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RESEARCH ARTICLE

Carbon (IV) Oxide (CO_2) Capture Using Amine-Functionalized Coconut Shell-Based Activated Carbon as Adsorbent

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Abstract

Global Warming has become one of the most important environmental problems in the 21st century and the rise in CO_2 emission is considered as the main cause for the global warming. The emissions of this carbon dioxide (CO_2) from burn fossil fuels are the major reason for the increase in the concentration of this gas in the atmosphere. The amount of CO_2 in the atmosphere is currently increasing globally by around 6 billion tons per year which must be reduced to prevent global warming and the adsorbents available for the removal of this harmful substance is quite expensive. Activated carbon produced from coconut shell that can be readily available at an inexpensive rate was used for this purpose. The adsorption of carbon dioxide (CO_2) on activated carbon (AC) prepared from coconut shell has been investigated by using adsorption apparatus.

The adsorption equilibrium and breakthrough curves were determined at different time of 10, 20, 30, 40, 50 and 60 minutes in order to investigate the adsorption capacities of the activated carbon at different dosage of activated carbon and flow rates of CO_2.Maximum CO_2 sorption capacity on activated carbon occurred at 50th and 60th minutes with the uptake values of 27.4, 63.0 and 105.0mg for 0.5, 1.0 and 1.5g respectively of activated carbon quantity measured which was subjected to the respective flow rates of 1L/min, 2L/min and 3L/min. Different characterization methods were carried out and applied and on the basis of CO_2 adsorption, FTIR investigation was employed to the different functional groups of the adsorbents present in the analysis as different peaks were clearly indicated and interpreted after adsorption.BET and SEM were also applied to investigate the surface area of the adsorbent and observe the surface physical morphology of the adsorbent respectively before and after the adsorptions. The rate of adsorption of the adsorbent was determined through the weight differential measurement at different flow rate. The performance of the adsorbent was evaluated using a cylindrical adsorption column and analytical weighing balance. The adsorption was carried out at ambient (room) temperature of $25^{o}C$.The results obtained in this study conclude that activated carbon prepared from coconut shell can be considered as adequate adsorbent to separate carbon dioxide from flue gases and serves as a benchmark while searching for inexpensive and superior activated carbon production in future studies.

Keywords: Activated Carbon, Adsorbent, Amine-Functionalized, Carbon (IV) Oxide (CO_2), Coconut Shell.

1. Introduction

The release of CO_2 has become one of the most important environmental problems in recent times. Akinloye (2024a, 2024b, 2025) noted that it is affecting the health of people and as a result causing communication issue. The emissions of this carbon dioxide (CO_2) from burn fossil fuels are the major reason for the increase in the concentration of this

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gas in the atmosphere (Adilla et al., 2013, Brunauer et al., 1938, Cruz et al., 2012). The traditional method of capturing post combustion carbon is the amine scrubbing process; it is done by the separation of carbon dioxide (CO_2) from methane (CH_4). The regeneration of the amine solution and the subsequent compression of CO2 for transportation and storage make the process energy intensive. This is not only makes carbon capturing more expensive but also ineffective (Udorah & Adeniran, 2025; Hozerberg et al., 1993). A less expensive method of carbon capture is use of adsorbents, it could be physical or chemical adsorbents and in this case, kaolinite is used. Carbon capture using physical adsorbents such as Activated Carbon, activated Kaolin, Silica, and Alumina is low cost and easily available (Fernandes et al., 2003; García et al., 2011).

The underlying aim of this research is to carbonize the waste of Coconut Shells in Gidan-Kwano, Minna, convert it to activated carbons as a value added product and use this activated carbon for separation of carbon dioxide ($CO_{2)}$ from coal-fired power plants (Brunauer et al., 1938; Cruz et al., 2012). Since the impact of precursors, carbonization method, activating agents and conditions, metal impregnation on physical and chemical properties and CO_2 adsorption behavior of activated carbon are not clear, the objectives were to prepare activated carbon using activating agents; prepare activated carbon from coconut shells under different carbonization conditions; characterize the produced activated carbons; and adsorp CO_2 with the adsorbent (Udorah & Adeniran, 2025).

The use of fossil fuels in manufacturing, construction and transportation sectors have led to increase of gas pollutants in the atmosphere (Herzog & Meldon & Hatton, 2009; Jang, D., & Park, 2012). The increase in the intensity of these emissions is major cause of global warming, acid rain and climate change (Yang et al., 2008). Carbon dioxide is the major cause for greenhouse emissions due to its high level of emissions worldwide (Konduru et al., 2007).

Although, alternative fuels like biodiesel are being developed to eventually replace the use of fossil fuels, fossil fuels are still being used prominently worldwide, thus, making it necessary for measures such as carbon capture be developed to cope with the pollution being caused by the emission of greenhouse gases (Liu & Wilcox, 2013; Zevenhoven & Kilpinen, 2001). Carbon capture using adsorbents is being explored due to its low cost and the high availability of the adsorbent materials unlike amine scrubbing which consumes a lot of energy thereby making the process less effective (Somy et al., 2009; Lastoskie et al., 1993).

