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Production, Chemical Activation and Absorption Potential of Corn cobs Biomass Carbon

Olabimtan Olabode.H[1*], Mohammed Rihanat.O[2], Aronimo Samuel.B[3], Yahaya Yakubu[4], Abdulsalam ismaeel[5]

[1]Department of Industrial and Environmental Pollution,
National Research Institute for Chemical Technology, Zaria Kaduna State, Nigeria.
[2]Department of Integrated Science,
Kogi State College of Education (Technical), Kabba, Kogi State, Nigeria.
[3]Department of Chemistry,
Kogi State College of Education (Technical), Kabba, Kogi State, Nigeria.
[4]Department of Applied Chemistry,
Kaduna Polytechnic, Kaduna State, Nigeria.
[5]Department of Phytopathology,
Seed Science and Technology, University of Life Sciences, Graduate School, Poznan, Poland

Corresponding author email: Olabode4angel@gmail.com

Abstract: *Activated carbon has a wide range of industrial and environmental applications due to its high surface area and ability to adsorb various contaminants. In this study, chemically synthesized activated carbon was produced from corn cob biomass using ammonium sulphate ($(NH_4)_2SO_4$ as an activator at certain technical conditions. The proximate analysis of the product revealed 10.65± 0.0707 % moisture content, 29.05± 0.005 % volatile matter, 29.7 ± 0.1414% ash content and 69.4% fixed carbon. The adsorption capacities of with the three dosages (1, 2 & 3g) across the range of 5, 10,15,20,25 & 30 minutes with the solution of anhydrous potassium phosphate were justified with the models; $y = -0.0116x^2 + 1.773x + 57.536$ at $R^2 = 0.9551$, $y = -0.0471x^2 + 2.1177x + 77.769$ at $R^2 = 0.9373$ and $y = -0.0161x^2 + 0.742x + 91.924$ at $R^2 = 0.9632$ respectively. These findings suggest that chemically synthesized activated carbon from corn cob using ammonium phosphate as an activating agent is a potential adsorbent for the elimination of contaminants from water.*

Keywords: Activated carbon, corn cob, ammonium sulphate, potassium phosphate and proximate analysis.

1.0 INTRODUCTION

Purifying waste water before releasing it into natural waters has become more and more important in recent years due to growing environmental awareness of the effects of organic and inorganic substances. A number of conventional treatment systems have been considered for treatment of waste water polluted with organic material. Activated carbon is thought to be the most effective substance for regulating this organic load among them, and the adsorption process has been determined to be the most effective way [1].That Common active carbons available are usually developed by thermochemical means using activating agents and heating ovens, thus producing activated carbons that take a longer time with limited pore structures but are better and more efficient activated carbons that can be produced rapidly at a cheaper rate [2]. The term “adsorption” is the accumulation of a substance at the interface between two phases, such as solid and liquid or solid and gas. The accumulating components at the interface is called 'adsorbate' and the solid on which adsorption occurs is 'adsorbent'. The first quantitative investigations on adsorption were reported on the uptake of gases by charcoal and clays, despite the fact that some adsorption-related phenomena were known in antiquity [3]. The observations of Lowitz, who used charcoal to decolorize tartaric acid solutions, came next [4]. Similar phenomena were noted by Larvitz in 1792 and Kehl in 1793 using vegetable and animal charcoals, respectively [5]. However, Bois-Reymond was the one who came up with the word "adsorption," which Kayser (Abrowski, 2001) [6] later added to the literature. Since then, separation of solutes, their solutions, and gases from the atmosphere has been largely accomplished by the adsorption process. At the solid's surface, there are unbalanced forces of attraction that are responsible for adsorption. In cases where the adsorption is due to van der Waals forces, it is adsorption by physical means [7]. Conversely, there may be a chemical bonding between the adsorbent and the adsorbate molecule, and such a type of adsorption is referred to as chemisorption [7]. Activated carbon is nothing but a carbon framework that is formed from carbonaceous materials like corn cobs, nutshells, wood, peat, coir, coal, lignite, and petroleum pitch. In this process, precursors are converted into activated carbons using gases. This is largely achieved with carbonization, which is the process where material having an appreciable percentage of carbon is pyrolyzed between 600-900 °C, without oxygen within an inert system or atmosphere using a furnace, and activation/oxidation process where the carbonized feed stock is exposed to oxidizing atmospheres such as carbon monoxide, oxygen, or steam at temperatures above 250 °C, usually within 600 and 1200 °C [8]. Prior to the process of carbonization, the raw feedstock is infused with certain active chemicals that can typically be an acid, a salt, or a strong base [9]. The role of activator is to open the pore size across the

