RESEARCH ARTICLE

Preparation of activated carbon from pyrolytic conversion of musa paradisiaca

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ABSTRACT

Activated carbon is a porous carbonaceous material with high adsorption capacity that can be used as adsorbent material for purification of liquids and gases. In this research work, Pyrolytic conversion of plantain stems into activated carbon was carried out. The study was aim at comparing two chemical activating agents to determine the most suitable one for the preparation of activated carbon from plantain stems. The activating agents used were H_2SO_4 and HNO_3. Waste plantain stems were carbonized at 500–750°C and activated at 600°C to produce activated carbon. The effect of various activating agents on percentage yield, ash content (AC), percentage burn-off, bulk density, surface area determination, moisture content determination, fixed carbon, methylene blue number, loss on ignition, pore volume, and iodine number was characterized. From the results, it was observed that H_2SO_4 at activation temperature of 600°C gave the highest value of bulk density with increasing impregnation ratios of 0.05, 0.1, 0.2, 0.3, 0.4, and 0.5, with the value ranging from 0.2223 to 0.2561 g/cm³ followed by HNO_3 ranging from 0.2225 to 0.2359 g/cm³. The values of percentage yield show that H_2SO_4 activation was observed to have 77% as the overall best higher than HNO_3 with 76% which shows that the activation temperature at 600°C does not favor the impregnation ratio of HNO_3 but rather favors H_2SO_4, and with HNO_3 low percentage yield resulted in high percentage burn-off at 33–29%. It was observed that the AC of each of the impregnation ratios of different activating agents was high because it ranged from 33.6% to 39.4%. Similarly, the iodine number obtained showed that iodine adsorption of activated carbon prepared with H_2SO_4 with activation temperature at 600°C is the best because the micropores content on the surface of activated carbon was the highest at the impregnated ratio of 1337.1–1269.1 g/kg while that of HNO_3 had the lowest value though chemical activation values were better than thermal valves which shows that H_2SO_4 as activating agent was found to be the best for the preparation of activated carbon from plantain stems.

Key words: Activated carbon, agricultural waste, *Musa paradisiaca*, pyrolysis, thermochemical decomposition

INTRODUCTION

Pyrolytic resulting from pyrolysis is thermochemical decomposition of organic material at elevated temperature in the absence of oxygen or any halogen. It involves the simultaneous change of chemical composition and physical phase and is irreversible.

The word is coined from the Greek derived elements pyro "fire" and lysis "separating." Pyrolysis is a type of thermolysis and is most commonly observed in organic materials exposed to high temperature. It is one of the processes involved in charring wood, starting at 200–300°C [390–570°F]. It also occurs in fires where solid fuels are burning or when vegetation comes into contact with lava in volcanic eruptions. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content char,

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extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization. The process is used heavily in the chemical industry, for example, to produce charcoal, activated carbon, methanol, and other chemicals from wood, to convert ethylene dichloride into vinyl chloride, to produce coke from coal, to convert biomass into syngas and bio char, to turn waste plastics back into usable oil, or waste into safely disposable substances, and for transforming medium-weight hydrocarbons from oil into lighter ones like gasoline. These specialized uses of pyrolysis may be called various names, such as dry distillation, destructive distillation, or cracking. Pyrolysis is also use in the creation of nanoparticles, zirconia, and oxides utilizing an ultrasonic nozzle in process called ultrasonic spray pyrolysis. Pyrolysis also play important role in several cooking procedures, such as baking, frying, grilling, and caramelizing. It is a tool of chemical analysis, for example, in mass spectrometry and in carbon-14 dating, indeed, many important chemical substances, such as phosphorus and sulfuric acid, were first obtained by this process. Pyrolysis has been assumed to take place during catagenesis, the conversion of buried organic matter to fossil fuels. It is also the basis of photography in their embalming process, the ancient Egyptians used a mixture of substances, which the obtain from the pyrolysis of wood.

Plantain (*Musa × paradisiaca*) was originated in south east Asian in 500 B.C. mostly in Malaysia, plantain can be considered as the variety of banana which is generally not eaten raw due to is non-sweet flavor, plantain belong to the family of (*Musaceae*). There are many ways to utilize the plantain, from fruits till its wastes. The fruit can be cooked, or processed becoming candy or liquor. The rotten fruit can be processed to feed poultry, pigs, and other animals. The leaves can be used in wrapping food. The plantain stems contain fiber, plantain as of 2004 was grown in a total of 52 countries which were said to be world's producer of plantain, producing a total of 33 million metric tons. Despite the down trend of plantain production in Nigeria between 1990 and 2004, it was still ranked fifth in the world with eight African countries name among the top ten plantain producers in the world. Plantain is grown in at least 107 countries with world's production of over 76 million metric tons with a downward trend in terms of plantain yields per hectare in Nigeria. Currently Nigeria ranks sixth and is the world's largest producer in West Africa with and annual production of about 2.4 million metric tons mostly obtained from the southern states. Despite its prominence, Nigeria does not feature among plantain exporting nation; it produces more for local consumption than export.

The production of activated carbon from plantain stem has potential economic and environmental impacts; first, it converts unwanted low value agricultural waste to high value adsorbents; and second, activated carbons are increasingly used in water to remove organic chemicals and economic concern. Finally, it will reduce the important of activated carbon wherefore increasing our economic base as a country.