Carbon based materials such as activated carbon, charcoal and coal have been reported for high pressure CO_2 capture applications where activated carbon is used to adsorb CO_2 using amine solution as the activating agent in this work. But adsorption time and carbonization temperature were not varied.

2. Materials

2.1 Activated carbon (From Coconut shells)

The activated carbon used in this study was a by-product of fast pyrolysis of coconut shells provided by MallamGarbaHaruna, located opposite FUT Minna main gate, Gidan-kwano, Minna-Niger State. The activated carbon yield of this process was 10-15 wt. %. The produced activated carbon was sieved, and particle size range of 178-710 µm was collected for activation processes.

Sample Preparation: Coconut shell was used to produce activated carbon, the powder of which was subjected to adsorption experiments. The high and unevenly distributed water content in coconuts makes carbonization and activation temperatures difficult to control, which affects the quality of the activated carbon. For this reason, a pre-treatment that involves cutting open the coconuts, removing all of the coconut pulp and some of the fibres and air-drying the remaining shell was performed. For uniform quality in carbonization and activation, the water content of the shells was maintained at between 13% and16%.

The dried shells were cut into pieces with dimensions of 5cm (length) X 4cm (width) X 2-3cm (thickness) and placed in a high –temperature kiln for carbonization. Induction heater; a compact charcoal kiln was used to produce coconut shell activated carbon. Its maximum capacity is about 1kg of raw materials per batch. Induction heater which incorporate a coil directly fed from the electricity supply, were installed in the kiln walls for generating heat energy to carbonize coconut shells.

Temperature sensors were placed inside the charcoal kiln for monitoring the carbonization temperature. The carbonization temperature was controlled by setting the temperature of the pyrolysis process (A pyrolysis is the transformation of a substance produced by the action of heat in the absence of oxidant like oxygen).

Inert gas i.e. Nitrogen (N_2) was pumped into the kiln at 10ml/min to prevent the coconut shells from coming into contact with air during carbonization and activation. During carbonization, the temperature was increased at 15°C/min to 500°C and held for 60min (1hr). Following the activation process, steam, the activation fluid, was immediately pumped into the furnace at 3ml/min.

The activation temperature of 600°C and two activation time (60 and 120min) were adopted for comparing the quality of coconut shell-based activated carbon. Subsequently, the heater and gas flow were turned off and the carbonized coconut shell activated carbon was allowed to cool naturally inside the kiln to room temperature (25°C). Finally, the shells were grinded into powder (30 meshes). CO_2 adsorption apparatus was used to evaluate the CO_2 adsorption capacities of the samples and compared the results with those of commercially available activated carbon.

2.2 Physically activated carbon

Physically, activated carbon was prepared using carbon dioxide and steam as activating agents. Before activation, sieved activated-carbon or activated-char was dried in air for 12 h at 110 °C. The process conditions of the steam and CO_2 activated carbon were chosen to obtain similar Brunauer-Emmett-Teller (BET) surface area and total pore volume in both products. In physical activation, the coconut shells are first paralyzed, as described earlier, and reacted with an oxidizing gas stream such as H_2O or CO_2 at 900^{o}Cor higher (Sai et al. 3625). The resulting activated carbon has a finer structure and smaller pores, making it better suited for absorbing small particles in liquid and gas streams (ApelsaCarbones).

Physical activation is chosen over chemical activation for this process. While chemical activation requires lower reaction temperatures and less energy to produce the steam, the harsh doping agents are hard to remove at the end of the process and remain trapped in the activated carbon. However, these agents can later desorb, releasing the chemicals into the liquid or gas that is being purified with activated carbon (Plaza et al., 2010; Shahkarami et al., 2015). Physical activation only uses steam, so no chemicals are trapped in the final products. In addition, the macro-pores produced by chemical activation have a low surface-area to volume ratio and are too large to trap contaminants selectively (Plaza et al., 2010; Shahkarami et al., 2015). Only physical activation generates the smaller pores needed to remove the contaminants from flue gas treatment, physical activation was chosen despite its higher temperature and energy requirements. Water is chosen over CO_2 as the oxidizing gas because of its lower cost and environmental impact (Su et al., 2017).

2.3 Steam Activation Process

In each batch, 20 g of the activated carbon was loaded into the reactor and heated to 700°C with the heating rate of 3°C/min while flowing nitrogen carrier gas at the flow rate of 140 standard mL/min. Steam was injected into the reactor with the steam-to-carbon mass ratio of 1.06 for 1.4 h. After the injection, the reactor was cooled down to room temperature under nitrogen flow. The yield of product was 55 wt. % in steam activation process (Wang et al., 2011; Yang, 2003).

