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Production of Activated Carbon from Baobab Fruit (Adansonia digitata L.) Shell

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ABSTRACT

Activated carbon (AC) is an amorphous form of carbon with a highly developed internal pore structure and large surface area, making it an excellent adsorbent. This study investigates the optimal conditions for producing activated carbon from baobab fruit shells, an abundant agricultural waste in Sudan, by varying carbonization temperature, particle size, time, and activation agent. The highest yield (29.653%) was obtained for particle sizes of 6–14 mm at 500°C for 2 hours. HCl was the most effective activation agent (1 M, 60 min exposure), achieving 98.6% methylene blue adsorption. This work highlights the potential of baobab shells as a low-cost and sustainable precursor for activated carbon production, reducing waste and import dependency.

1. INTRODUCTION

Activated carbon (AC) is a generic term for a family of highly carbonaceous materials, none of which can be characterized by a specific structural formula [1]. It is one of the most important industrial carbon materials and is prepared by the carbonization and activation of various organic raw materials such as wood, coal, and lignite [2]. The characteristics of activated carbon depend on the physical and chemical properties of the raw materials as well as the method of activation [3]. The process for preparing activated carbons involves carbonization and activation of the carbonized product by physical or chemical activation [4]. The carbonization process enriches the carbon content and to create an initial porosity in the char while activation further develops the porosity and creates some ordering of the structure, thereby generating a highly porous solid as the final product [5].

One major drawback of naturally occurring organic substances as precursors for activated carbon is that the resulting pore size distribution cannot be controlled [6]. This led to the use of synthetic resins and polymers [7]. As a result of increasing demand for adsorbents locally available carbonaceous materials have proven worthy for producing ACs [8]. In search of alternative sources and cheaper carbons, agro wastes with average carbon content of 35 percent have attracted the interest of researchers [9]. Agricultural waste is important starting material to produce ACs. Activated carbon produced from agro-waste materials typically has a large surface area and high carbon content. ACs is porous, solid and black carbonaceous materials. ACs is excellent adsorbents because they have high porosity, extremely high surface area, large adsorption capacity and ease of regeneration [10]. A wide variety of carbons have been prepared from agricultural wastes such as rice husks, pith, bagasse, sawdust, parthenium plant, hazelnut shells and apricot stone [11]. Each of the activated carbons has its own characteristic properties and variations exist in their efficiency.

2. REVIEW OF BAOBAB

The baobab is a large iconic tree indigenous to

Africa where it is found in many countries. Baobab trees are widely distributed throughout the hot, drier regions of Africa, 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 tons per year (Africa's production in 2008) [12] 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 [13]. The different parts of the plant provide food, shelter, clothing, and medicine as well as material for hunting and fishing [14]. Baobab tree provides income and employment to rural and urban communities [15]. However, baobab currently has limited economic exploitation in many regions. In this study activated carbons were produced from baobab fruit shell and its determined characteristics are reported.

3. MATERIALS AND METHODS

The activated carbon product production process is shown in figure (1) and detailed next. The key steps of the process are shown in Figures (2-5).

3.1 Preparing the Sample

Eight whole Baobab Fruits were weighed resulting in 922 grams. A test was conducted to determine the most suitable conditions that give the highest yield percentage for

Figure 1: Block Diagram of AC Production in This Study producing AC from the shells. Baobab Shell was obtained from the fruit by cutting it in half then removing the unwanted contents such as fibers and seeds. The shells were placed in an oven at 110°C to remove moisture and obtain an accurate estimation of the sample mass. then

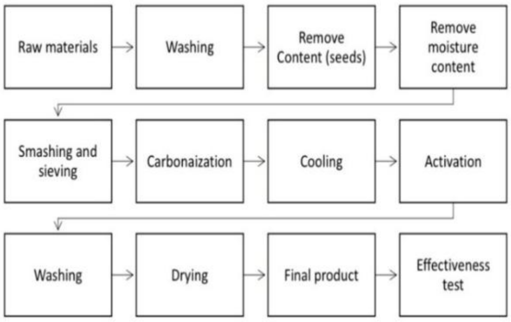

Figure 1: Block Diagram of AC Production in This Study

smashed using a hammer into small flakes Six different mesh sizes (Sieve) were used ranging from 35 mm – 0.45 mm to split the shells particles according to their size.

Figure 2: Baobab Fruit**.**

Figure 3: Sample Sieving

3.2 Carbonization

For the carbonization procedure time, temperature and Shells size were controlled as variables. The temperatures used were 400, 500 and 600 °C , samples were placed in furnace for 1, 2 and 3 hours for groups A, B and C. Twentyseven samples were analyzed in total. Sample was placed inside of the crucibles which were placed in the furnace. At prescribed times a sample of each ratio was withdrawn from the furnace and allowed to cool in desiccators to the room temperature. The carbon was weighed, and the weight percentage relative to the initial shell weight was calculated. The results of carbonization process shown in table (1).