Activated carbon is an amorphous form of carbon in which the high degree density has been developed during manufacturing or treating. This high degree of porosity and associated large surface area make it and excellent adsorbent for a wide variety of heavy metals in both liquid and gaseous phases (Olatunji *et al.*, 2017). The use of carbon dates back to ancient Egypt (1500BC) where it was employed for medicinal purpose. Later in ancient Greece, wood chars were used to treat host of alignments (Yehaskel, 1978). In 18th century, and application was found for the removal of foul odors from gangrene (Al-Omair and El-Sharkawy, 2001). Subsequently, the application of charcoal was used mainly as decolorizing agents for sugar (Sun and Xu 1997). A wide variety of agricultural by-products and agricultural waste comprising mostly cellulose matrix were tried by different workers for the removal of heavy metals from their aqueous solution. This include pine bark (Al-Asheh *et al.*, 2000), saw dust (Argun *et al.*, 2007), cotton (Ozsoy and Kumbur, 2006), fibre (James *et al.*, 2007) biomass of fungi and yeast (Kumud and Emilia, 2007), and *Carica papaya* seed (Omeiza *et al.*, 2011). The preparations of activated carbon from agricultural wastes are motivated by cost considerations (relatively cheaper), local generation in developing countries and effectiveness in the removal of heavy metals (Loo, 1974 and Madukasi *et al.*, 2010). This investigated the efficiency of activated carbon produced from plantain stem in the adsorption of three selected heavy metals

(cadmium, copper, and chromium) from their aqueous solutions under variable factors such as: Agitation speed, agitation time, particle sizes, pH, initial concentration of the adsorbate, and different chemical activation among others.

Nigeria is one of the West African Country that consumes plantain, the plantain stem is dumped as a waste, but this agricultural waste that is obtain from plantain stems can be used in the production of activated carbon and biofuel which can be used by industries and also for economic growth of any developing country. Plantain is easier to find and is affordable in Nigeria, conversion of plantain stem into activated carbon is essential because the activated carbon that will be produces will help the economic and environment in various ways such as water purification, medicine, air filters, gas purification decaffeination, gold purification and compressed air and many other applications. Therefore, the objectives of this research work are: To prepare activated carbon from plantain stem through pyrolytic process and to characterize the activated carbon produced with different activating agents and determination of physiochemical properties of the activated carbon produced.

MATERIALS AND METHODS

Materials

Equipment used: The equipment used in the experiments was: Electronic weighing balance was used to weigh the plantain stems before pyrolysis, while a more sensitive (+0.001) balance (Adams AFP 360L) was for other analysis. A laboratory electrical oven, Laboratory electric muffle furnace (Type: OH85TR), locally fabricated pyrolysis reactor with thermocouple, mortar and pistol, graduated cylinder, Spectrophotometer Nitric acid, sulfuric acid, crucible, desiccator, stop watch, Funnel, Standard iodine solution, Thiosulfate solution, Starch indicator, Burette, clamped stand, polyethylene bag, distilled water, effect of nitric, and sulfuric acid on activated carbon from the pyrolysis of plantain stem analysis were carried out at the Chemical/petrochemical laboratory, Akwa Ibom State University, Mkpat Enin, Akwa Ibom State, Nigeria.

Methods

Precursor selection
The substrate is plantain stem, cultivated from local farm, peel and process at Akwa Ibom State University, Nigeria.

Particle sizes separation
The stem of plantain precursor passed through manual standard sieved size of 2.80 mm. Thereafter, the sieve fraction was collected and weighed 700 g for thermo-cracking process.

Carbonization process

This is a process in which organic substance can be converted into carbon through thermo-chemical or decomposition known as pyrolysis. 800 g of solid plantain fibers were introduced into petri-dish and pre weighed Petri dish with the sample. The samples were dried in the oven for 1 h at 100°C, the process was. The samples were pre-weighed again and the final weight was introduced into a pyrolysis reactor at initial product temperature of 30°C, the speed of heating (regulated on the level of [T]) was maintained at every 10 min. Around 35°C, very intense white vapors were observed. On the walls of the two condensers, first drop of a black liquid of oily aspect of which the quantity increased as the temperature goes up was also observed. The final product temperature was at 151°C depending on the nature of sample and a steady temperature was obtained for three consecutive time at 10-min interval, at this point no gaseous emission was observed. The Carbonization lasted for 2 h and 10 min, meaning that the process is a slow pyrolysis. Thereafter, the charred products were transferred into desiccator and allowed to cool to room temperature. Carbonization charred material was poured into the crucible to determine the final weight. Yield on pyrolysis (carbonization) was calculated from the weight, before carbonization (Wb) and after carbonization (Wa). The % yield is thus calculated as stated in accordance with (Yoshiyuki and Yutaka, 2003).

$$Yield\ (\%) = \frac{Wa}{Wb} \times 100 \qquad (1)$$

Wa and Wb = weight of carbon after and weight of sample before carbonization.

Activation (step process)

After achieving the carbonized materials of plantain stem, the activation was thus carried out in chemical activation using HNO_3 and H_2SO_4 at different concentrations.

