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Investigation of Jute Stick Carbonization for the Optimum Production of Charcoal

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ABSTRACT
Bangladesh is one of the largest jute producing countries next to India. After, extracting fiber from jute, jute sticks remain unused. These sticks are generally used as household fuel in the rural area. Jute stick has a hollow structure with composition almost similar to other woody substances. One of the alternative use of these sticks could be converting them into charcoal. However, the current industrial process in Bangladesh is not efficient and has a yield about seventeen percent only. Therefore, an investigation had been done in this research project to compare the yield and quality of charcoal produced 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 ASTM standard (D1762 – 84). From the output result, an ideal temperature range 300-350 degree Celsius had been deduced that could allow a substantial yield and fixed carbon of charcoal production in industrial cases.

Keywords: Jute stick, Charcoal, Carbonization, Yield, Fixed Carbon.

1. Introduction

Jute is widely recognized as golden fibers in Bangladesh. It is one of the most affordable natural fibers next to cotton. After extracting the fiber from jute, these sticks were sold outside to use as fuel. Later, after the invention of the gas stove, electric stove, etc. individuals reduced the usage of these sticks as a resource of cooking fuel [1]. Therefore, these sticks can be considered at present as agricultural wastes. Statistical data shows, in 2017-18 premises, Bangladesh produced around 1655.8 thousand tons of jute, which had been 53.44% of the whole world's production [2]. A new immerging sector has risen that can convert these sticks into a flow of cash by producing charcoal from them [3]. A Comparison study between hardwood and jute stick composition suggested a similar type of structure [4]. Therefore, these sticks can be taken as an ideal for charcoal conversion.

Charcoal is the solid form of carbon derived by heating organic material in the absence of air. An insightful description of charcoal had been given by Chaturvedi et al. (1943) as follows: "Charcoal of good quality retains the grain of the wood; it is jet black in color with a shining luster in a fresh cross-section. It is sonorous with a metallic ring, and does not crush, nor does it soil the fingers. It floats in water, is a bad conductor of heat and electricity, and burns without flame." [5]. The ideal quality of charcoal for commercial use should have fixed carbon content of around 75%.[6]

Some technologies involving charcoal production include Earth Pit and Earth Mound Kilns, which are widely used to produce charcoal [7]. These kilns have a conversion rate of around 8% to 12 % [6]. Currently, per ton of charcoal is sold at about $1000 according to their quality and grade [8]. In 2016, about 1.74 Million USD worth of charcoal was exported to China from Bangladesh [8]. These exported charcoals are used to produce cosmetics, drugs, printing inks, toothpaste, medicines, water purification equipment, etc. [9]. Currently, the technology used to produce charcoal in Bangladesh is very primitive and the conversation rate is around 17% [8]. The Problem involving the current method is that they are not efficient and not safe for workers. Therefore, there is a possibility to improve the current production method that would result in better quality and quantity of charcoal production.

Similar work had been conducted by Banerjee et al., 1985 regarding the carbonization of jute stick. That study suggested that the jute stick imposes some problems due to its hollow structure at elevated temperatures. At elevated temperature, jute stick tends to become more flammable. The study suggested that the hemicellulose part of the jute stick composition allows it to burn with flame at elevated temperatures [4].

In this paper, research had been carried at different temperatures to measure the quality and yield of jute stick charcoal. Proximate analysis is carried to measure the quality of product. From the result, an optimum temperature range is proposed for decent quality and quantity of charcoal.

2. Methodology

2.1 Sample Preparation

This step involves collecting raw jute sticks. These sticks were collected from the local market at a very cheap rate of around 25 Tk per kilogram. After collecting them, they were cut into 40 to 50 mm chips and dried in the sun.

2.2 Weight Measurement of Sample

Dried jute stick chips were put into a constructed steel jar (**Fig. 1**). The sample was weighted with a weight balance. The weight balance had a precision of 0.001. The weight balance had also been used to measure the final product and to perform proximate analysis.

2.3 Experimental Setup

The jute chips were taken into steel cylindrical jars. These jars had an inner diameter of 50.8 mm and a height

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of 63.5 mm. The jar had been covered with aluminum foil (**Fig. 2).** Few holes were made on the foil to ensure the volatile escape. After that, the jars were closed with led and brought to the muffle furnace for heating purposes (**Fig. 3)**. . The temperature had been set at the muffle furnace with the help of a temperature controller (**Fig.4)**. The experiment was conducted in four different temperature ranges which were 250°C, 300°C, 350°C & 400 °C. The heating was carried out for 2.5 to 3 hours depending on the temperature. Three samples were taken for each observation to maintain the accuracy of the analysis.

Fig.1 Preparation of jute stick

Fig.2 Wrapping with Aluminum foil

Fig.3 Steel jar placement in muffle furnace

Fig.4 Heating controlled by thermocouple & controller

2.4 Analysis of Charcoal

For proximate analysis, ASTM standard (D1762 – 84) had been followed to determine moisture, volatile, ash, and fixed carbon [10].

2.4.1 Product Yield

The weight of the product after carbonization denoted the yield value of charcoal.

Yield % = (Weight after Carbonization / Weight before Carbonization) x 100

2.4.2 Moisture Content

For moisture, a sample of 0.8 to 1.2gm chips had been taken from the yield sample into porcelain crucible and heated for 2h at temperature 100-105 °C in the oven **(Fig. 5)**. After that, from the reduction of weight, moisture had been calculated. This weight had been used as an oven-dried weight to measure the content of ash.