Figure 4: Washing the Carbon in Activation Process

Figure 5: Exposure Process of Products

3.3 Activation

One molar Potassium Hydroxide solution was prepared alongside a Hydrochloric Acid solution and Sulfuric acid of the same concentration and volume (750 ml each). The carbon sample was divided into six equal-weight groups each placed on a paper filter (three flasks for testing for each KOH, HCL and H2SO4 solutions), the filters are placed on flasks. 250 ml of solution is poured on Carbon in each flask, time is controlled as a variable and the prescribed times are 30 and 60 min for both solutions. A sample of each ratio was withdrawn at prescribed times and washed with distilled water until an acidity of approximately (7) on the Potential Of Hydrogen scale (pH) is reached, a digital pH meter was used for this procedure. The samples were left to dry in a closed container until the following day.

3.4 Adsorption Test

The adsorption efficiency of Activated Carbon can be tested by placing AC in a solution that has a known concentration for a specific period of time and observing the change of the concentration of the named solution during that period. In this study, Methylene Blue solution will be used as test solution and a UV spectrophotometer will be the instrument used to observe the change in concentrations.

3.5 Methylene Blue Solution

Methylene Blue is a cationic dye, meaning it carries a positive charge, which allows it to interact with various types of surfaces and adsorb onto them. In addition, it has a distinct color, which makes it easy to track and measure its concentration.

In this study, three Methylene Blue solutions were made with concentrations of 100, 200, and 300 ppm. Each solution was poured on 1 gram of Activated Carbon in three different flasks for period of 100 min, each solution was tested for the AC that was activated using (KOH, HCL, and H2SO4) in their periods of 30 and 60 min, resulting in eighteen adsorption test samples. Methylene Blue solution was scanned by UV spectrophotometer before and after being adsorbed by Activated Carbon.

4. RESULTS AND DISCUSSION

The following characteristics were acquired using the researchers' human sensory systems. The activated carbon obtained was black, granular, and odorless. It is insoluble in water and organic solvents and all usual solvents. When heated to redness it burns slowly without a flame.

4.1 Physicochemical Properties

The produced AC was black, granular, odorless, with low ash content (~5–8%) and moisture (~5–10%).

4.2 Carbonization Results

Various raw materials were tested as shown in Table 1 below. It was found that a yield of 29.653% obtained at an optimal condition (500°C, 2 h, 6–14 mm particles). Variations for the different groups of raw materials used are also shown in Figure 6.

4.3 Adsorption Results

HCl-activated AC (60 min) showed 98.6% adsorption for 100 ppm methylene blue. Adsorption efficiency decreased with higher initial dye concentration.

5. DISCUSSION

It was found that the conditions that were the most The most efficient conditions for producing activated carbon were a pyrolysis temperature of 500°C and a pyrolysis time of 2 hours for Group C.

The highest adsorption percentage (98.6%) was achieved using HCl as the activation solution with a duration of exposure of 60 minutes. The result also showed how DE affects the percentage of adsorption significantly, which complies with the result of [31]. The mentioned experiment showed that the adsorption efficiency of Activated Carbon is inversely proportional to the initial concentration of Methylene Blue.

Local production cost estimated at ~$500–800/ton (raw materials + energy). Imported AC costs $2000–2500/ton (2025 prices). This represents 60–75% savings, plus environmental benefits from waste valorization.

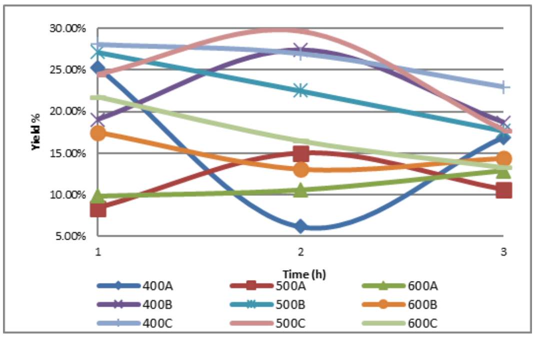

Figure 6 :Variation of yield, time and temperature

CONCLUSION

Baobab fruit shells can be used as a precursor for the preparation of activated carbon with high surface area and adsorption capacity. The results of this study demonstrate that valuable adsorbents can be produced from this renewable and abundant waste material. The variations in characteristics were influenced by activation process, activating reagent, and temperature. Shells crushed to particle sizes ranging from 6 to 14 mm yielded the highest production efficiency. The optimum carbonization temperature was 500°C for 2 hours. Among the activation agents tested, HCl with a 60-minute exposure period produced the best adsorption performance (98.6%).

Baobab fruit shells represent a promising, low-cost, and sustainable alternative to imported activated carbon, offering both environmental and economic benefits.

Table 1: Yield vs. temperature and time

	Time\Temp (°C)	400	500	600
Group A, 20-35mm	1 hour	25.28%	8.39%	9.88%
	2 hours	6.18%	14.99%	8.62%
	3 hours	16.92%	10.61%	12.88%
Group B, 14-20mm	1 hour	19.01%	27.16%	17.50%
	2 hours	27.46%	22.52%	13.05%
	3 hours	18.66%	17.70%	14.36%
Group C, 6-14mm	1 hour	28.07%	24.46%	21.74%

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