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The Effects of Carbonization Temperature on some Physicochemical Properties of Bamboo Based Activated Carbon by Potassium Hydroxide (KOH) Activation

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Research Article

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ABSTRACT

The effects of carbonization temperature on some physicochemical properties of Bamboo waste by the chemical activation with potassium hydroxide have been investigated.
The bamboo based activated carbon was characterized in terms of the yield rate, ash, porosity, density, and specific surface area at different carbonization temperature in the chemical activation process using standard methods of analysis. The results showed specific surface area, density, yield, moisture content porosity and ash content were 234m3/g, 0.483g/cm3, 32.67%, 0.74 and 2.92% respectively. The metal contents present were Pb2+, Fe2+, Ni2+, Zn2+,and Cd2+ with Z2n2+ having the highest concentration (31.40mg/kg) and Cd2+(8.9mg/kg), the lowest. The yield rate decreases with increase in temperature, while ash, density and specific surface area increases with increase in temperature. KOH activation of bamboo was suitable for the preparation of charcoal which are essentially microporous.

Keyword: Bamboo, KOH, Activation, Properties, Activated carbon.

INTRODUCTION

Activated carbon can be used for removal of organic chemicals, chlorine, lead, unpleasant tastes and odors in effluent or coloured substances from gas or liquid streams by the mechanism of adsorption. Adsorption can be defined as absorption on the surface of the material due to capillary condensation inside the multitude of pores/active sites available.

It is well known that activated carbons can be prepared from a large variety of raw- materials with a high carbon content and low levels of inorganic compounds. While there has been much indigenous effort in converting coal, wood, coconut, bagasse, palm shell and maize Cob into activated carbon, certain initiatives were necessary for an investigative study of conversion of bamboo (Babarinde, 2002).

Bamboo charcoal is made of bamboo by pyrolysis process. According to the types of raw material, bamboo charcoal can be classified as raw bamboo and bamboo briquette charcoal. Raw bamboo charcoal is made of bamboo body such as culms, branch and root. Bamboo pyrolysis, including bamboo carbonization, bamboo destructive distillation, bamboo activated carbon and bamboo gasification, is a manufacturing method which makes bamboo heated to form many pyrolysis products under condition of isolating air or letting little air in. (Jiang, 2004).

Generally, the manufacture of activated carbon involves two main steps: the carbonization of the carbonaceous raw material below 1073K in the absence of oxygen and the activation of the carbonized product. In the chemical activation process, these two steps are carried out simultaneously using chemical activating agents as dehydrating agents or oxidants (Bansal et al, 1988); while the physical activation involves carbonization of carbonaceous processor followed by the activation of the resulting char at elevated temperature in the presence of activating agents (Philip and Girgis, 1998). Several types of chemicals are used as the activating agent including KOH as different agents provide activated carbons with different properties (Hayashi et al, 2000).

Bamboo charcoal contains many pores and gaps in the structure, making it excellent for adsorption, electromagnetic shielding and infrared emitting. One of the more popular process used in making bamboo charcoal is with brick kiln. There are several different quality of bamboo charcoal, such as density, fixed carbon content, ash and volatile matter content, specific surface area, etc. The temperature used in carbonizing bamboo charcoal will affect its absorption capacity of to methanol, benzene, methylbenzene, ammonia and chloroform. The electric conductivity of bamboo will be reinforced with the rising of carbonization temperature. Therefore, bamboo charcoal carbonized under high temperature has effective property for shielding electromagnetism. Currently, bamboo charcoal products are gaining popularity as it has excellent and infrared radiation properties. The main constituent of bamboo culms are cellulose, hemi-cellulose and lignin which amount to over 90% of the total mass. The minor constituents of bamboo are resins, tannins, waxes and inorganic salts compared with wood, however, bamboo has higher alkaline extractives, ash and silica contents (Chen 1985). Bamboo contains other organic compositions in addition to cellulose and lignin. It contains about 2-6% starch, 2% deoxidized saccharide, 2-4% fat and 0.8-6% protein.

With the continued rapid development of the global economy and constant increase in population, the overall demand for wood and wood based products will likely continue to increase in the future (FAO 1997). As a cheap and fast- grown resource with superior physical and mechanical properties compared to most wood species, bamboo offers great potential as an alternative to wood. The chemistry of bamboo is important in determining the utilization potential. Several studies have investigated the chemical composition of bamboo. But systematic and thorough research in a commercially important bamboo species is needed to determine utilization potential for the products such as medium density fiber board (Amada et al, 1997).

This work seeks to study the effects of carbonization temperature on the properties of bamboo charcoal, the yield rate, ash, volatile content, density and specific surface area at different carbonization temperature.

MATERIAL AND METHODS

The bamboo used in this was obtained from Choba, Port Harcourt, Nigeria. Bamboo was crushed to a desired mesh size. Particle size of bamboo is 60-80 meshes. The crushed bamboo pieces were washed with water for the removal of adherent extraneous matter.

