bangladesh Jute Research Institute (BJRI), Dhaka Bangladesh. Before going to the charcoal preparation jute sticks moisture was measured by standard methods.

2.1. Physical Measurements

Fourier transform infrared (FT-IR) spectra of samples were recorded on an FT-IR spectrophotometer in the region of 400cm^{-1}-4000cm^{-1}. The thermal stability of the charcoal samples was tested by a thermogravimetric analysis (TGA) analyzer.

2.2. Analysis of Charcoal

For proximate analysis, the American Society for Testing and Materials (ASTM standard D1762-84) had been followed to determine moisture, volatile, ash, and fixed carbon (FC) [7].

2.3. Determination of Yield

The weight of the product after carbonization denoted the yield value of charcoal which was calculated using the following formula:

$$\text{Yields \%} = \frac{\text{(Weight after Carbonization}}{\text{Weight before Carbonization)}} \times 100$$

2.4. Determination Moisture

The charcoal was heated at 600°C in a closed crucible for 1h. The weight drop is for volatile materials which were calculated using the following formula:

$$\text{Moisture \%} = \frac{\text{weight reduction}}{\text{weight before heating at oven}} \times 100$$

2.5. Determination Volatile

The charcoal was heated at 600°C in a closed crucible for 1h. The weight drop is for volatile materials which were calculated using the following formula:

$$\text{Volatile\%} = \frac{\text{Weight lose}}{\text{weight of oven-dried sample}} \times 100$$

2.6. Determination Ash

Charcoal was heated at 1000°C in an open crucible for 1h. During this time, all the samples were converted into ash. Ash content was calculated using the following formula:

2.7. Determination Fixed carbon (FC)

Moisture, volatile matter and ash percentages were subtracted from 100% charcoal and thus the fixed carbon was calculated using the following formula:

$$FC = 100 - (Moisture + Volatile + Ash)\ \%$$

2.8. Preparation of Charcoal

Jute sticks were cut into chips 8-10cm and 20-30g of loose jute chips was taken for carbonization where the jute sticks were covered with perforated aluminum foil in order to promote the escape of volatile substances. The carbonization was carried out in an electric muffle furnace having internal dimensions with thermocouple heating and temperature control. The Jute sticks were carbonized until 4h at 750°C. After the end of carbonization when it was cool at room temperature, the aluminum foil-covered carbonization jute chips were taken out. After opening the cover it was weighed. The yield of charcoal was calculated on an oven-dry basis after the determination of moisture. Figure 1 shows the flow diagram for the preparation of Charcoal from jute sticks.

3. Results and discussion

Carbonization is one of the best technologies to convert biomass to hydrocarbon, biofuels, oxygenated fuel additives, and petrochemical replacements. This process is known as the thermal decomposition of organic materials at high temperatures in an inert atmosphere [8]. It involves a change of chemical composition. It is also considered the first step in the processes of gasification or combustion [9-11]. It can be explained by this equation:

$$\text{Jute Sticks} \xrightarrow[\text{Anaerobic Processes}]{\text{Carbonization}} \text{Allotropes/Amorphous Carbon} + C + CO_2/CO + H_2O + \text{Volatile Materials} + \text{Ash}$$

In this process, jute sticks produce volatile products and leave char, a carbon-rich solid residue. From figure 2, it had been observed that the yield percentages of jute-sticks charcoal decrease with the increase of temperature. At 250°C and 300°C temperatures, charcoal yields are 40-45% and 33-40%. Grayish color charcoal was obtained at below 300°C. At higher temperatures, the carbon percentage (FC) might be increased therefore, the total yield was decreased. However, at the temperature range, 350°C to 550°C, the slope of the graph was less steep. We have observed that after 500°C charcoal yield nearly the same up to 750°C and it is about 8-10%. The highest yield had been observed at 250°C around 45 % and the lowest had been observed at 500°C around 8%.

