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CHARACTERIZATION OF ACTIVATED CARBON DERIVED FROM MILLET CHAFF AND ITS COMPARISON WITH COMMERCIAL ACTIVATED CARBON

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Abstract

This work has examined the characteristics of activated carbon produced from millet chaff and a commercial activated carbon. The chaff is the waste generated from processing millet to produce pap (akamu) which is used as a weaning food in most families. Activated carbon was produced from millet chaff using chemical and physical methods. The chemical activation was done with 1M phosphoric acid and was carbonised in a furnace at 600°C for an hour. The formed activated carbon was removed, rinsed with 0.1MHCl, washed with distilled water and dried to obtain chemical activated carbon (ChAC). Direct heating of the chaff in the furnace at 400°C for 2 hours produced physical activated carbon (PAC). The produced activated carbons and a commercial activated carbon (CAC) were characterised for: pH, moisture content, ash content, pore volume, porosity and bulk density using standard methods. The results obtained for the characterization showed parameter value to be: pH (6.8, 7.3 & 7.1), moisture content (3, 5 & 3.5 %), ash content (8, 24 & 6.5 %), pore volume (0.5, 0.80 & 0.49 ml), porosity (0.05, 0.08 & 0.04) and bulk density (0.49, 0.72 & 0.39 g/cm^3) for ChAC, PAC and CAC respectively. The results therefore showed that

KEYWORDS: *millet chaff, activated carbon, characterization, parameters, analysis*

ChAC compared favourably with CAC except PAC which had poor qualities. The work has showed that value-added product can be created from millet chaff normally disposed as waste.

INTRODUCTION

Activated carbon is a black solid substance resembling granular or powdered charcoal. It is a processed carbon material with a highly developed porous structure and a large internal surface area (Helena *et al.,* 1991). Two general processes for the preparation of activated carbon are thermal or physical and chemical. In physical activation process, carbonization of the raw material is performed in an oxygen free environment at temperature above 500^{o}C while in chemical process; raw material is impregnated with an activating agent and heated in an inert atmosphere (Dileck & Oznuh, 2008). Activated carbon can be produced from most of the carbon containing organic materials but commercial process makes use of activated carbon precursors which are either degraded or coalified plant matter (e.g. peat, lignite and all ranks of coal). Activated carbon of botanical origin (e.g. plants, wood, nuts and chaff) has high carbon and is inexpensive. Materials from botanical origin or in other words lingo-cellulosic materials have low organic matter and relatively high volatile content. The first characteristic results in producing activated carbon with low ash and the second helps to control the production process (Hussein *et al*., 1996). In this research, a local agricultural waste which is millet chaff is used to produce activated carbon due to its higher availability. It is presently being generated in abundance and there is no immediate use for it. Its presence constitutes environmental problem. The common practice by people as a way of disposal is through burning and dumping in the environment. This practice is found to be inadequate and environmentally unfriendly, therefore converting it to activated carbon thereby adding value to it, is a good option. The activated carbon will have many applications such as water filtration, removal of colour in water sample and noise mask production, these are beneficial to man and environment.

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MATERIALS AND METHODS

Sample Collection and Preparation

Millet grain was bought from Keffi central market. The grain was properly washed using distilled water to remove dirt. The washed grain was soaked for a period of 8 hours. Thereafter, water was drained off. The soaked grain was ground into a paste using Kenwood BL440 500W blending engine and filtered. The residue (chaff) was dried using an oven at 110°C then stored in polyethylene bag. This was used for the activated carbon generation.

Preparation of Activated Carbon

Activated Carbon for this work was produced from the millet chaff using both chemical and physical processes.

Chemical Activation

Chemical process involves the use of 1M phosphoric acid (H_3PO_4) to activate the chaff followed by carbonisation. Approximately 100.0g of the millet chaff was mixed with 100 ml of 1M H_3PO_4. The sample mixture was kept for 24 hours after which it was put into a furnace at 600°C for 1 hour. The sample was then removed, cooled and allowed to stand at room temperature for about an hour to give activated carbon. The activated carbon produced was washed using 0.1M HCl to remove surface ash. This was followed with washing with distilled water then dried in an oven at 110°C for 2 hours. The dried activated carbon was kept in desiccator for further analysis (Al Qadah & Shawabkah, 2009).