The washed bamboo pieces were dried in oven at 150^{0}C for 4 hours for removal of moisture. These bamboo precursors were immersed in KOH solution (25% by volume). The weight ratio of bamboo precursors to KOH was kept constant. The mixture was dehydrated in an oven for 12 hours at 150^{0}C. The dried bamboo and KOH mixture was then subjected to carbonization process at 300-600^{O}C maintained 4 hours at each temperature. The carbonized mass was washed with water for the removal of carbonizing promoter.

Characterization of Bamboo Based Activated Carbon.

The specific surface area of the bamboo based activated carbon was determined using the European spot method used by Kandhal and Parker (1998) and Santamaria et al, 2002: moisture content was determined using ASTM D 2867-91. Bulk density was determined using the method of Okiemen et al, (2007). Ash content was determined by ASTM D 4607-94. pH of the carbon was determined by immersing 1g of sample in 100ml of distilled water and stirring for 1hour. Volatile matter was determined by ASTM D 1762-84 (R 2001). The metal content was analysed by using Atomic Adsorption Spectrophotometer (AAS).

The pore volume was determined gravimetrically by saturating the sample with a liquid of known density and noting the weight increases using porosimeter. The porosity was determined as the ratio of the pore volume to the bulk volumes. Similarly, the tortuosity was determined by computing the inverse of the porosity.

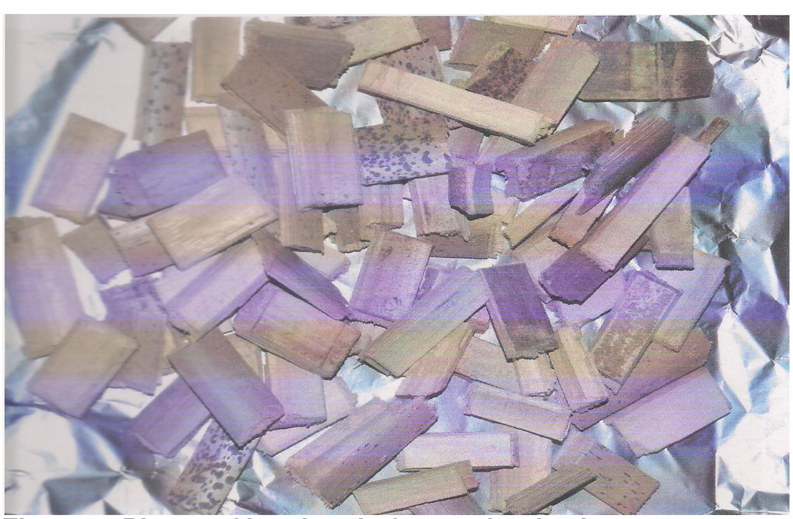

Figure 1: Pieces of bamboo before carbonization.

Figure 2: Bamboo activated carbon.

RESULTS AND DISCUSSION

The characteristics of activated carbon synthesized from bamboo were determined and reported in Tables 1-3

Table 1: Physical properties of bamboo based activated carbon.

Characteristic	Value
Surface area (m^2/g)	341.77
Density (g/cm^3)	0.5333
pH	6.64
Ash content (%)	2.92
Moisture content (%)	38.92
Specific gravity	1.61

Table 2: Heavy metal Analysis from Bamboo Activated carbon

Parameter	Content mg/kg
Pb^{2+}	22.10
Fe^{2+}	24.70
Ni^{2+}	11.40
Zn^{2+}	31.40
Cd^{2+}	8.90

Table 3: Structural properties of Bamboo Based Activated carbon

Parameter	Content mg/kg
Porosity	0.74
Pore volume	4726
Bulk density	0.4866
Tortuosity	1.35

Table 4: Effect of carbonization Temperature on some physical properties.

Properties	Carbonization Temperature (^{O}C)			
	300	400	500	600
Specific surface area(m^2/g)	234	337	364	310
Density (g/cm^3)	0.483	0.593	0.609	0.685
Yield (%)	32.67	30.67	26.37	25.02
Moisture content (%)	38.92	39.36	39.02	38.70
Porosity	0.74	0.82	0.79	0.65
Ash content (%)	2.92	3.45	3.51	3.73

+Yield rate means the percentage of final bamboo charcoal made from raw bamboo.

The effects of carbonized temperature on some physicochemical properties of bamboo based activated carbon are presented in table 4. The pH of the bamboo carbon is 6.64. Accordingly, for most application, carbon pH 6-8 is acceptable (Ahmendna et al, 2006).