carbon so as to increase its adsorption capacity. After impregnation, the raw material needs to be charred at controlled temperatures of 450 to 900 °C [9]. It is assumed that the activation or carbonization step proceeds concurrently with the chemical activation. The chemical process of activation is recommended over most methods because of its short activation time and lower temperature requirements [9]. However, activated carbons are microporous inert carbon with a large internal surface, and on this surface, organic molecules from liquids or gases can adsorb. Adsorption is the natural phenomenon in which molecules from the gaseous or liquid phase are adhere to the surface to the solid. Carbon materials are activated by a sequence of procedures that include dehydration, conversion of organic material to single elemental carbon, eliminating the non-carbon portion (carbonization), burning off tars, and enlarging pores (activation) [10].

The fundamental unit of activated carbon is closely approximated by the structure of pure graphite. The graphite crystal is composed of layers of fused hexagons held together by weak Van der Waals forces. Activated charcoal, or carbon, is a disorganized form of graphite by nature of its amorphosity, impurities, and preparation system. The structure that develops is a function of carbonization and activation temperature. The micropores are developed primarily during carbon activation and result in the large surface area for adsorption to occur [11]. This research focuses on the preparation and specific evaluation of corn cob chemically activated carbon.

2.0 MATERIAL AND METHODS

Poly-ester bag, distilled water, drying oven , mechanical shaker, electronic weighing balance ,muffle furnace ,beaker , mechanical mixer ,ammonium sulphate ,measuring cylinder ,filter paper ,test tube**,** colorimeter, vanadomolybdophosphoric acid and potassium phosphate.

2.1 Corn cobs pretreatment

Corn cobs were picked from a locally within Zaria, Kaduna state, Nigeria, with hand glove in a polyester bag. They were first washed with water to remove dirt. They were then sun-dried for a few hours, after which they were dehydrated in an oven at a temperature of 105 °C overnight to ensure that there was no after-water residue in the precursor. The precursor was grounded to a uniform particle size.

2.2 Chemical activation

100 g of the precursor was carbonized at 700^0C for 2h in a stainless steel vertical tubular reactor placed in a muffle furnace. The char produced was then added to an aqueous ammonium sulphate which was produced by adding 50g of ammonium sulphate to 300ml of distilled water. The mixture was mixed in a mechanical mixer for 1 hrs to ensure the mixture was properly mixed. After that, the mixture was dehydrated in an oven at105^0C for 2hrs. To eliminate undiluted ammonium sulphate residue, the activated product was rinsed with hot distilled water and then cooled in a desiccator. The precursor was then oven dried for one hour at 105^0C. Finally, while being stored in plastic containers for later usage, the dry carbon precursor was crushed and sieved to obtain a consistent particle size [12].

2.3 Proximate analysis of activated carbon

The distribution of products produced when carbonaceous sample is baked under specific conditions can be easily determined using the proximate analysis of a substance. According to ASTM D 121, the percentage by mass of the moisture content, volatile matter content, ash content, and fixed carbon content of activated carbon were calculated [13].

2.3.1 Moisture Content

A given amount of the sample of activated carbon was heated in a furnace at a temperature of 1050C for an hour. The moisture content is determined by the weight change to the initial weight change represented as a percentage [14]. It is given by

$$\frac{W_L}{W_O} \times 100$$

Where W_L = Weight loss (Original weight – final weight)
W_O = Original weight

2.3.2 Volatile matter content

A given amount of the sample of moisture-free activated carbon was heated in a furnace at a temperature of 600^0C for 10 mins in the absence of air. The volatile matter content is determined by the weight change relative to the starting weight, represented as a percentage [15]. It is given by

$$\frac{W_L}{W_O} \times 100$$

Where W_L = Weight loss (Original weight – final weight)
W_O = Original weight

2.3.3 Ash Content

A given amount of the sample of moisture-free activated carbon was heated in a furnace at a temperature of 600^0C for 30 mins in the absence of air. The ratio of change in weight expressed in percentage gives the ash content [15]. It is given by

$$\frac{W_F}{W_O} \times 100$$

Where W_F = Final weight
W_O = Original weight

2.3.4 Fixed Carbon Content

This is the residue left after the moisture, volatile and ash is given up. It is deduced by subtracting from 100, the percentage of moisture, ash content and volatile matter [16].