In chemical activation; concentration of activated agent (nitric acid) was prepared on the basis of 0.05 M, 0.1 M, 0.2 M, and 0.3 M and neutral. The duration of impregnation ratio was maintained at 4 h for all samples. 10 g of each carbonized precursor were weighed and mixed in a separate beaker containing 30 ml of activating agents (HNO_3) and H_2SO_4. The precursor mixtures were transmitted into crucible and laid to a muffle furnace at 600°C for 1 h activated sample was then remove and put to desiccator cooled at room temperature. The activated carbon generated above was washed with distilled water to removed residual acid and washing was complete when pH value of 7 was determined, and dried in an oven at 105°C for 3 h. The final product was kept in an air tight polyethylene bag, ready for use. According to (Fapetu, 2000), the yield of activated carbon is defined as the ratio of the weight of the resultant activated carbon to that of the original precursor with both weight on a dry basis.[1-10]

$$\% \, yield = \frac{Wi}{W0} \times 100 \qquad (2)$$

Characterization of adsorbent

Activated carbon yield (ACY) determination

The dried weight, Wca of each activated carbon sample was determined and the ACY was calculated as follows;

$$Activated \, carbon \, yield = \frac{Wca}{Wf} \times 100 \qquad (3)$$

Fapetu (2000) activated carbon sample, Wf = weight of activated carbon retrieved from Where, Wca = oven dried weight of the furnace.

Percentage burn off determination

10 g of each carbonized char were perfectly weighed and noted to be Wa and also allowed to pass through activating process step at 600°C for 1 h, thereafter the sample were weighed and noted as Wi.

$$\% \, burnoff = \frac{Wa - Wi}{Wa} \times 100 \qquad (4)$$

Itodo et al., (2008).

Bulk density determination

The particle bulk density was determined using Ahmedna et al., (1997), procedure as follows: An empty measuring cylinder was weighed and the weight noted. The cylinder was then filled with a sample of activated carbon from mango seeds and gently tamped until no more change in the level of the sample in the measuring cylinder was noticed. The volume occupied by the packed sample was recorded and noted. If Wc is the weight of empty cylinder and W is the weight of cylinder and sample, then weight of sample; Ws = W-Wc. Versus is the volume occupied by the packed sample.
Then,

$$Bulk \, Density \, (Bd) = \frac{Ws}{Vs} \qquad (5)$$

Surface area determination

The diameter (assuming spherical shape) of the activated carbon was obtained by passing the crushed carbon through sieve size of 2.80 μm and the external surface area was calculated by the relation;

$$Surface \, area, SA = \frac{6(cm)^3 / g}{BbPd} \qquad (6)$$

Where,
Bd = bulk density
Pd = particle size (particle diameter).

Moisture content determination (MC %)

Thermal drying method was used in the determination of MC of the samples. 1.0 g of the dried activated carbons was weighed and placed in washed, dried, and weighed crucible. The crucibles were placed in an oven and dried at 105°C to constant weight for 1 h. The percentage (MC %) was computed as follows.

$$(MC\%) = \frac{Wi}{Wa} \times 100 \qquad (7)$$

Where,
Wi = Loss in weight on drying
Wa = Initial weight of sample.

Determination of ash content (AC %)

The standard test method for AC –ASTM D2866-94 was used. 1.0 g activated carbon was taken, dried in an oven at a temperature of 105°C for 1 h.
The final weight after drying was measured and recorded as (Di = oven dry weight). Thereafter, the dried activated carbon was sent to muffle furnace and the temperature was allowed to rise until it reaches 450–500°C. It was removed from the muffle furnace and allowed to cool in a desiccator at room temperature and reweighed again and it weight was recorded as (Df = ash weight).[11-20]
The percentage AC was determined as thus;

$$(AC\%) = \frac{Df}{Di} \times 100 \qquad (8)$$

Where; Di - initial weight of sample,
Df - final weight sample.

Determination of iodine number

Procedure of the iodine value test: I Standardization of Iodine solution
- 10 ml of 0.1 M iodine solution was taken in conical flask
- 1 drops of Starch solution were added to it
- The pale yellow color of Iodine Solution turned Blue
- Titration of the formed solution was done with 0.100 M Sodium Thiosulfate till it becomes Colorless
- Burette reading corresponds to blank reading (B).
II:
- 0.2 g of activated carbon was weighed very accurately
- It was introduced into the iodine flask which should be completely dry
- 30 ml of 0.1M iodine solution was then added
- The flask was shaken properly and leave for 24 h and then filtered
- The filtrate was collected in a dry flask and then 10 g of the filtrate was titrated against.
- Standard sodium thiosulfate solution using starch as indicator

- Burette reading corresponds to (A).
Calculations involved in iodine adsorption number are as follows:

$$= \frac{B - S}{B} \times \frac{V}{W} \times M \times 126.91 \qquad (9)$$

Where $M = molarity \left\{ \frac{mol}{dm^3} \right\}$

B = blank reading (ml)
S = volume of thiosulfate used (ml)
V = volume of iodine used. (ml)
W = weight of sample used (g/kg).

Fixed carbon

The standard test method for AC –ASTM D2866-94 was used.
1.0 g activated carbon was taken, dried in an oven at a temperature of 105°C for 1 h.
The final weight after drying was measured and recorded as (Di = oven dry weight).
Thereafter the dried activated carbon was sent to muffle furnace and the temperature was allowed to rise until it reaches 450–500°C. It was removed from the muffle furnace and allowed to cool in a desiccator at room temperature and reweighed again and it weight was recorded as (Df = ash weight).
The percentage AC was determined as thus;

$$(AC\%) = \frac{Di - Df}{Di} \times 100 \qquad (10)$$

Dara (1991).
Where; Di - initial weight of sample, Df - final weight sample.