Physical Activation

The physical activated carbon was produced by taking approximately 100.0g of the millet chaff into a furnace for 2 hours at 500°C. The activated carbon was removed from the furnace, cooled and washed properly with distilled water. It was then dried in an oven at 110°C for

2 hours (Al Qadah & Shawabkah, 2009). The formed activated carbon was stored in desiccator and kept for further analysis.

Characterisation of Activated Carbons

The activated carbons produced (physical and chemical) and commercial activated carbon (CAC) were characterised. Parameters investigated include: pH, moisture content, ash content, pore volume, porosity and bulk density.

pH

Approximately 2.0g of the chemical activated carbon (ChAC) sample was measured in 50 ml of deionised water. The mixture was heated and stirred adequately for 5 minutes to ensure proper dilution of the sample. The clear solution of the sample was filtered out and its pH was determined using H-4383A pH/mU Temp meter (Ademiluyi *et al*., 2008). The pH value reading was recorded. The same experimental procedure was repeated for the physical (PAC) and commercial activated carbons (CAC), respectively.

Moisture Content

Approximately 2.0g of the ChAC sample was weighed (W_1) and dried in an oven for 5 hours at temperature of 105°C. The dried sample was cooled, weighed and recorded (W_2). The drying and weighing was continued until the weight of the sample became constant (W_2) (Abdul Halim *et al.,* 2001). The same experimental procedure was repeated for PAC and CAC. The moisture content X_o for the samples was calculated using the relation:

$X_o = (W_1-W_2)/W_1 X100$

Where X_o=Moisture Content

W_1=Initial weight of sample

W_2=Final weight of the sample after drying

Ash Content

Approximately 2.0g of the ChAC sample (W_S) was placed in a pre-weighed porcelain crucible (W_e) and later heated in a muffle furnace. The inorganic matter was burnt off and the organic material remaining was cooled and weighed (W_c). The procedure was performed at 500°C (Yusufu *et al*, 2012). This same experimental procedure was repeated for PAC and CAC. The Ash Content of the samples was calculated using the relation:

$AC = (W_C - W_e)/W_S \times 100$

Pore Volume

Approximately 2.0g of the ChAC sample was weighed and transferred completely into a 10 ml measuring cylinder and its height in the cylinder was recorded. This was poured into a beaker containing 20 ml of deionised water and boiled for 5 minutes. The content in the beaker was filtered and measured. The pore volume of the sample was determined by dividing the increase in weight of the sample by the density of water (Aneke & Okafor, 2005). The same experimental procedure was repeated for both the PAC and CAC respectively.

Porosity

The porosity of the sample was calculated by dividing the pore volume of the sample by its total volume (Aneke & Okafor, 2005). For the physical and commercial activated carbons, the same experimental procedure was repeated respectively.

Bulk Density

Approximately 2.0g of the CHAC sample was measured and transferred completely into 50 ml of distilled water. The volume of water displaced was calculated by dividing the mass of the sample by the volume of the water (Aneke & Okafor, 2005). The same experimental procedure was repeated for PAC and CAC respectively

RESULTS AND DISCUSSION

Table 1: Characterisation of Chemical, Physical and Commercial Activated Carbons

Parameter	ChAC	PAC	CAC
pH	6.8	7.3	7.1
Moisture Content (%)	3	5	3.5
Ash Content (%)	8	24	6.5
Bulk Density(g/cm^3)	0.49	0.72	0.39
Pore Volume (ml)	0.5	0.80	0.49
Porosity	0.05	0.08	0.04

Discussions

Characterization of derived Activated Carbons (ChAC and PAC) and Commercial Activated Carbon (CAC).

The result of the characterization of the activated carbons derived from millet chaff (ChAC and PAC) and the commercial activated carbon (CAC) as presented in Table 1 showed that:

The result of the pH values for the three activated carbons investigated were 6.8, 7.3 and 7.1 for ChAC, PAC and CAC respectively. The pH values obtained in the work compared favourably with that of activated carbon prepared from Nigerian-based bamboo; 7.0 (Inyang *et al*., 2010). It was observed that ChAC had a low value of 6.8 compared with the other adsorbents; this low value by ChAC could be due to the fact that phosphoric acid was used for its preparation and the acid was not properly removed during the washing, PAC and CAC have pH values that are neutral. pH value determines whether the activated carbon is acidic or basic, The pH values of 6.5-7.5 is said to be ideal for activated carbon (Shanmugapriya *et al*., 2013). Too high pH value may indicate presence of contaminants while too low pH value may mean that the activated carbon is not properly washed (Shanmugapriya *et al*., 2013). From the result obtained, it can be said that the ChAC and CAC are good activated carbons materials.

