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Characterization of the Baobab fruit shells as adsorption material

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Abstract

The Baobab (*Adansonia digitata* L.) is a large iconic tree indigenous to Africa where it is found in many countries. The Baobab tree has various uses, as it produces food and non-food products such as medicines, fuel, timber and fodder. This research is focused on the characterization of the Baobab fruit shells in terms of lignin (54.08%), cellulose (24.87%) and hemicellulose (21.05%) content, as well as proximate analysis such as ash content (5.17%), moisture content (6.48%), volatile matter (86.73%) and carbon content (1.22%). This assessment will play a vital role in exploring the benefits of utilizing baobab fruit shells in the production of activated carbon as well as set a foundation for future research.

Introduction

Baobab trees are widely spread throughout the hot drier regions of Africa (FAO, 1988), covering an estimated area of 9,345,000 hectares. The average mature fruiting baobab produces around 200 kg of fruit per season and a potential yield of whole fruit that is just over 670,000 tonnes per year (Africa, 2008). The plant is a very massive tree with a very large trunk (up to 10 m diameter) which can grow up to 25 m in height and may live for hundreds of years. Baobab tree has multi-purpose uses and every part of the Plant is reported to be useful (Igboeli *et al.*, 1997; Gebauer *et al*., 2002). The different parts of the plant provide food, shelter, clothing and medicine as well as material for hunting and fishing (Venter and Venter, 1996; Sibibe and Williams, 2002). Baobab tree provides income and employment to rural and urban communities (Kaboré *et al.*, 2011). However, baobab fruit shells (BFS) have no economic benefit. This research will study the physical characteristics of baobab fruit shells to provide vital information for future research on activated carbon.

Materials and methods

Preparation of raw material

First the baobab shells were washed and dried at 105°C for 24 hours; to reduce the moisture. Then crushed and sieved to a particle size of 1mm. 10-20 g for each sample.

Estimation of cellulose

A 1g of the sample was mixed with about 3ml of acetic: nitric reagent (150 ml of 80% acetic acid + 15ml of concentrated nitric acid) in a vortex mixer and placed in water bath at 100°C for 30min. After centrifugation, the residue was collected and washed with water while 10 ml of 67% H_2SO_4 was added and left for 1h. 1ml of the solution was diluted in 100 ml and then 10 ml of anthrone reagent is added to 1ml of the solution and mixed very well. The tubes were heated in a water bath for 10 minutes and the absorbance was measured at 630 nm after cooling. The amount of cellulose present was determined from the standard curve (40-200 micrg/L of cellulose).

Estimation of lignin

A 0.1 gram of sample was added to 2 ml of (72%) sulfuric acid. The mixture was mixed at room temperature 27°C for two hours. Then 72 ml of water was added and the sample was autoclaved at 121°C for 15 minutes. Next the sample was filtered and dried for 12 hours to calculate the insoluble lignin Equation (1). The optical density of the filtrate was measured at 205 nm to calculate the soluble lignin content Equation (2). The total lignin was calculated by Equation (3) (Kline *et al*., 2010).

$$\%\ \text{Insoluble lignin} = \frac{\text{Weight of lignin after drying}}{\text{Initial weight of sample}} \times 100\% \quad (1)$$

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$$\%\ \text{Soluble lignin} = \frac{Abs_{205}}{\varepsilon_{205}} \times 100\% \quad (2)$$

Where Abs_{205} is an average absorbance for lignin standard in IL 205 nm, ε_{205} is the extinction coefficient for lignin standard at 205 nm ($110 Lg^{-1}cm^{-1}$) and l is the path length (1 cm).

$$\%\ \text{Total lignin} = \%\ \textit{Soluble lignin} + \%\ \textit{Insoluble lignin} \quad (3)$$

Moisture content

The moisture content of the baobab shells is determined by oven-drying 2 grams of the material at 105°C for 24 hours until consistency of weight is obtained (Zahangir Alam *et al*., 2007). The weight difference gave the amount of moisture in the sample Equation (4).

$$\text{moisture content (\%)} = (W-D)/W \times 100 \quad (4)$$

Where, W is the mass of the original sample, and D is mass of dried sample.

Ash content

For the ash content, two replicates were used to obtain a more accurate result. A 2 g sample is placed in the furnace from room temperature to 600°C for two hours; the ash constituted the remaining mass at the end of the analysis. In addition, an empty crucible is also placed in the furnace under the same conditions to consider the effect of temperature on the crucible, which is found to be negligible (Jun *et al*., 2010), the percentage of ash is calculated by Equation (5).

$$\%\ \text{ash} = (\text{remaining solids weight})/(\text{original material weight}) \times 100 \quad (5)$$

Volatile matter content

For the volatile matter, a previously dried sample is placed in the furnace at 750°C for 7 minutes, and then moved to the dissicator to cool. Volatile matter content is determined from weight loss after dehydration. The quantity of volatile matter is then determined by Equation (6) (Wahi *et al*., 2009).

$$\text{Volatile Matter} = (W(\text{Volatile}))/(W(\text{Initial})) \times 100 \quad (6)$$

W (Initial) is the weight of sample before placing in the furnace.
W (Volatile) = The weight before placing in the furnace – weight after placing in the furnace.

