Effect of varying concentrations on the yield of activated carbon produced from African star apple

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Abstract. Activated carbon has been developed using different techniques and activating agents. The activation of carbon is done using different chemical, physical, and bio activating agents. This activating agent gives various outcomes of the activated carbon depending on the structure of the cursor used. The increase in population has also brought about a significant increase in waste generated. In this work, we were able to produce activated carbon from African star apple seed using the seed, husk, and shell. This work was carried out using a furnace at 500 C. The carbon produced was then activated using different concentrations of Phosphoric acid (H3PO4), which are 0.2M, 0.4 M, 0.6 M, 0.8 M and 1.0 M. Whole seed which was impregnated with 0.2 M gave the highest yield of 87.192%. The amount of activating agent used did not determine the yield.

1. Introduction

According to World bank, the world population is increasing daily, so also do we have the waste on the increase [1]. These wastes are generated from households, industries, religious centers, etc. Some agricultural waste can be converted into activated carbon in order to purify other waste for usage, especially waste water from different sectors of industries and households [2]. Water pollution is one of the key problems confronted internationally due to the unsystematic discharge of domestic and urban polluted waters, agricultural wastes and industrial wastes into water bodies. Food industries produce a lot of waste water and if not well treated and disposed can pollute the environment (Mohamed 2016). It was also stated that the quick industrialization rate has caused discharge of wastes encumbered with pollutants into our water bodies which has affected humans, marine life and the environs at large [4]. This pollution can also be related to the cost incurred in treating the waste water. Producing activated carbon from other waste can be a source of reduction in cost if the field is high. In this present day several activated carbon has been produced from different materials like rice husk, Moringa seed husks, palm shells, coconut Shells etc. [2] The manufacture of activated carbon by means of agricultural waste is more cost-effective likened to commercially activated carbon [3].

Activated carbon (AC) was defined as a form of carbon that was primed to make it astonishingly porous to achieve a widespread surface area available for adsorption responses [6]. It was also defined it as a non-graphitizable carbon, denoting that it cannot be converted into graphite just by extraordinary heat treatment [7]. Arvanitoyannis has made it known that the surface region of Activated carbon can be
larger than 1000 m$^2$/g [8]. This implies that it is possible for 5 g of activated carbon to have a surface area which is larger than that of a football field. The process of preparing activated carbon are carbonization of raw materials and carbon activation [9]. Carbonization is done when the raw material is decomposed thermally which removes non-carbon species. This helps to create fundamental pore structure which are small in size. Activating the carbon helps to increase the pores largely. Activation can be done chemically or physically. Chemical activation is done using activating chemical agents like Sulphuric acids, Phosphoric acids, Zinc Chloride, Nitric acids, Sodium Chloride, etc. [10]. Bio-activators can also be used to manufacture bio centered activated carbon particularly in the medical field, food and pharmaceuticals industry [11]. Yield of activated carbon will be very important to the economic value.

Table 1 below shows the yield from different activate carbon which were activated using Phosphoric acid.

| Raw Material                  | Molarity of Phosphoric acid (M) | % yield | Source |
|-------------------------------|---------------------------------|---------|--------|
| 1 Pineapple peel              | 1.5                             | 58.15   | [12]   |
| 2 Pineapple crown             | 1.5                             | 15.24   | [12]   |
| 3 African Star Apple seed husk| 0.008                           | 55.3    | [2]    |
| 4 African Star Apple oil seed | 0.008                           | 54.3    | [2]    |
| 5 African Star Apple whole seed | 0.008                        | 41.6    | [2]    |
| 6 Coconut shell               |                                 | 77.74   | [13]   |
| 7 Orange peel                 |                                 | 72.9    | [13]   |
| 8 Banana peel                 |                                 | 60.8    | [13]   |

The study of Ref [4] was done using a single molarity. In this work further steps have been carried out to vary the concentration of phosphoric acid in activating the carbon. The carbon was activated using various concentrations of phosphoric acid.

2. Materials and methods

The ripe African Star Apple fruit was gotten from Tejuosho Market, Yaba, Lagos Nigeria and Industrial Waste Water from Honeywell Industries, Nigeria. De-ionized water available in the laboratory Covenant University and Phosphoric acid (J.T.Baker Deventer- Holland). Digital Weighing Balance (OHAUS Scout pro 2000g); Mechanical Stirrer (JENWAY 1000 Hot Plate & Stirrer ST15 OSA, UK); SVAC2 Compact Vacuum Drying oven, 1.7 Cubic Foot, 240°C, Model SVAC2; Model F6018, Thermo Scientific Thermolyne A1 Premium Muffle Furnace - 208V; Mercury-in-glass Thermometer (GH Zeal LTD, 76mm 0-360°C); Conical Flask (250 ml); Measuring Cylinder, Beaker (500 mL); Plastic containers for samples; Mortar pestle; Spatula and Stopwatch.