2.4 CO_2 Activation Process

In each run, 15g of activated carbon was placed in the fixed-bed reactor under an argon flow rate of 100 standard mL/min. The temperature of the reactor was increased to 890 °C with the heating rate of 3°C/min. Then, the gas was switched to CO_2 with the flow rate of 130 standard mL/min. After 100min, the reactor was cooled down to room temperature under argon gas flow. The yield of product was 52 wt. % in CO_2 activation process (Wang et al., 2011; Yang, 2003).

2.5 Chemically activated carbon

The coconut char can be converted to activated carbon by physical or chemical activation. In chemical activation, the raw coconut shells are doped with a chemical agent such as $ZnCl_2$ and H_3PO_4, and then heated to a moderate temperature between 400 and 800^{o}C (Wang et al., 2011; Yang, 2003). The pyrolysis and activation steps occur at the same time, and produce activated carbon with an open, macro-porous structure (ApelsaCarbones). The physical activation set-up was also used for chemical activation of activated carbon. KOH was used as the activating agent. The activated carbon was impregnated with KOH in 100 mL of distilled water with carbon-to-KOH mass ratio of 0.81 on dry basis.

After 4hrs at the room temperature, the prepared mixture was dried in oven at 110°C for 12h. 20g of the dried sample was placed in the reactor under a nitrogen flow of 240 standard mL/min and was heated to 300°C with the heating rate of 3°C/min, and was held for 1h at 300°C. Then, the temperature of the reactor was increased to 775°C with the heating rate of 3°C/min and held at this temperature for 2h before cooling down to room temperature. In the next step, the sample was washed with hot water, followed by

0.1M HCl, and finally by distilled water to remove the soluble salts and the potassium compounds. Then the sample was dried in oven over-night at 110°C in air. The product yield of chemical activation was 33 wt. %.

2.6 Characterization of the Activated Carbon

Characterization of the produced activated carbon was done using the following analysis.

The Fourier Transform Infrared Spectroscopy (FTIR): Which was done to determine the chemical composition of the activated carbon, and the functional group. Fourier transform-infrared analysis (FTIR) is a well-known method for analysing surface chemistry. It can be used to detect the functional groups present in the sample, the atoms in molecules are not static, but vibrate about their equilibrium positions, even in the solid state. Each atom vibrates with a frequency which depends on its mass and the length and strength of any bonds it has formed.

Molecular vibrations are stimulated by bonds absorbing radiation of the same frequency as the natural frequency of vibration of the bond (i.e., in the range 1.20 × 1013 - 1.20 × 1014 Hz) which is in the infrared region of the electromagnetic spectrum. Surface functional group containing oxygen have a major role in AC properties such as surface behaviour and reaction, hydrophobicity, surface charges, electron density of graphene layer and may be further used for surface modification. Different functional group present in activated carbon sample were carboxylic, carbonyl, phenol and lactones etc.

The Scanning Electron Microscopy (SEM): Which was done to determine the morphology (structure) and purity of adsorbent? A scanning electron microscope (SEM) is a type of electron-microscope that images a sample by scanning it with a high-energy beam of electrons in scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical conductivity. Different pores were observed in activated carbon sample. Due to carbonization and activation, volatiles are removed producing a fixed carbon mass with widening of pore networks that are present inactivated carbon sample. The micro-pore presences contribute towards gas adsorption activated carbons are known to have large adsorption capacity for CO_2 and they can be produced from low cost and abundant precursors such as activated carbon (Leung et al., 2014; Sing et al., 1982).

The Brunauer-Emmett-Teller (BET): The BET theory was developed by Brunauer, Emmett and Teller in 1983. It measures the surface area of the adsorbent. Generally, the larger the specific surface area of the adsorbent, the better its adsorption performance will be (Guo and Lua, 2003). The most widely used commercial active carbons have a specific surface area of the order of 600-1200 m^2/g. The pore volume limits the size of the molecules that can be adsorbed whiles the surface area limits the amount of material which can be adsorbed, assuming a suitable molecular size. The adsorptive capacity of adsorbent is related to its internal surface area and pore volume (Hu and Srinivasan, 1999). It has been shown that surface area and pore size distribution of activated carbon affect CO_2 capture performance of activated carbon. Moreover, starting precursors have a significant effect on CO_2 adsorption behaviour of activated carbons. However, a comparison of different methods of activation of bio-char on its CO_2 adsorption performance has to be reported. This work focused on the effect of different activation methods on porosity, surface area and adsorption capacity of the activated carbons to explain CO_2 adsorption behaviour in activated carbons.