Methylene blue number

The Methylene blue number is defined as the maximum amount of dye adsorbed on 0.5 g of adsorbent. In this method, 0.5 g of activated carbon was placed in contact with 30.0 ml of 1 g/l L Methylene blue solution for 24 h at room temperature followed by intermittent shaking. The solution was thereafter filtered using whatman number one filter paper and an aliquot room temperature and the solution was taken for analysis. The remaining concentration of methylene blue was analyzed using an Atomic Adsorption

Spectrophotometer. The amount of methylene blue adsorbed was calculated using the mass balance equation as follows:

$$qe = \frac{Co - Ce}{M} V \qquad (11)$$

Cleiton *et al*., (2011).
Where Co = Equilibrium concentration of methylene blue (1000 conc. prepared).
Ce = initial concentration of methylene blue (cy = standard curve equation = 1.4674x + 1.1876 for H_2SO_4 and 1.4426x +1.1991 for HNO_3.
M = 0.5 g of activated carbon
V = volume of methylene blue used = 30 ml.
The liquid phase of the extract was measured at 480 nm using spectrophotometer model: 721. The total methylene blue number in activated carbon was estimated with reference to standard curve derived from methylene blue concentration mixed with 0.5 g activated carbon using water as the blank, total methylene blue data were fitted to equation below.

$$qe = \frac{Co - Ce}{M} V \qquad (12)$$

Loss-on-ignition

0.5 g of activated carbon that passed through a sieve of 2.80 mm mesh was further dried at 105°C. The samples were subjected to calcination for 5 h at 300°C (Miyazawa *et al*., 2000). Subsequently, the samples were weighed and the difference between the initial and final mass corresponded to the loss on ignition of activated carbon.

Loss on ignition % = Co–Ce × 100 (13)

Where Co = initial mass of activated carbon.
Ce = final mass of activated carbon.

Pore volume

The sample (1 g) was collected and transferred completely into a 10 ml measuring cylinder in order to get the total volume of the sample. The sample was then poured into a beaker containing 20 ml of deionized water and boiled for 5 min, the content in the beaker was then filtered, superficially dried,

and weighed. The pore volume of the sample was determined by dividing the increase in weight of the sample by the density of water (Aneke and Okafor 2005).
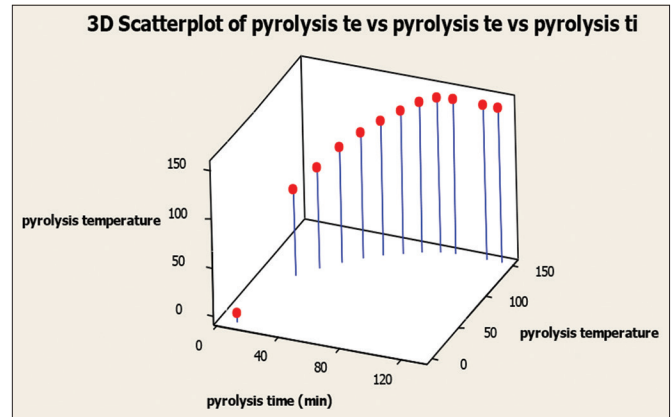
Figure 1: The scattered plot obtained from pyrolytic conversion of plantain stem into char
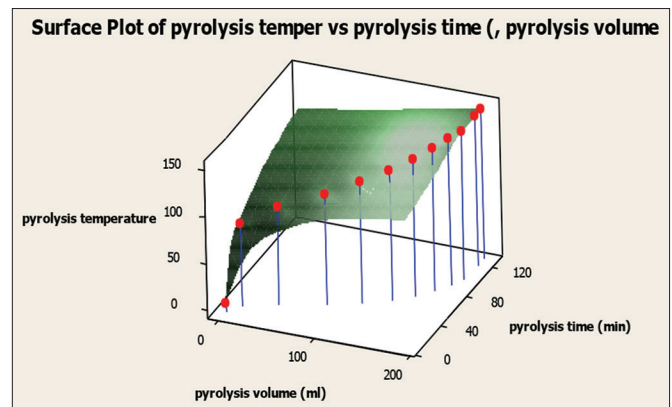
Figure 2: The surface plot obtained from pyrolytic conversion of plantain stem into char
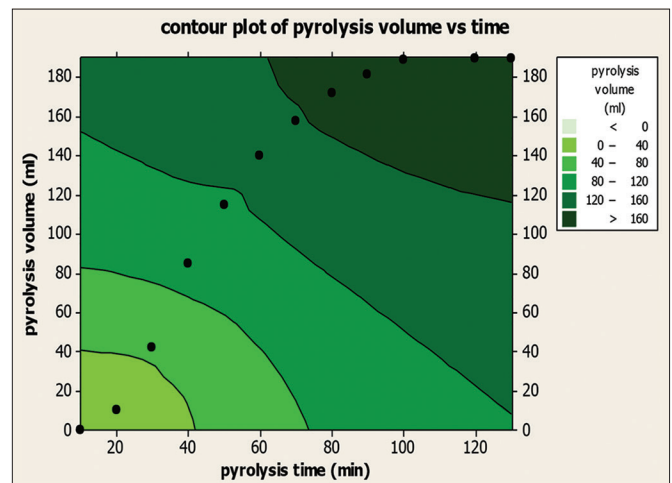
Figure 3: The contour plots obtained from pyrolytic conversion of plantain stem into char

RESULTS AND DISCUSSION

Pyrolysis process conversion of plantain stem into char

Figures 1-4 shows the scattered plot, surface plot and contour plots respectively obtained from pyrolytic conversion of plantain stem into char.