2.1 Removal and drying of seed husks:

The seed kernels of the African star apple were physically torn apart from fleshy fruit, retrieved and washed to remove grease and debris and then dried for 3 days in the sunlight after which it was dehydrated in an oven at temp 105 °C for 3 hours to ensure all effective removal of all water residue in the seeds. The dried precursor was separated into 3 samples (seed, husk and shell) and were ground using mortar and pestle and then the ground kernels were ground further to make particle size of -6 to +40 mesh.
2.2 Preparation of Activated Carbon:

Precisely measured samples of African Star Apple seeds (husk, whole seed and shell) that was dried, were carbonized in crucibles at 500°C in furnace. The charcoal produce obtained was milled and sieved to 2mm size. Five solutions of known concentrations; 0.2 M, 0.4 M, 0.6 M, 0.8 M, and 1 M of the Phosphoric acid (H₃PO₄) were made. Three separate 10 g servings of the African Star apple samples were stirred and left to be soaked distinctly in 100 mL of 0.2 M, 0.4 M, 0.6 M, 0.8 M and 1 M H₃PO₄ respectively for 24 hours. The samples were the labelled ABD1, ABD2, ABD3, and ABD to ABD15 respectively before being heated in the oven at a temperature of 105°C for 2 hours. The activated carbon was then cooled to 27 °C and washed with warm distilled water until it reached a pH of 7 to remove any undiluted residue of phosphoric acid after which the precursor was dried in an oven at a temperature of 105 °C for 1 hour. Finally, the dried precursor was milled and sieved to get the molecule size of 125-150μm. All proximate analysis was done on the activated carbon. It was kept in plastic containers for further use and the results were tabulated. Table 2 shows the activated carbon sample at different concentrations.

| Sample Name | Precursor | H₃PO₄ Concentration(M) |
|-------------|-----------|-----------------------|
| ABD1        | Seed husks| 0.2                   |
| ABD2        | Seed husks| 0.4                   |
| ABD3        | Seed husks| 0.6                   |
| ABD4        | Seed husks| 0.8                   |
| ABD5        |            | 1                     |
| ABD6        |            | 0.2                   |
| ABD7        |            | 0.4                   |
| ABD8        | Oil seed  | 0.6                   |
| ABD9        | Oil seed  | 0.8                   |
| ABD10       |            | 1                     |
| ABD11       |            | 0.2                   |
| ABD12       |            | 0.4                   |
| ABD13       | Whole Seed| 0.6                   |
| ABD14       |            | 0.8                   |
| ABD15       |            | 1                     |

3. Result and discussion

The yield of each activated carbon sample produced by chemical activation with phosphoric acid was obtained from calculations and is being summarized in Figure 1 It is calculated as a function of the ratio of the Mass of carbonized sample to Mass of activated sample after washing and drying.

\[ \text{Yield (\%)} = \frac{W_o}{W_c} \times 100 \]

Wo = Mass of carbonized sample
Wc = Mass of activated sample after washing and drying
From the results, it is clearly shown that as the concentrations of each precursor increases, the resulting yield exhibits a form of decreasing trend. Concentration levels of 0.2N for seed husks, seed shells and whole seeds (ABD1-72.56%, ABD6- 76.471% and ABD11- 87.192%) respectively being the smallest concentration levels displayed the highest amount of yields. In particular, that of whole seed at 0.2 M gave the highest yield. The yield for seed husk (ABD1, ABD2, ABD3, ABD4, and ABD5) decreased as the concentration increased. The same trend was seen in the yield for the oil seed (ABD6, ABD7, ABD8, ABD9, and ABD10). The trend for the whole seed (ABD11, ABD12, ABD13, ABD14, and ABD15) was similar, although the yield at 0.8 M was slightly above that of 0.6 M. The combination of the seed husk and the oil seed could be the reason while it had the highest yield suspecting that the structure will definitely be different from when it was treated separately and also because of its non-volatile structure, the chemical transformations which include degradation and dehydration of molecules achieved mainly by impregnation with the phosphoric acid did not seem to evolve gaseous products from its well-developed char structure which could lead to decreasing yield of activated carbon [14].

It also stated that the yield of the raw materials could be dependent on its original structure before activating it [3]. The bulk mass of the whole seed gives it a more weight retentive ability and the less concentration levels of the activating agent favours its yield as well because of less gasification of char and reduced loss in weight of carbon. Higher concentrations of acid in turn leads to a greater gasification level of char achieved resulting in a decreased final mass and yield of activated carbon.

4. Conclusion
The concentration of activating agent used can also be a major determining factor to the yield of activated carbon produced from waste generated in the agricultural sector. Phosphoric acid is a good activating agent but it best of it is gotten when the right concentration is used. The yield as relating to the concentration does not depend on the amount used but more on the type of carbon been activated.

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