Table 1. *List of Materials and reagents used*

Materials and Reagent used	Sources
Amine Solution and Inert gas (N_2)	Institute of Chemical and Leather Research Zaria
Potassium Hydroxide (KOH)	Institute of Chemical and Leather Research Zaria
ISteam (Activation Fluid)	Institute of Chemical and Leather Research Zaria
Coconut Shell	MallamGarbaHaruna's Shop, Opposite Gate
Carbon (IV) Oxide (CO_2)	Gas Depot Minna
Distilled Water	Chemical Engineering Department, FUT Minna

Table 2. *Instruments and Equipment*

Apparatus	Sources
Analytical Weighing Balance	Chemical Engineering Department, FUT Minna
Volumetric Flask	Chemical Engineering Department, FUT Minna
Conical Flask	Chemical Engineering Department, FUT Minna

Funnels	Chemical Engineering Department, FUT Minna
Measuring Cylinders	Chemical Engineering Department, FUT Minna
Crucible	Chemical Engineering Department, FUT Minna
Furnace	Chemical Engineering Department, FUT Minna
Oven	Chemical Engineering Department, FUT Minna
Filter Paper	Chemical Engineering Department, FUT Minna
1mm sieve size	Chemical Engineering Department, FUT Minna
Cylindrical Adsorption Column	Chemical Engineering Department, FUT Minna
Kiln	Chemical Engineering Department, A.B.U Zaria
Induction Heater	Chemical Engineering Department, A.B.U Zaria
Temperature Sensors	Chemical Engineering Department, A.B.U Zaria

2.7 Preparation of Equipment

The adsorption column, the beaker, the spatula, the cork and the delivery hose were washed, properly rinsed and placed in warm water. This was done to avoid impurities whatsoever because some of the apparatus had been exposed for a while (especially the adsorption column)

2.8 Experimental Variables

In other to measure the effectiveness of a particular substance or material (e.g. activated carbon), all the factors responsible for its workability must be tested. This analysis helps to determine and establish the optimum point where the effectiveness of the activated carbon achieves the highest efficiency. Hence, the CO_2 adsorption in this experiment will be carried out by maintaining the flow rate of CO_2 into the adsorption column at the rate of 1L/Min, 2L/Min and 3L/Min by varying the mass of 0.5g, 1.0g and 1.5g of the activated carbon and the time taken for the adsorption process to be carried out.

2.9 CO_2 Adsorption Experiment

This work was done using a glass adsorption column, cylindrical in nature, 14cm long and an internal diameter of 1.2cm. The adsorption column was supported by a wooden standing, the hose through which the CO_2 was delivered from the gas cylinder was connected to the end of the column, the other end of the column i.e. the upper part has an open end where an exit hose can be fitted, the open end was corked and an exit was connected through the opening at the Centre of the hose (Alhassan et al., 2017). With the aid of analytical weighing balance, 0.5g of activated carbon was measured and placed in the column (with a foam support) and the gas cylinder's tap was opened at 1L/min, and the time of adsorption was varied (10, 20, 30…) min until an equilibrium was achieved. This operation was carried out at atmospheric pressure and at room temperature of 25°C. The same operation was repeated for 1.0g and 1.5g of activated carbon. All values gotten was recorded the experiment was carried out again at different flow rate of 2L/min and 3L/min. The weight of the activated carbon samples was measured at the end of each run (i.e. at 10 min interval) to ascertain the difference in weight of the activated carbon (sample) in other to determine the amount of CO_2 that has been adsorbed and to determine how long it will take the activated carbon to reach its maximum capacity.

3. Results and Discussion

This section presents the different results obtained from the CO_2 adsorption experiments carried out using activated carbon. The results obtained from the characterization of the adsorbent before and after the adsorption using both samples are analyzed in this chapter, and the effect of varying weight and time.

3.1 Carbon Dioxide Sorption Capacity

As earlier discussed in chapter three, section 3.6; 0.5g, 1.0g and 1.5g of adsorbent were measured to carry out this experiment. Figures 1-3 shows clearly the relationship between the adsorbent (activated carbon) dosage and the quantity of CO_2 adsorbed at different time intervals of 10,20, 30, 40, 50 and 60 minutes. It is noticed that the quantity of CO_2 adsorbed increases as the time of adsorption increases, and the optimum weight in this experiment as seen is 1.5g. This is because high weight results in high adsorption. And this will continue as the weight further increases because the more the adsorbent the more the active site for the adsorbent and the more CO_2 added (Alhassan et al., 2016).

For the activated carbon at the first flow rate of 1L/Min, there was a steady increase of the CO_2 adsorbed as time and weight increases. This will continue until all active sites of the activated carbon are occupied (Alhassan et al., 2016).

For the second and third flow rate of 2L/Min and 3L/Min respectively, there was a steady increase of CO_2 adsorbed until 40th minute where there was a slight drop in the CO_2 adsorbed, which could be attributed to environmental conditions such as temperature; and this reduces the amounts of CO_2 adsorbed. Equilibrium occurred at 50th minute in the three different flow rates as seen in the graph (Figures 1-3), which is as a result of all the available active sites of the activated carbon been occupied by the CO_2 gas.

The following graphs shows the relationships between CO_2 adsorbed and the contact time.