700 g well dried plantain stem were introduced into a pyrolysis reactor at initial product temperature of 30°C, the speed of heating (regulated on the level of [T]) was maintained at every 10 min. Around 35°C, very intense white vapors were observed on the walls of the two condensers, first drop of a black liquid of oily aspect of which the quantity increased as the temperature goes up was also observed. The final product temperature was 151°C and final product volume was at 190 ml depending on the nature of sample and this was obtained by having a steady temperature for 6 consecutive time at 10-min interval, at this point no gaseous emission was observed. The carbonization lasted for 2 h, 10 min simply means that the process is a slow pyrolysis. Thereafter, the charred products were transferred into desiccator and allowed to cool at room temperature. Carbonization charred material was poured into the crucible to determine the final weight. It was observed that the time of residence of sample in the reactor also influences the yield of the final material; the higher the activated carbon is maintained at the maximum temperature, the lower the yield.
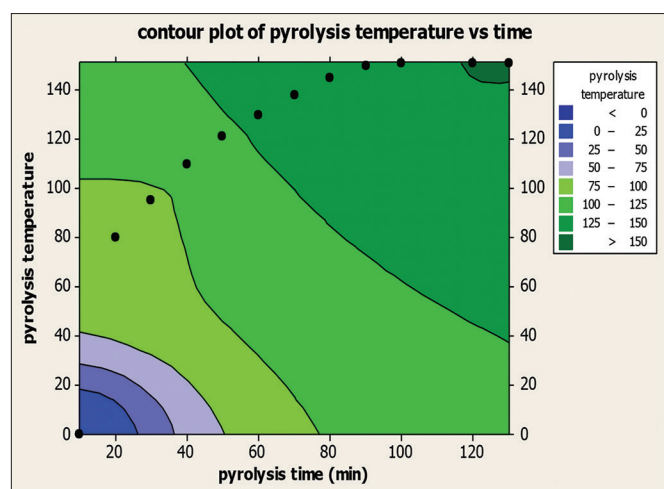
Figure 4: The contour plots prolysis temperature vs. Time

Effect of nitric and sulfuric acid activation on the yield of activated carbon from plantain stems

Figure 5 shows the results obtained from difference chemical activation agent. In general, this data reveal that the impregnation ratio strongly influences the yield. Indeed, the higher the impregnation ratio, the higher the yield of the final material, the time of residence also influences the yield of the final material; the higher the activated carbon is maintained at the maximum temperature, the lower the yield. Chemical activation was observed to favor plantain fiber. The results obtained were compared to the reported average yield by Otaru *et al.* (2013) and Abedi and Bahereini (2013), respectively. H_2SO_4 activation was observed to have 77% as the overall best higher than HNO_3 with 76%.

Effect of nitric and sulfuric acid activation on the percentage burn off of activated carbon from plantain stems

Figure 6 shows the percentage burnoff of carbons during activation. It was observed that activation burnoff is high with a resultant low % yield at
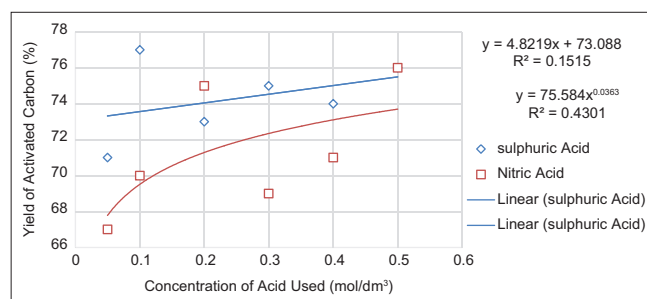

Figure 5: The effect of nitric and sulfuric acid activation on the yield of activated carbon from plantain stems
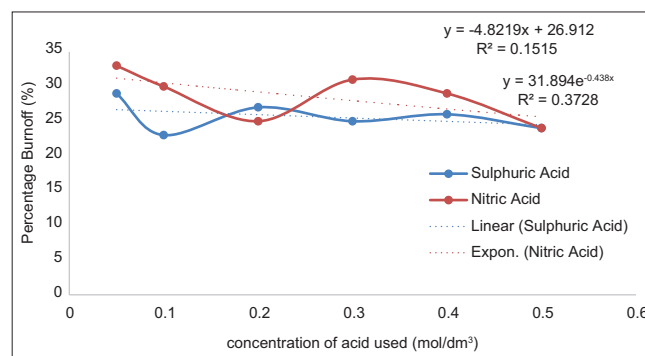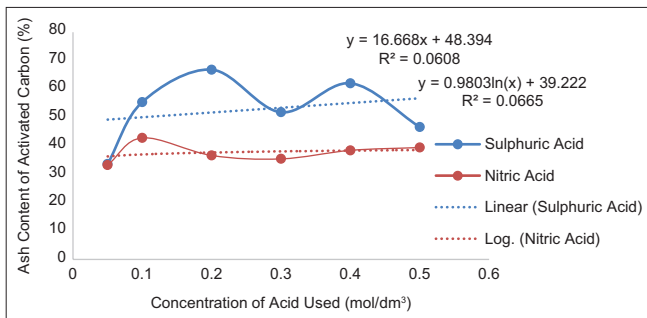

Figure 6: The effect of nitric and sulfuric acid activation on the percentage burnoff of activated carbon from plantain stems

24 h activation dwell time. The expected low yield with a corresponding high burnoff is more feasible for the one stage process. The results gotten from this work also give a proof that more volatiles are released from the char at longer dwell time, thereby resulting to higher burnoff with reduced yield. This corroborates the findings of Ahmedna *et al.*, 2000. The results also investigated that burn-off was higher in HNO_3 with 33% than H_2SO_3 with 29%.