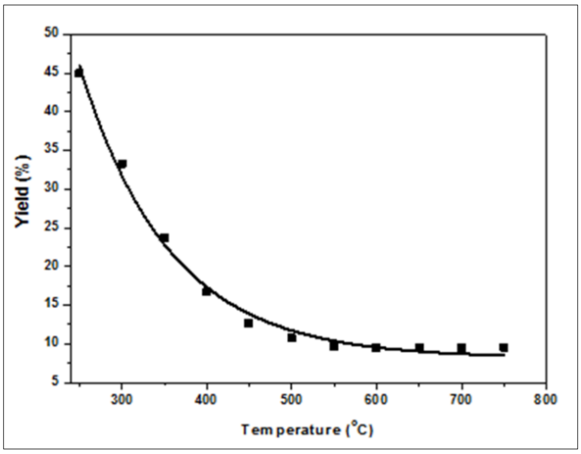

Figure 2 Charcoal preparation at various temperatures

Any types of fresh charcoal contain very little moisture and it is normally less than 1%. Mainly charcoal absorbs moisture about 5-12% from the humidity of the air with time. Without proper carbonization of biomass, charcoal may contain pyroligneous acids and soluble tars that could be back onto the charcoal by rain or humidity of the air. The hygroscopicity of the charcoal is increased and the natural or equilibrium moisture content of the charcoal can rise to 12-15% or even more. Moisture is an adulterant that lowers the calorific or heating value of charcoal. As a result, the moisture content is an important parameter in charcoal, and hence, it is needed for determining the calorific value of charcoal. The analytical results of jute charcoal moisture of eleven samples is 10.54, 10.70, 9.44, 11.82, 8.78, 9.07, 9.13, 9.21, 10.16, 9.99 and at 9.89 percent. The average percentage was observed 9.88 (Figure 3) which has a similarity reported by other researchers [12]. Table 1 shows the moisture percentage of charcoal is made by different types of species. Figure 4 shows the infrared spectrum of jute stick charcoal, and it could show the purity of charcoal. In this spectrum O-H stretching vibration at around 3400cm^{-1} is not present which means the charcoal sample was dry enough. The peak observed at 1,585cm^{-1}-1412cm^{-1} is due to the C=C and C-C stretching band those can be attributed to the aromatic ring [13-15]. The wave number with an absorption band peak of 872cm^{-1}-812cm^{-1} indicates the presence of aromatic C-H group vibrations [16-18]. Figure 5 shows the thermogravimetric analysis of jute stick charcoal and reveals that the thermal decomposition of the analyzed charcoal occurred in three main phases. The first phase (50−175°C) is associated with moisture release (5.16% weight loss). The most intensive decomposition of an organic matter occurred in the range of 175−500°C (additional 92.01% weight loss). In this range of temperature, all carbon materials are oxidized to form carbonmonoxide or carbondioxide, and the rest inorganic materials become ash [19, 20]. For the preparation of charcoal from jute stick, it is an important task to fix the pyrolysis temperature. Herein, to detect the appropriate temperature to make the pure charcoal various temperatures had used (200-750°C). To see the infrared spectrum and thermogravimetric analysis, it might be predicted that carbon purity is better. But, carbon purity depends on the removal of ash in the charcoal it will be observed next time. However, Jute will be the more economical source for making charcoal for fuel and chemical carbon than the hardwood resources, for that reason, further development work is in progress in our laboratory for preparing this charcoal under pilot-plant conditions, and for the study of its performance in the various applications indicated above.

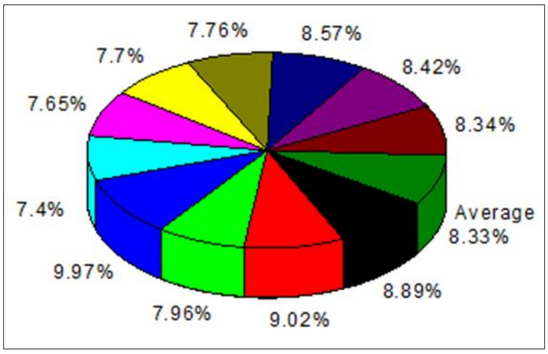

Figure 3 Moisture percentage of jute charcoal

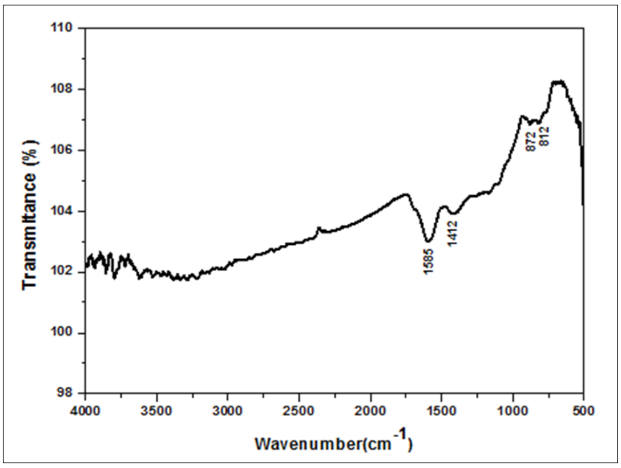

Figure 4 FTIR spectra of jute stick charcoal

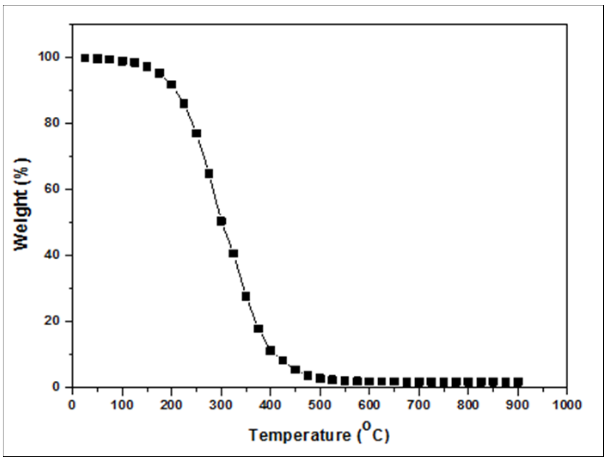

Figure 5 Thermogravimetric graph of jute stick charcoal

Table 1 Moisture summary of deferent type of species charcoal

Deferent type of species Charcoal	Moisture content (%)
Dakama	7.5
Wallaba	6.9
Kautaballi	6.6
Mixed Tropical Hardwood	5.4
Oak	3.5
Coconut shells	4.0
Eucalyptus Saligna	5.1
Jute Stick	8.89

4. Conclusion

This new approach of charcoal production from jute stick lessen deforestation as well as the destruction of the green environment which increases some aspects of well-being (e.g. household assets), has a commercial activities of numerous types (i.e. activities related to food, Agro and metal processing; industries based on forest products, minerals or textile products; industrial or commercial activities of miscellaneous types) as well as alleviates poverty and improves environmental sustainability.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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