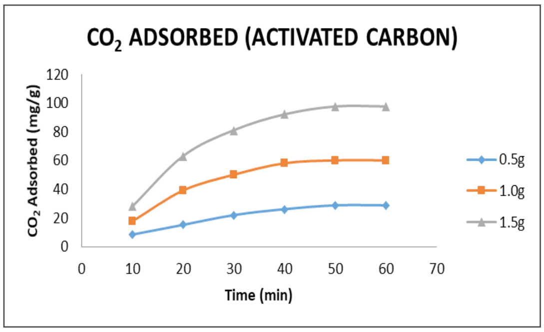

Figure 1. *Graph of CO_2 adsorbed against time at 1L/Min (Activated Carbon)*

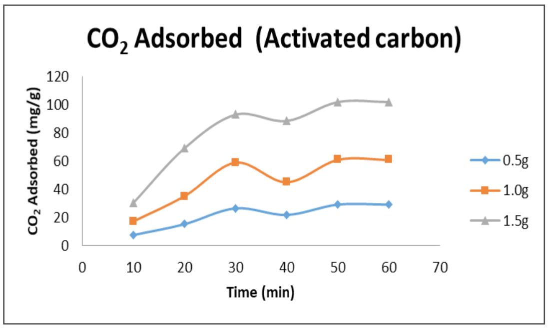

Figure 2. *Graph of CO_2 adsorbed against time at 2L/Min (Activated Carbon)*

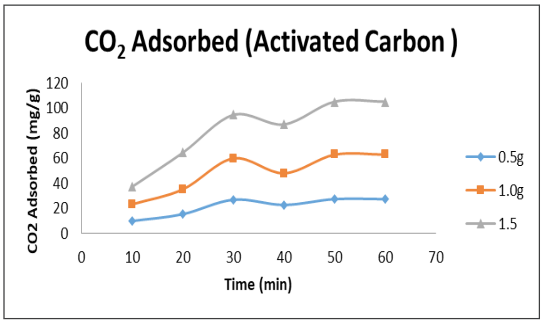

Figure 3. *Graph of CO_2 adsorbed against time at 3L/Min (Activated Carbon)*

From the graph shown in Figure 1, it was noticed that, as the contacts time was increasing progressively, i.e. from 10 minutes, 20 minutes, 30 minutes and 40minutes; there was a progressive increment in the values of the CO_2 uptake due to more residence time until 50th and 60th minutes where equilibrium occurred. The reason for the equilibrium was that, all the active sites of the activated carbon measured has been occupied by the CO_2 uptake, so there was no more room for the CO_2 to occupy.

In the graphs showing in Figures 2 and 3, as contact time increases from 10, 20 and 30th minutes, there was a proportionate increment in the values of carbon (iv) oxide uptake due to more residence time until 40th minutes where there was a sharp drop in the value of CO_2 adsorbed (as shown in the sinusoidal patterns of the graphs movements in Figures 2 and 3). These were attributed to some environmental factors such as temperature. At 50th and 60th minutes, the graph maintained a straight line pattern (equilibrium points) where no more carbon (IV) oxides could be absorbed onto the activated carbon surface.

3.2 Characterization of Adsorbent

3.2.1 Fourier Transform Infrared Spectroscopy (FT-IR)

The FT-IR analysis is carried out to investigate the functional groups of the adsorbents used in the experiment. Functional groups not only affect the adsorption behaviors, but also dominate the adsorption mechanism.

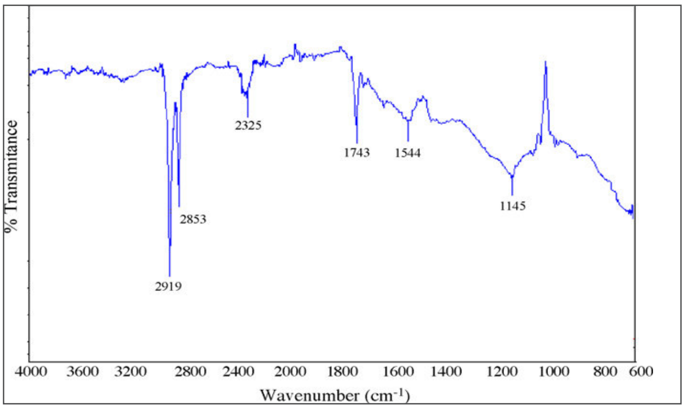

Figure 4. *FT-IR after adsorption*

3.2.2 FT-IR Results Interpretation (Coconut Shell-Activated Carbon)

From the above FT-IR analysis, the peak at 1544/cm is due to the absorption of water molecules as a result of an O-H stretching in phenol vibration mode of hydrogen bonds and adsorbed water for coconut shell-derived activated carbon. The peak at 1743/cm corresponds to the stretching vibration of C=O. The peak at 2919/cm may be attributed to the aromatic C=C stretching vibration typically found in carbonaceous material; for instance, activated carbon.

The peak at 2853/cm represents ionized linkage P^+ - O^- in acidic phosphate esters and symmetrical vibration in a chain of P-O-P or C-O in carboxylic acids. The peak at 2325/cm is attributed to the stretching of C=C stretch and this is also found in carbonaceous material. The peak at 1145/cm is attributed to the bending of C-O in carboxylic acid. Overall results indicate that coconut shell is a good source of precursors for preparation of activated carbon.