Effect of nitric and sulfuric acid activation on the surface area of activated carbon from plantain stems

The surface area from the results obtained was found to be 1152 m²/g as the highest using H_2SO_4 activation and 963 m²/g was reported as the highest for HNO_3 activation. In this work the inquiry carried out in the laboratory proven that H_2SO_4 generated the best surface area. The surface area obtained from this work is in conformity with (Mohammed *et al.*, 2015). It was observed that there is variation of surface area because of different in concentration of activated agent used. The variation in surface area is as a result of chemical added. In addition to the

Figure 7: The effect of nitric and sulfuric acid activation on the ash content of activated carbon from plantain stems
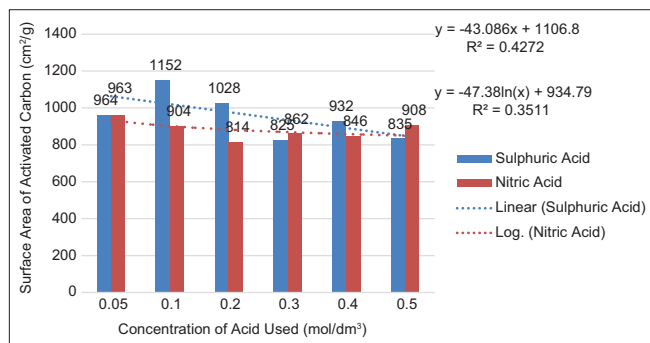
Figure 8: The effect of nitric and sulfuric acid activation on the surface area of activated carbon from plantain stem

surface area the performance of activated carbon is also influenced by surface chemistry. The different heteroatoms on the surface of activated carbon govern its chemistry. Hetero atoms such as oxygen, nitrogen, and hydrogen are borne to peripheral carbon atoms and exist as organic functional groups.

Effect of nitric and sulfuric acid activation on the MC of activated carbon from plantain fibers

The MC in this work from the graph above was found to fall between 17% and 30%.

MC, according to Olatunji *et al.*, (2011) has a relationship with porosity (α) of a given carbon. Adsorbent with high MC is expected to swell less, thus retarding pore size expansion for adsorbate uptake.

Effect of nitric and sulfuric acid activation on the AC of activated carbon from plantain stem

Figure 7 shows exact amount of carbon that has turned into ash during activation in furnace at 500°C for 1 h. Ash is a measure of inorganic impurities in the carbons (Bansode *et al.*, 2003). The AC in this research was found to be 66.8% using H_2SO_4 activated agent which is in range of most AC of agricultural waste [Figures 8, 9, 10].

Effect of nitric and sulfuric acid activation on the fixed content of activated carbon from plantain stems

Figure 11 shows the amount of carbon that has remained after volatile, ash and MC has been removed. Fixed carbon content is the residual amount of carbon present in the sample. The results
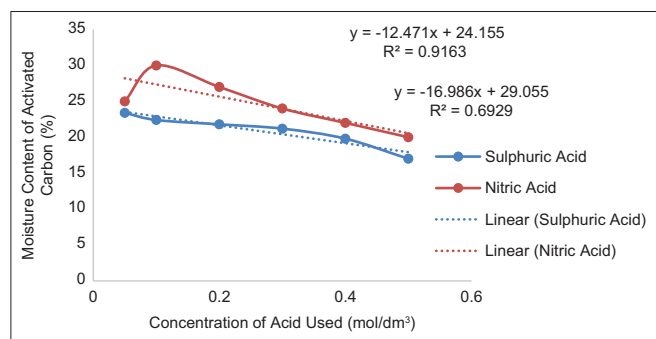
Figure 9: The effect of nitric and sulfuric acid activation on the moisture content of activated carbon from plantain stems

obtained from H_2SO_4 activation agent show that fixed carbon content is 66.8%. This is in concord with the findings of Malik *et al*., (2006) who reported that most of the carbon composition of A.C falls within 33–66.8%. It was observed that fixed carbon is high with a resultant low AC.

Effect of nitric and sulfuric acid activation on the bulk density of activated carbon from plantain stems

Figure 12, bulk density shows the fiber content of the adsorbent from different activated carbon. It was observed that 0.2 M concentration of HNO_3 gave the highest bulk density. The density of a generated activated carbon plays a great role on adsorbate uptake. In general, higher density carbons hold more adsorbate per unit volume (Jibril, *et al*., 2007). According to Itodo *et al*., (2008) bulk density has impact on adsorbate-retention level by any adsorbent.
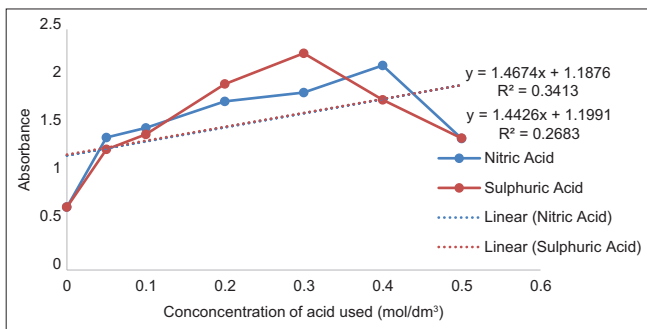
Figure 10: Standard curve derived from methylene blue concentration
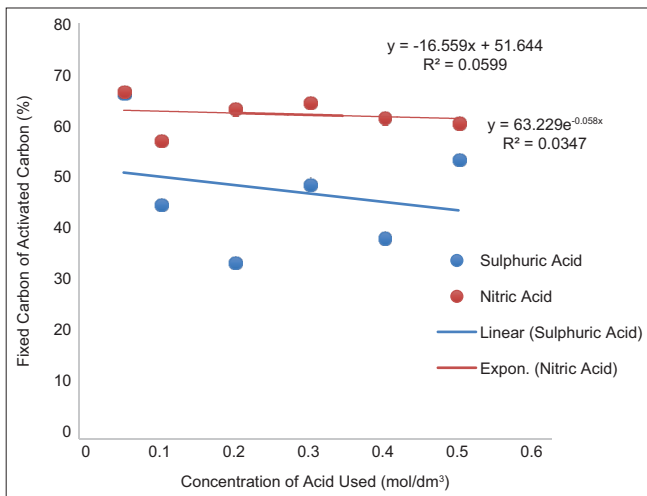
Figure 11: The effect of nitric and sulfuric acid activation on the fixed content of activated carbon from plantain stems

An adsorbent with bulk density need not be regenerated frequently because it can hold more adsorbate per unit weight. With difference in activation agents used, the results are in line with (0.165 g/cm³) commercial bulk density of activated carbon.