Moisture = (weight reduction / weight before heating at oven) x 100 %

2.4.3 Volatile Content

For volatile, the residue sample had been heated at over 500°C in a closed crucible for 7 minutes. From the reduction of weight, the volatile percentage had been determined.

Volatile % = (Weight reduction/ weight of oven dried sample) x 100

2.4.4 Ash Content

For ash determination, the left-over sample had been heated over 700°C in an open crucible for 2h. During this time, all the samples converted into ash. The ash percentage had been measured by dividing the ash weight to the weight of the oven-dried sample.

Ash % = (Weight of Ash/ weight of oven-dried sample) x 100

2.4.5 FC Content

FC (Fixed carbon) refers to the solid burnable material which remains after the reduction of moisture & volatile content minus ash content that remains afterward the combustion is complete [11]. For fixed carbon determination, all the other above percentages obtained had been subtracted from 100%.

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

Fig.5 Analysis of Charcoal

3. Results and Discussion

For each observation at a specific temperature, three samples had been taken to determine the yield percentage. For proximate analysis, two samples had been taken from the yield sample.

Table 1 shows the summary result of all observations of carbonized jute chips. Proximate analysis results (Moisture, Volatile, Ash, FC) are averaged value of total samples taken for the analysis.

Fig.6 shows the visual representation of result data for carbonized jute sticks.

From the graph, it had been observed that the yield percentage had a linear fixed decline slope from 250°C to 350°C temperature range. However, at the temperature range 350°C to 400°C, the slope of the graph was less steep. The yield percentage reduced with the increase in temperature, the highest yield had been observed at 250 °C around 44.5 % and the lowest had been observed at 400°C around 16%. Trendline shows a decline in yield percentage with the increased temperature which suggests above 400 °C yield would be very less.

Table 1 Result summary of carbonized jute chips

Temperature (°C)	Duration (hour)	Yield %	Moisture %	Volatile %	Ash %	FC %
250	2.5-3h	44.50	8.16	31.20	2.20	58.44
300	2.5-3h	32.07	9.30	21.67	2.53	66.50
350	2.5-3h	20.20	8.56	18.25	2.92	70.26
400	2.5-3h	15.95	9.18	6.94	3.92	79.96

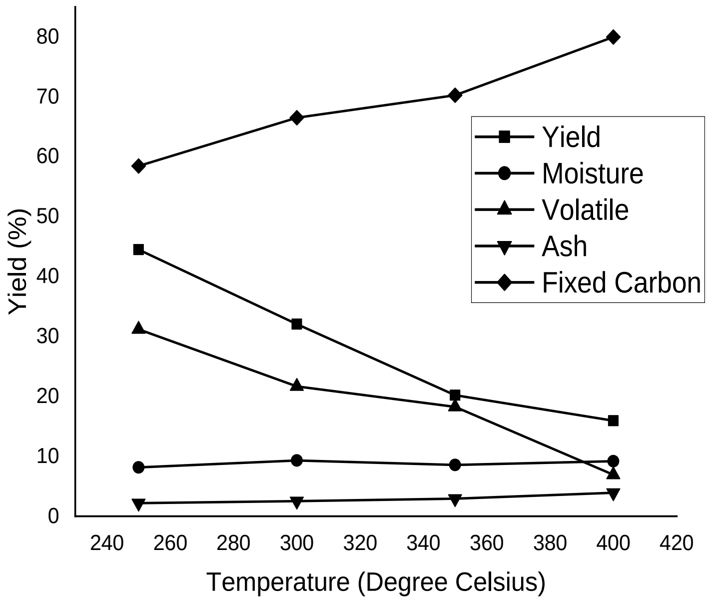

Fig.6 Graphical presentation of Table 1

However, Moisture content had been observed almost the same at all temperatures with an average ranging from 8 to 9 %. The high-temperature condition had almost no effect on the moisture content on samples.

Volatile content had been seen to vary from 31 to 7% as temperature increases. The volatile peak percentage observed at 250°C was around 31.20% and the lowest was observed at 400 °C around 6.94%.

On the other hand, the ash percentage remains almost the same for all temperatures, about 3-3.5 %. However, at an elevated temperature of around 400°C, Ash percentage had been observed around a little higher to 4%.

Finally, the fixed carbon had been observed to increase at elevated temperatures. At 400°C the value reaches to a maximum value which is about 80%. The lowest fixed carbon value had been observed at 250°C around 57%.

The goal had been to find an ideal temperature zone that would result in a better fixed carbon percent and moderate yield of charcoal. In order to achieve a better quality of coal, higher fixed carbon is always desired during charcoal production. At elevated temperature, despite having higher FC content, the yield percentage drastically reduced. Therefore, a temperature range in between 300-350°C suggest better yield with significant higher percentage of fixed carbon content during jute stick charcoal production.

5. Conclusion

The research started with analyzing the carbonization effect on jute sticks to determine an optimum temperature range for a decent quality & quantity of charcoal. To achieve that, the sticks had been carbonized in a set of temperature ranges and proximate analysis had been conducted according to ASTM standard (D1762 – 84). The summarized result from proximate analysis gives an exact point of view of outcome products. Higher fixed carbon content denotes greater quality of charcoal production. It shows that fixed carbon increases with the increase of temperature. Whereas, volatile and yield percentage decrease with the increase in temperatures. In Fig.6, slopes were less steep around 300°C to 350°C. From that we can conclude, for better quality and significant yield percentage, the heating temperature range should be in between 300-350°C for charcoal production.

6. References

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