The Brunauer-Emmett-Teller (BET): The BET theory was developed by Brunauer, Emmett and Teller in 1983. It measures the surface area of the adsorbent. Generally, the larger the specific surface area of the adsorbent, the better its adsorption performance will be (Guo and Lua, 2003). The most widely used commercial active carbons have a specific surface area of the order of 600-1200 m^2/g. The pore volume limits the size of the molecules that can be adsorbed whiles the surface area limits the amount of material which can be adsorbed, assuming a suitable molecular size. The adsorptive capacity of adsorbent is related to its internal surface area and pore volume (Hu and Srinivasan, 1999).

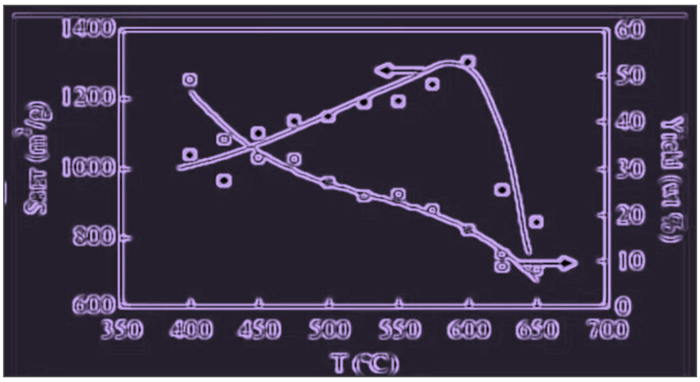

Figure 5a. *BET before adsorption*

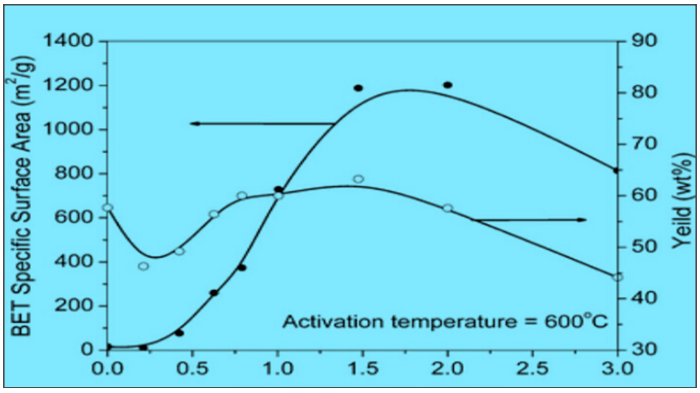

Figure 5b. *BET after adsorption*

3.2.3 Scanning Electron Microscopy (SEM)

SEM was used to observe the surface physical morphology of the adsorbent.

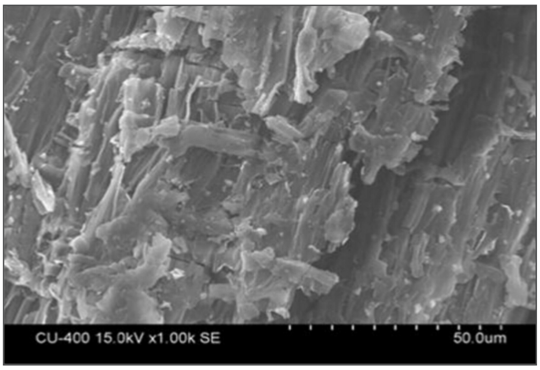

Figure 6a. *Surface Morphology of the activated carbon before adsorption*

SEM analysis is been carried out to study the physical surface morphology of the activated carbon. Figure 6 shows the presence of some flaky structures and pores which are quite poor in porous cavity. But after adsorption, there would be the presence of wide pore from the various variations. The wide pore space is attributed to the activation done on it.

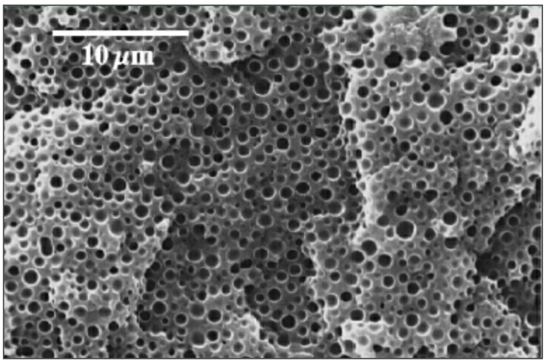

Figure 6b. *Surface Morphology of the activated carbon after adsorption*

3.2.4 Thermo-Gravimetric Analysis (TGA)

The Figure 7 shows the thermo-gravimetric analysis of the adsorbent. In this analysis, the adsorbent was measured continuously while subjected to heating. There was a steady decomposition (loss of mass) of the adsorbent and a rapid loss at a temperature between 220^{O}C to 350^{O}C.The loss is attributed to the elimination of water absorbed in the pores of the carbon (Mettler Toledo, 2001)