Adsorbents can be characterized according to shape, size, porosity and surface area. In table 1, the specific surface areas of bamboo carbon are 234, 337, 364 and 310 m^2/g at 300, 400, 500 and 600 ^0C respectively. This is due to its micro porous pores. An increase in surface area increases or greatly enhances the adsorbents capacity and efficiency because it provides a large surface area thereby increasing the number of available active sites. Also, the larger the surface area, the higher the pore volume, porosity and this structural property lowers tortuocity of the adsorbent (table 3). This is in agreement with that reported in the literature (Wu and Tseng,2005). The use of KOH as an activating agent for bamboo derived activated carbon gives activating carbon with greater specific surface area and pore volume than the use of other activating agents such as $Zncl_2$ and H_3P0_4. (Mui et al, 2010). The bulk density of bamboo carbon was found to be 0.486g/l. Bulk density determines the amount of carbon that can be contained in a filler of a given solids capacity and the quality of the treated liquid that is retained by the filter cake (Hutchin,1988). The metal analysis presented in table 2 shows that metal ions are present in minute quantities.

The ash of bamboo carbon is its inorganic constituent, which is white or shallow red substance after bamboo carbon has burned completely at high temperature. The ash percentage in bamboo carbon increase from 2.92 to 3.73 % with the rising of carbonization temperature (Table 4). The ash elements in bamboo carbon are complex, the inorganic components in bamboo will remain in ash, among which Si, K, Mg, Na, Mn are negatively more. The relationship between specific surface area and carbonization temperature is show in figure 3.

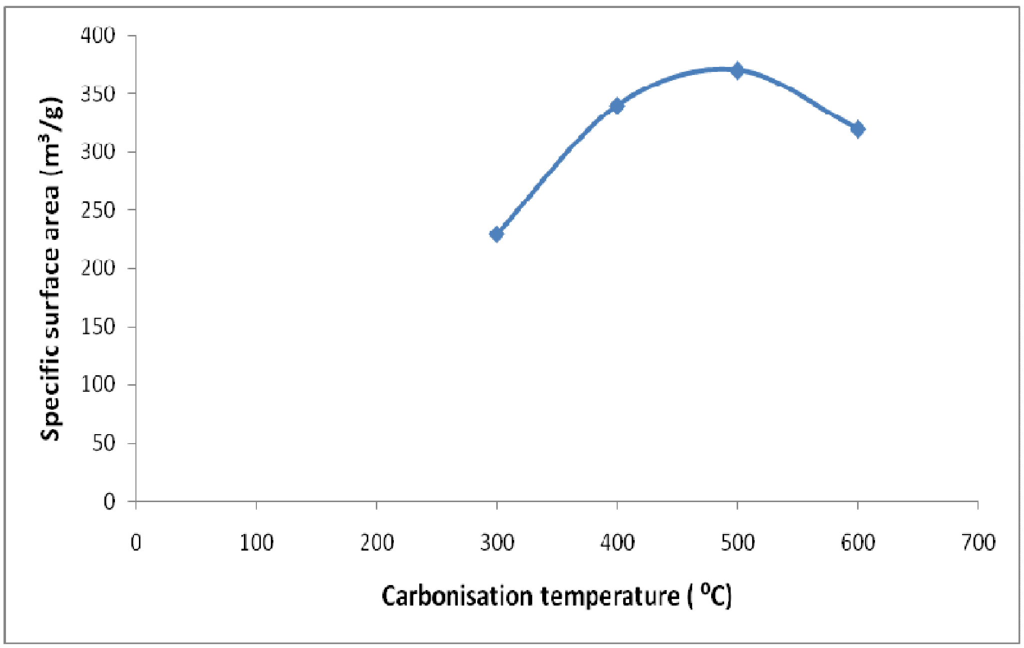

Figure3. The relationship between Specific Surface area of bamboo charcoal at carbonization temperature (^OC).

The maximum specific surface area (364 m^3/g) is formed when the carbonization temperature reaches 500°C; the specific surface area value is smaller when carbonizing under low temperature (table 4) due to the less porosity resulted from incomplete carbonization. Under high temperature, the porosity reduces too, the reason might be that some cavities have been burned and the surface area corresponding reduced. (Jiang Shenxue, 2004).

The moisture content of bamboo directly influences the carbonization time and the consumption of fuel. The drying period of bamboo carbonization will prolong if the moisture content is too high and as a result, the carbonization process will extend with more fuel consumption. The lower moisture content of bamboo speeds up the bamboo carbonization process. But the output of bamboo charcoal will be decreased and its mechanical strength reduced by the rigorous exothermic reaction if the moisture content of bamboo is too low.

CONCLUSION

The present study showed that bamboo activated carbon prepared by chemical activation with potassium hydroxide possesses sufficient meso and microporosity with varying molecular size. The yield rate is inverse to the temperature of carbonization, that is, the higher carbonization temperature, the lower yield rate.

Ash and density of bamboo carbon are positively correlated to the temperature of carbonization. The relationship between specific area and temperature is similar to quadratic equation ($-0.003x^2+3.787x-549.2$), R^2 =0.999. When the temperature goes up, the value of specific area increases, then gradually goes down.

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