Effect of nitric and sulfuric acid activation on the Iodine number of Activated Carbon from plantain stems

Figure 13 shows effect of nitric acid activation on the iodine number of different activated carbon from plantain stem. Iodine number for commercial adsorbent range from 300 to 1200 g/kg and above is good. In the other words the results of adsorptive property obtained indicates that plantain stems is a very good source of raw material for the production of activated carbon of high efficiency. Iodine number of this work is within the range of Malik *et al*., 2005. It was observed that there was much effect on all the concentrations. From experimental results obtained, it was observed that H_2SO_4 activation attained the highest iodine number.

Effect of nitric and sulfuric acid activation on the methylene blue number of activated carbon from plantain stems

Figure 14 shows that the methylene blue number is correlated with ability of activated carbon to absorb color and high molecular weight substance. It was observed for the sample that color reduction was proportional to the quantity of activated carbon used. For instance, using 0.5 g of the activated carbon on the methylene blue concentration, the color was reduced to light blue from the original deep blue color. The observed increase in color
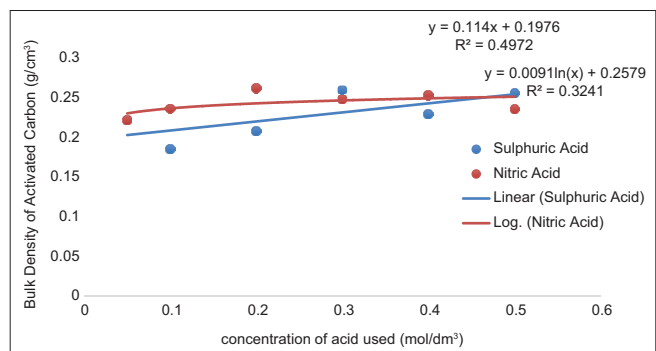
Figure 12: The effect of nitric and sulfuric acid activation on the bulk density of activated carbon from plantain stems

reduction with the quantity of activated carbon is probably due to the availability of more adsorption sites until saturation point is attained. This could also be as a result of an increase in the collision frequency between the molecules of the coloring matter and the activated carbon. It was observed that 0.05 concentration of H_2SO_4 has the best methylene blue number of 59.8713.[21-30]

Effect of nitric and sulfuric acid activation on the percentage loss on ignition of activated carbon from plantain stems

Figure 15 shows the percentage loss on ignition of activated carbons during activation. It was observed

Table 1: Data's for yield (%) of activated carbon from plantain stem

S\N	H_2SO_4	HNO_3
0.05	71	67
0.1	77	70
0.2	73	75
0.3	75	69
0.4	74	71
0.5	76	76

Table 2: Data's for percentage burnoff (%) of activated carbon from plantain stems

S\N	H_2SO_4	HNO_3
0.05	29	33
0.1	23	30
0.2	27	25
0.3	25	31
0.4	26	29
0.5	24	24
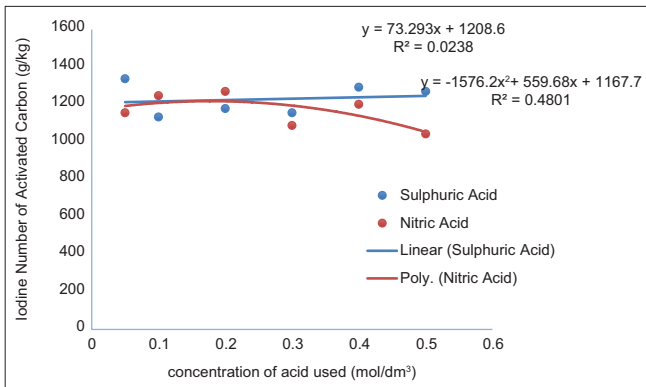
Figure 13: The effect of nitric and sulfuric acid activation on the iodine number of activated carbon from plantain stems

that at 300°C for 5 h volatile substances of activated carbon escaped and the mass ceases to change shown in Tables 1-12.