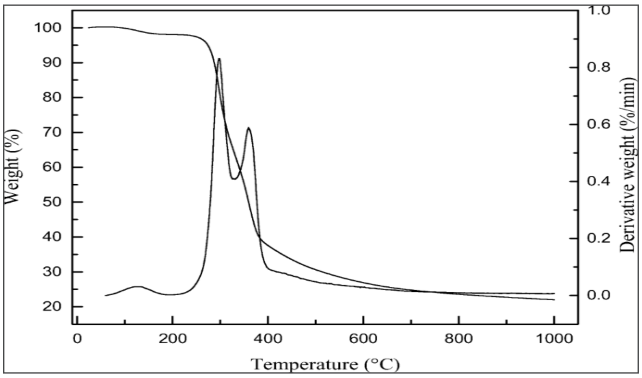

Figure 7. *TGA before adsorption*

Table 3. *Quantity of CO2 Adsorbed at 1l/min*

Time (Min)	CO_2 uptake (0.5g) mg	CO_2 uptake (1.0g) mg	CO_2 uptake (1.5g) mg	q_t(0.5g) (mg)	q_t(1.0g) (mg)	q_t(1.5g) (mg)
10	8.5	17.5	27.9	17.0	17.5	18.6
20	15.2	39.0	63.0	30.4	39.0	42.0
30	21.9	50.0	81.0	43.8	50.0	54.0
40	26.0	58.0	92.0	52.0	58.0	61.3
50	28.6	60.0	97.5	57.2	60.0	65.0
60	28.6	60.0	97.5	57.2	60.0	65.0

Table 4. *Quantity of CO2 Adsorbed at 2l/Min*

Time (Min)	CO_2 uptake (0.5g) mg	CO_2 uptake (1.0g) mg	CO_2 uptake (1.5g) mg	q_t(0.5g) (mg)	q_t(1.0g) (mg)	q_t(1.5g) (mg)
10	7.6	17.0	30.0	15.2	17.0	20.0
20	15.2	35.0	69.0	30.4	35.0	46.0
30	26.3	39.0	93.0	52.6	59.0	62.0
40	21.7	45.0	88.5	43.4	45.0	59.0
50	28.9	61.0	102.0	57.8	61.0	68.0
60	28.9	61.0	102.0	57.8	61.0	68.0

Table 5. *Quantity of CO2 Adsorbed at 3l/Min*

Time (Min)	CO_2 uptake (0.5g) mg	CO_2 uptake (1.0g) mg	CO_2 uptake (1.5g) mg	q_t(0.5g) (mg)	q_t(1.0g) (mg)	q_t(1.5g) (mg)
10	9.5	23.0	37.5	19.0	23.0	25.0
20	15.1	35.0	64.5	30.2	35.0	43.0
30	26.9	60.0	94.5	53.8	60.0	63.0
40	22.7	48.0	87.0	45.4	48.0	58.0
50	27.4	63.0	105.0	54.8	63.0	70.0
60	27.4	63.0	105.0	54.8	63.0	70.0

4. Conclusion and Recommendation

4.1 Conclusion

CO_2 adsorption study using activated carbon has been carried out, from the results gotten, it can be deduced that activated carbon is a better adsorbent compared to other adsorbents such as zeolites, kaolin, etc; (from the previous research using zeolites and kaolin as adsorbents). From the results of the characterization of the activated carbon, the activated carbon has a very good sorption capacity which makes it a better performer in CO_2 adsorption. The adsorption capacity of each of the masses are; 0.057, 0.060 and 0.065mg/g with flow rate of 1L/min; 0.058, 0.061 and 0.068mg/g with flow rate of 2L/Min and 0.055, 0.063 and 0.070mg/m with the flow rate of 3L/Min at 50 Minutes and 298K.

The differences in the amounts of CO_2 adsorbed could be attributed to the differences in pore volume and surface area which could be as the result of differences in surface area.

The surface area of the activated carbon is $328m^2/g$ and the adsorption capacities of each mass of the adsorbent loaded are good. A very good and porous activated carbon with a high adsorption capacity produced from coconut shell and used in this work had a better CO_2 adsorption capacity compared to other adsorbents such as zeolites and kaolin for both commercial and laboratory use because of the larger pore size.

4.2 Recommendations

Carbon dioxide (CO_2) capture is a broad research topic with different and lots of its aspects examined; therefore, just one research work cannot cover all necessary variables as far as CO_2capture is concerned. The fact that there is always room for improvement has also made it necessary that recommendations should be made to open up broader gate for more research on the topic. Therefore, the following recommendations are made as regards this work.

- The experiment should be carried out at different temperature using coconut shell activated carbon just like what (Adilla et al., 2013) did using different activated carbon.
- AThermo-gravimetric analyzers should be used instead of the adsorption column due to the difficulty in measurement using the analytical weighing balance.