The fixed carbon content (FC) is given as

FC = 100 – (%moisture + %volatile matter + %ash)

2.4 Adsorption capacity of the developed activated carbon

This was done to test the activated carbon's ability to absorb substances when the adsorbent dose and time were altered. Standard phosphate solutions were made by combining 1g of anhydrous potassium phosphate with distilled water [17]. The standard phosphate solutions totaling 600 ml were divided among three beakers (200 ml each). Each beaker additionally received one drop of vanadomolybdophosphoric acid indicator, which was added and swirled magnetically at a slow pace [18]. The chemically activated carbons were then added in doses of 1, 2, and 3 g to each beaker. A 5 ml amount was filtered and collected into a test tube at intervals of 5, 10, 15, 20, 25 and 30 minutes. The initial and residual phosphate concentrations were determined by the vanadomolybdophosphoric-acid colorimetric method [19].

3.0 RESULT AND DISCUSSION

Two process variables were tracked while corn cobs were converted into activated carbon. The first is the proximate examination of the activated carbon and the second is figuring out how much adsorbate it can adsorb. Table1, 2, 3 and Figure 2 illustrate the proximate evaluations while Figure 2, present the absorption profile with respect to various dosage of the activated carbons.

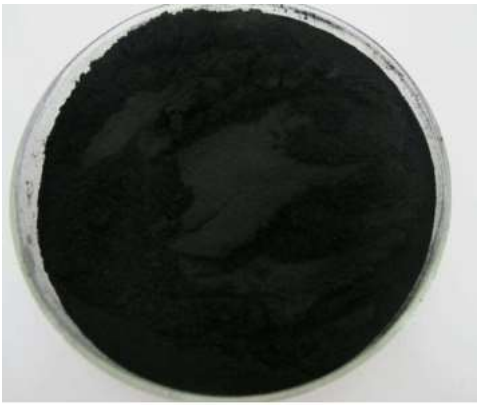

Figure1. Chemically activated corn cob carbon

The result of the proximate analysis of the chemically synthesized activated carbon is shown in table 1, 2, 3 and Figure 2.

Table 1. Moisture content determination of the chemically activated corn cob carbon

	1st Run	2nd Run	3rd Run
Original weight of activated carbon (Wo) (g)	10	10	10
Final weight of activated carbon (Wf) (g)	8.95	8.93	8.94
% Moisture	10.5	10.7	10.6
Average % moisture	10.65 ± 0.0707		

The moisture level of activated carbon is important because it can affect the performance of the carbon in various applications. Consequently, if the percentage moisture is too high, the activated carbon may not be able to adsorb contaminants from water or air effectively, resulting in reduced performance. Similarly, the moisture content can affect the stability and handling of the activated carbon through clumpness that can make it difficult to use in certain applications [20]. The knowledge of level of moisture in activated carbon is very important for quality control purposes as activated carbon manufacturers and users need to ascertain this parameter is within the acceptable limits for optimal performance.

Table 2. Volatile matter of the chemically activated corn cob carbon

	1st Run	2nd Run	3rd Run
Original weight of activated carbon (Wo) (g)	10	10	10
Final weight of activated carbon (Wf) (g)	7.08	7.1	7.09
% Moisture	29.2	29	29.1
Average % moisture	29.05 ± 0.005		

Volatile matter is an essential analytical test for many types of materials, including activated carbon. It is defined as the portion of a material that is lost when the material is heated to a specific temperature under specified conditions. In the case

of activated carbon, it can provide important information about the purity and quality of the carbon. A higher volatile matter content may indicate the presence of impurities or other contaminants in the carbon, which can affect its performance in various applications. In addition to providing information about the purity and quality of activated carbon. It can also be adopted to determine the suitability of the carbon for certain applications.

For example, activated carbon with a low volatile matter content may be more suitable for applications where it needs to withstand high temperatures, such as in gas purification or metal extraction processes [21].