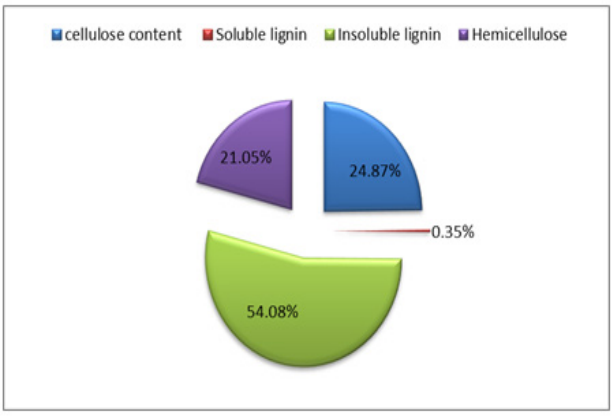

Figure 1. Composition of BFS

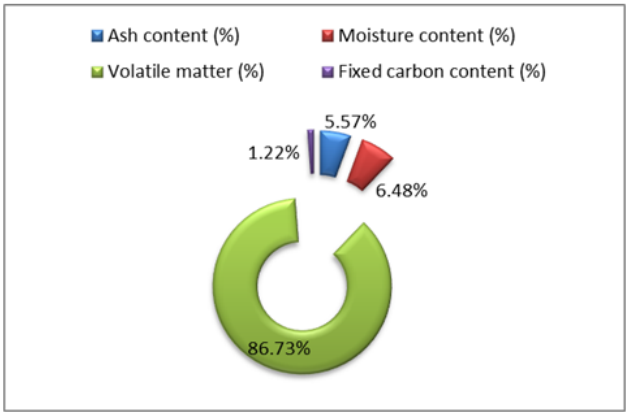

Figure 2. Proximate Analysis for BFS

Fixed carbon

Fixed carbon is obtained by subtracting the sum of the percentage of moisture, ash, and volatile matter from 100.

Results and discussion

Cellulose content and lignin content

The composition of the precursor is very important in the preparation of activated carbon and the formation of a porous structure, especially the percentages of Cellulose and Lignin present. This is important since materials with high Lignin content will lead to production of activated carbon with high macropores (>50 nm) while materials with a high cellulose content will yield activated carbon with high microporous structure (Daud and Ali, 2004). The results below suggest that the activated carbon produced will be high in macropores.

Proximate analysis

Proximate analysis of the raw material in Figure 2 shows the three tests that were conducted; moisture content, ash content and volatile matter content. The results obtained for the moisture and ash content were 6.48% and 5.57% respectively. These results were very similar to those obtained by Gebauer *et al*. (2002) where they provided the Chemical

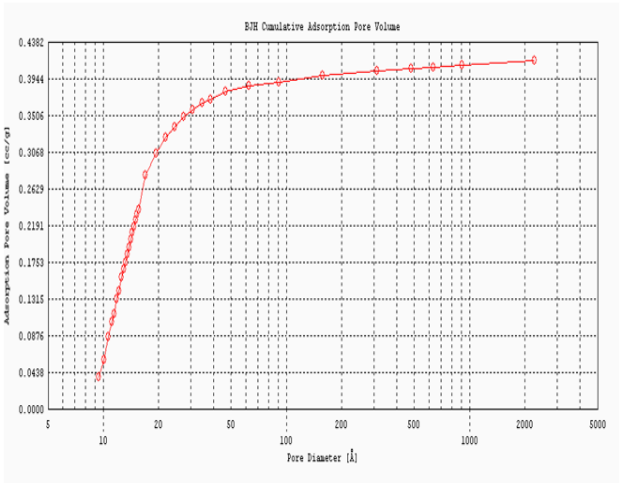

Figure 3. BFH Cumulative adsorption pore volume

composition of baobab fruit pulp. Moreover, the BFS has high volatile matter content making this material a good precursor for production of activated carbon, because, in general, a starting material for activated carbon is expected to be high in carbon and volatile contents but low in ash content De *et al.* (2013).

The characterization also showed the result as in Figure 3 below, where the pore diameter of Baobab against adsorption pore volume show progressive development as in the figure.

Conclusion

In this study, the characterization of the Baobab fruit shells as adsorption material has been determined. The shells in terms of lignin was found to be 54.08%, cellulose 24.87% and hemicellulose 21.05% content, as well as proximate analysis such as ash content 5.17%, moisture content 6.48%, volatile matter 86.73% and carbon content 1.22%. The study is expected to assist in the ongoing researches for activated carbon production to reduce the consumption of conventional activated carbon as well as the positive impact on the environment.

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