Effect of nitric and sulfuric acid activation on the pore volume of activated carbon from plantain stems
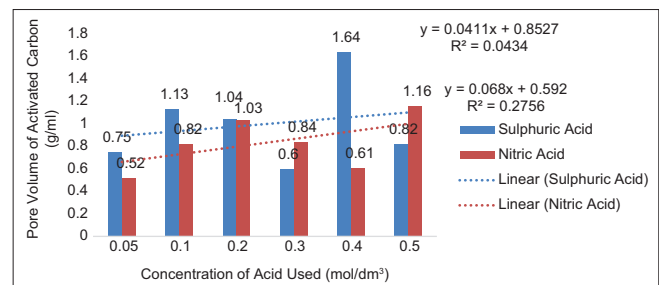
Figure 16 shows the pore volume of activated carbons during activation. The total volume of very
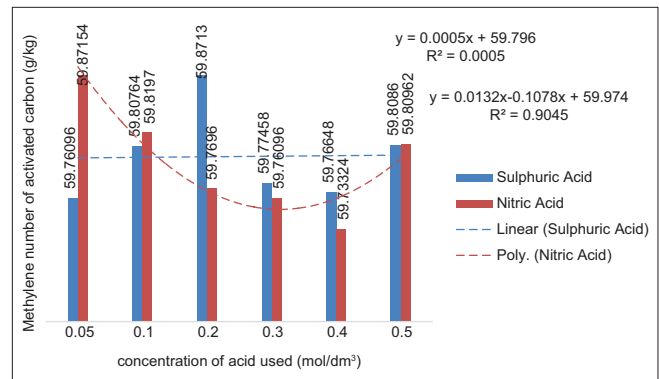
Figure 14: The effect of nitric and sulfuric acid activation on the methylene blue number of activated carbon from plantain stems
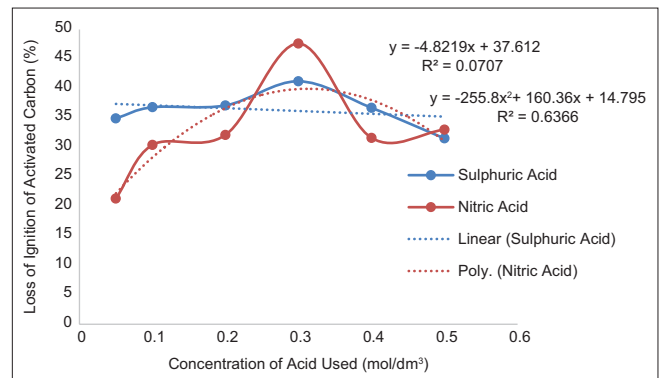
Figure 15: The effect of nitric and sulfuric acid activation on the percentage loss ignition of activated carbon from plantain stem

Figure 16: The effect of nitric and sulfuric acid activation on the pore volume of activated carbon from plantain stems

Table 3: Data's for surface area (cm^2/g) of the activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	964	963
0.1	1152	904
0.2	1028	814
0.3	825	862
0.4	932	846
0.5	835	908

Table 4: Data's for moisture content (%) of the activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	23.4	25
0.1	22.4	30
0.2	21.4	27
0.3	21.2	24
0.4	19.8	22
0.5	17	20

Table 5: Data's for ash content of the activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	33.6	33.2
0.1	55.4	42.8
0.2	66.8	36.6
0.3	51.8	35.4
0.4	62	38.4
0.5	46.6	39.4

Table 6: Data's for fixed content of activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	66.4	66.8
0.1	44.6	57.2
0.2	33.2	63.4
0.3	48.6	64.6
0.4	38	61.6
0.5	53.4	60.6

Table 7: Data's for bulk density (g/cm^3) of activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	0.2223	0.2225
0.1	0.1860	0.2363
0.2	0.2083	0.2619
0.3	0.2597	0.2484
0.4	0.2297	0.2532
0.5	0.2561	0.2359

Table 8: Data's for iodine number (g/kg) of activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	1337.1	1155.7
0.1	1133.1	1246.44
0.2	1178.5	1269.1
0.3	1155.8	1087.8
0.4	1291.8	1201.1
0.5	1269.1	1042.5

Table 9: Data's for methylene blue number (g/kg) of activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	59.760	59.871
0.1	59.807	59.819
0.2	59.871	59.769
0.3	59.774	59.760
0.4	59.764	59.733
0.5	59.000	59.807

Table 10: Data's for percentage loss on ignition (%) of activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	34.9	21.3
0.1	36.8	30.4
0.2	37.1	32.1
0.3	41.2	47.6
0.4	36.7	31.6
0.5	31.5	33

Table 11: Data's for pore volume (g/ml) of activated carbon from plantain stems

S\N	H$_2$SO$_4$	HNO$_3$
0.05	0.75	0.52
0.1	1.13	0.82
0.2	1.04	1.03
0.3	0.6	0.84
0.4	1.64	0.61
0.5	0.82	1.16

Table 12: Data's for standard curve derived from methylene blue concentration

S/N	H$_2$S0$_4$	HON$_3$
0.0	0.653	0.653
0.05	1.252	1.376
0.1	1.408	1.476
0.2	1.931	1.751
0.3	2.251	1.843
0.4	1.767	2.124
0.5	1.368	1.365

small openings in a bed of adsorbent particles was observed. The results obtained shows rapid access of absorption during activation of carbon particles. The results obtained were compared with those of (Hameed *et al.*, 2006, Ademiluyi *et al.*, 2008, and Inyang *et al.*, 2010).

CONCLUSION

From the experimental observation of the research work, result and analysis can be inferred that the plantain stem sample use as activated carbon has these:

It is cheap, good alternative source for activated carbon production and the one step activated method of preparation with suitable activating agent and agitation time can be employed.

The adsorption process is highly dependent on particle size, activating agents, adsorbent dosage, agitation speed, pH, and initial concentration.

The adsorption capacity of activated carbon prepared from plantain stem with both acid and base activators has comparable strength adsorption rate which is not higher than commercial activated carbon.

RECOMMENDATION

Ability of the adsorbent to be employed in the treatment of water dispensed for public consumption should be investigated. Solid phase adsorption of gas should be examined. Use of other activating agent includes KOH, HCL, and among others. Study the adsorption process using zinc, lead, and copper.

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