Table 3. Ash content of the chemically activated corn cob carbon

	1st Run	2nd Run	3rd Run
Original weight of activated carbon (Wo)(g)	10	10	10
Final weight of activated carbon (Wf) (g)	2.03	2.02	2.04
% Moisture	29.7	29.8	29.6
Average % moisture	29.7 ± 0.1414		

Ash content of the chemically activated carbon is an important parameter that provides information about the purity and quality of the carbon. It illustrates the volume of inorganic material retained after carbonization at a specific temperature. A high ash content in activated carbon may indicate the presence of impurities or other contaminants, which can affect the performance of the carbon in various applications. A high ash content may reduce the surface area of the carbon, which is an important factor in its ability to adsorb contaminants. In addition to generating facts about the purity and quality of activated carbon, the ash content also declares the suitability of the carbon for certain applications. Activated carbon with a low ash content may be more suitable for applications where the presence of inorganic material could cause problems, such as in the purification of drinking water [22].

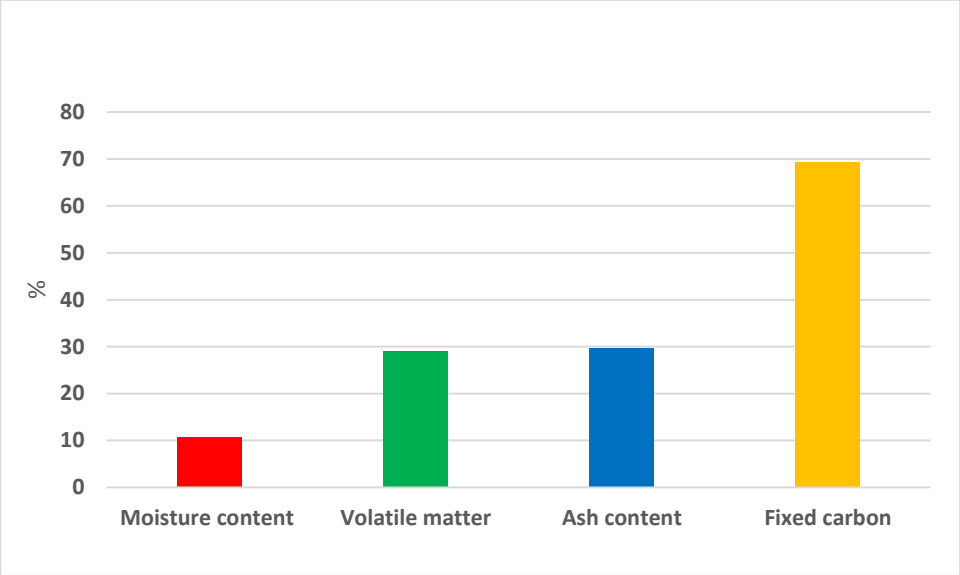

Figure 2. The selected proximate analysis of chemically activated corn cob carbon

The result for the determination of the adsorption capacity for chemically activated carbon where the percentage variation of the potassium phosphate removed in a given period of time is shown below.

Table 4. Adsorption capacity of the chemically activated corn cob carbon

Time (min.)	Phosphate adsorbed (%)		
	1g chemically activated carbon	2g chemically activated carbon	3g chemically activated carbon
5	66.00	85.98	94.98
10	75.94	95.94	97.97
15	76.97	99.98	99.92
20	92.09	99.98	99.95
25	93.98	99.997	99.997
30	99.98	99.999	100.00
Model	$y = -0.0116x^2 + 1.773x + 57.536$ $R^2 = 0.9551$	$y = -0.0471x^2 + 2.1177x + 77.769$ $R^2 = 0.9373$	$y = -0.0161x^2 + 0.742x + 91.924$ $R^2 = 0.9632$