Ash content is the inorganic (non-carbon) or mineral additive which is not chemically combined with the carbon surface. It consists of various mineral substances which became more concentrated during activation process and it primarily depends on the type of raw material used for the production of the activated carbon. The result for the ash content of all the three activated carbons investigated were 24%, 6.5% and 8% respectively. The result for ChAC and CAC values obtained compared reasonably with value (7.8%) obtained in a related work by Al-Qodah & Shawabkak (2009) produced from activated sludge. The Ash content shows the level of purity of carbon which is important in water filtration application; high ash content is undesirable for activated carbon since it reduces the mechanical strength of carbons and affects its (efficiency of reaction) adsorptive capacity. High ash content bring about cloudy water during use because phosphate ash could combine with metal ions to form mug or calcium precipitate. The lower the ash content, the better the quality of the activated carbon. The result obtained from this analysis showed that PAC had more inorganic matter than the other adsorbents, CAC and ChAC are good adsorbents as they have reasonable ash content.

Moisture content is the amount of water physically bound on the activated carbon under normal condition. The results for the moisture content for all the activated carbons investigated (ChAC, PAC and CAC) were 3%, 5% and 3.5% respectively. This result corresponds with the value obtained (3.6%) in the characterization of activated carbon from waste-Nigeian bamboo by some researchers (Ademiluyi *et al*., 2008). The permissible limit of moisture content is 3.0-6.0%. Low moisture content is desired for activated carbon because its presence increases the rate of adsorption of contaminants into the microspore of the activated carbon (Inyang *et al*., 2010). When the moisture content is high however, more contaminants will penetrate into the matrix of the adsorbent thus reducing the adsorbent working capacity. Low moisture content by ChAC and CAC suggests that they have limited amount of water physically bond to them, thus they are good activated carbons.

Pore volume is of importance in the facilitation of the adsorption process by providing sites and the appropriate channels to transport the adsorbate. The pore volumes obtained were 0.5ml, 0.8ml and 0.49ml for adsorbents ChAC, CAC and PAC respectively. Some researchers (Aneke & Okafor 2005) prepared activated carbon from coca-cola effluent and have reported the pore volume to be 0.45ml. This value compares adequately with the pore volume of ChAC and CAC obtained in this study. There was no much difference between the pore volume of ChAC and CAC showing that they are good activated carbons with highly developed porous structures as compared to PAC.

Porosity is the property used to determine the ultimate performance of the activated carbon, it shows the capacity of the activated carbon in terms of its efficiency. Porosity of all the activated carbons (ChAC, PAC and CAC) are 0.05, 0.83 and 0.04 respectively. Activated carbon used to determine pore volume by Aneke & Okafor (2005) gave porosity of 0.04.

Bulk Density did not affect the effectiveness of the activated carbon measured in adsorption per unit weight but will have an effect on adsorption per unit volume. Bulk density depends on the raw materials used and degree of activation. This property is required by Engineers to find out how many kilograms of activated carbon must be used to fill up a certain volume of tank or cartridge. The bulk density of the three activated carbons (ChAC, PAC and CAC) is

0.49g/cm^3,0.72g/cm^3 and 0.39g/cm^3 respectively. Bulk density of 0.386g/cm^3 was obtained from activated carbon prepared from phosphoric acid modified rice husk by Dada *et al*., (2012). From the results obtained, it can be concluded that ChAC and CAC have close bulk densities.

CONCLUSION

This study showed that good activated carbon can be produced from millet chaff an agricultural waste. It has good physiochemical properties that are comparable with commercial activated carbon. From the properties of the produced activated carbon such as ash content, moisture content, pH, bulk density, pore volume and porosity, it can be concluded that the chemically

formed activated carbon is better than the physical type and it compares favourably with the commercial activated carbon.

RECOMMENDATION

The authors wish to recommend that further analysis should be carried out on the produced activated carbon to evaluate its internal features using Scanning Electron Machine (SEM).

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