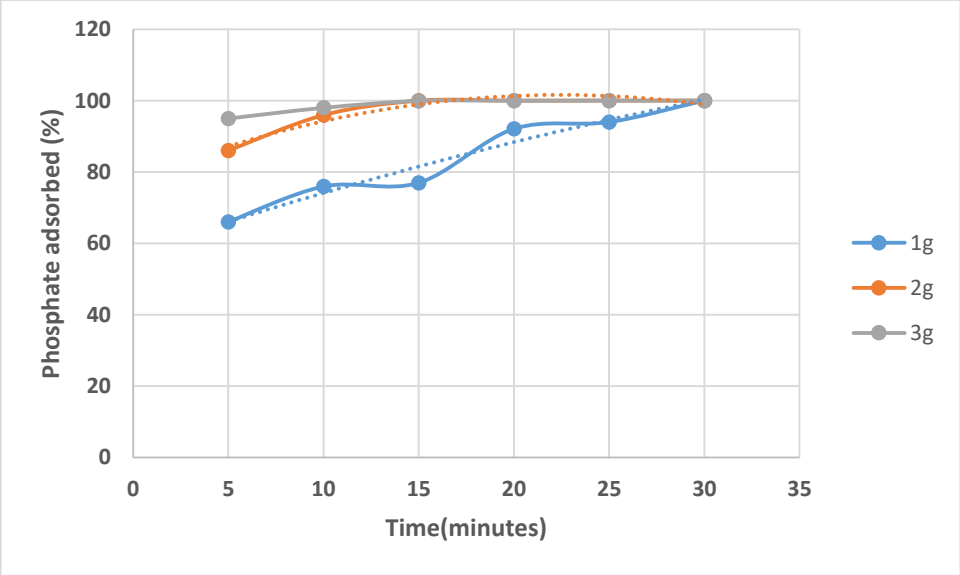

Figure 3.The plot of adsorbate against time

From the result of the study, it was perceived that the rate of phosphate removal varies with the various adsorbent doses of 1g, 2g & 3g. The adsorption potential of the chemically activated carbon increases as the time increases, therefore increase in time increases the adsorption rate. Finally the natures of the plots are indicative of the nature of formation of the layers on the adsorbent surface. The time variation curves for phosphate removal were smooth and continuous, indicating the formation of monolayer coverage on the exterior portion of the adsorbent [23]. This is an important parameter that determines its effectiveness in various applications as the concentration of a specific adsorbate that the activated carbon can trap per unit mass of the carbon the determination allows manufacturers and users to evaluate the performance of this product in different applications. For instance, if the adsorption rate of the carbon is high, it may be more effective at removing contaminants from water or air, leading to better performance in those applications. In addition, the adsorption capacity can also be used to compare the performance of different types of activated carbon,

allowing manufacturers and users to choose the most appropriate type of carbon for a specific application.

Meanwhile, The mathematical model $y = -0.0116x^2 + 1.773x + 57.536$ generated with the 1g dosage is a quadratic equation in which y is the dependent variable and x is the independent variable. The constants -0.0116, 1.773, and 57.536 are the coefficients of the x^2, x, and the constant term, respectively. The value of R^2 (0.9551), which is the coefficient of determination, indicates the strength of the relationship with the dependent and independent variables.

Also the model $y = -0.0471x^2 + 2.1177x + 77.769$ with 2g dosage is still a quadratic equation in which y is the dependent variable and x is the independent variable. The constants -0.0471, 2.1177, and 77.769 are the coefficients of the x^2, x, and the constant term, respectively. The value of R^2 (0.9373) indicates the strength of the relationship with the dependent and independent variables. And the final dosage of 3g with the model $y = -0.0161x^2 + 0.742x + 91.924$ is as well a quadratic equation in which y is the dependent variable and x is the independent variable. The constants -0.0161, 0.742, and 91.924 are the coefficients of the x^2, x, and the constant term, respectively. The value of R^2 (0.9632), also indicates the strength of the relationship between the dependent and independent variables. To interpret these models, the value of y which is the amount of adsorbate adsorbed for a given value of x which is the time used in minutes to be directly interpreted.

4.0 CONCLUSION

The method of activation can affect the activity of activated carbon produced as the resulting activated carbon retains a significant surface area and greater porosity, making it more effective adsorbent. Also, several advantages to using activated carbon made from waste biomass, such as corn cob, as opposed to using activated carbon made from other sources clearly include the fact that waste biomass is a readily available and a renewable resource, so using it to make activated carbon is a sustainable option.

The manufacturing of activated carbon from waste biomass is often less energy-intensive than from other sources, such as coal or wood. Activated carbon made from waste biomass typically has a higher surface area and greater porosity than from other sources, making it more effective at adsorbing various substances. Using waste biomass to make activated carbon can help to reduce waste and prevent pollution, as it provides a way to repurpose materials that would otherwise be discarded. Activated carbon made from waste biomass can be a cost-effective alternative to other types of activated carbon. Specifically, chemical activation of biomass for activated carbon has been reported to have several advantages over other methods of producing activated carbon. Some of these advantages include production of activated carbon with a higher surface area and greater porosity than other methods, making it more effective at adsorbing various substances. More precise control over the surface area and porosity of the resulting activated carbon, allowing for the preparation with specific characteristics to suit a particular application.

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