5. References

1. Adilla, N., Yusup, S., & Hameed, B.H. (2013). Kinetic studies on carbon dioxide capture Adsorption and Diffusion; Karge, H. G., Weitkamp, J., Eds.; Springer-Verlag Berlin Heidelberg, 2008; Vol. 53.
2. Akinloye, D. N. (2024a). Grandparent-grandchild Communication Synthesis of Integrative Model. Psychology Nexus, 1(1), 1-15
3. Akinloye, D. N. (2024b). Communication in Divorced Families with Adult Children: A Literature. Annals of Journalism and Mass Communication, 3(1), 70-79
4. Akinloye, D. N. (2025). Communication Patterns and the Influence of Social Media Contents on Young Adults' Wellbeing in Texas, United States of America. Journal of Communication, 6(2), 1-22.
5. Biochar: Production, Characterization, and Applications; Yong Sik Ok, Sophie M. Uchimiya,

Scott X. Chang, N. B., Ed.; CRC Press, 2015.

6. Brunauer, S.; Emmett, P. H.; Teller, E. Adsorption of Gases in Multimolecular Layers. J. Am. Chem. Soc. 1938, 60 (1), 309.
7. Cruz, D. C.; Berruti, F.; Briens, C. Production of Bio-Coal and Activated Carbon from Biomass. 2012, 1 (I), 30.
8. Fernandes, M. B.; Skjemstad, J. O.; Johnson, B. B.; Wells, J. D.; Brooks, P. Characterization of Carbonaceous Combustion Residues. I. Morphological, Elemental and Spectroscopic Features. Chemosphere 2003, 51, 785.
9. García, S.; Gil, M. V.; Martín, C. F.; Pis, J. J.; Rubiera, F.; Pevida, C. Breakthrough Adsorption Study of a Commercial Activated Carbon for Pre-Combustion CO2 Capture. Chem. Eng. J. 2011, 171 (2), 549.
10. Herzog, H.; Meldon, J.; Hatton, A. Advanced Post-Combustion CO 2 Capture; 2009.
11. Jang, D.-I.; Park, S.-J. Influence of Nickel Oxide on Carbon Dioxide Adsorption Behaviors of Activated Carbons. Fuel 2012, 102, 439.
12. Konduru, N.; Lindner, P.; Assaf-anid, N. M. Curbing the Greenhouse Effect by Carbon Dioxide Adsorption with Zeolite 13X. AlChE J. 2007, 53 (12), 3137.
13. Lastoskie, C.; Gubbins, K. E.; Quirke, N. Pore Size Distribution Analysis of Microporous Carbons: A Density Functional Theory Approach. J. Phys. Chem. 1993, 97 (18), 4786.
14. Leung, D. Y. C.; Caramanna, G.; Maroto-Valer, M. M. An Overview of Current Status of Carbon Dioxide Capture and Storage Technologies. Renew. Sustain. Energy Rev. 2014, 39, 426.
15. Liu, Y.; Wilcox, J. Molecular Simulation Studies of CO2 Adsorption by Carbon Model Compounds for Carbon Capture and Sequestration Applications. Environ. Sci. Technol. 2013, 47, 95.
16. Plaza, M. G., García, S., Rubiera, F., Pis, J. J., and Pevida, C. (2010). Post-Combustion CO_2 Capture with a Commercial Activated Carbon: Comparison of Different Regeneration Strategies. Chem. Eng. J., 163 (1–2), 41.
17. Shahkarami, S.; Dalai, A. K.; Soltan, J.; Hu, Y.; Wang, D. Selective CO2 Capture by Activated Carbons: Evaluation of the Effects of Precursors and Pyrolysis Process. Energy & Fuels 2015, 29, 7433.
18. Sing, K. S. W.; Everett, D. H.; Haul, R. a. W.; Moscou, L.; Pierotti, R. a.; Rouquérol, J.; Siemieniewska, T. Reporting Physisorption Data for Gas/Solid Systems. Pure Appl. Chem. 1982, 54 (11), 2201.
19. Somy, A.; Mehrnia, M. R.; Amrei, H. D.; Ghanizadeh, A.; Safari, M. Adsorption of Carbon Dioxide Using Impregnated Activated Carbon Promoted by Zinc. Int. J. Greenh. Gas Control 2009, 3, 249.
20. Su, F.; Lu, C.; Cnen, W.; Bai, H.; Hwang, J. F. Capture of CO_2 from Flue Gas via Multiwalled Carbon Nanotubes. Sci. Total Environ. 2009, 407 (8), 3017.
21. Udorah, F. N., & Adeniran, A. O. (2025). A Meta-Study on Smart Coating with Carbon Nanoparticles. Journal of Environmental Engineering and Energy, 2(1), 44-63.
22. US Department of Commerce, NOAA, E. S. R. L. ESRL Global Monitoring Division - Global Greenhouse Gas Reference Network http://www.esrl.noaa.gov/gmd/ccgg/trends/ (accessed Jan 6, 2016).
23. Wang, S.; Yan, S.; Ma, X.; Gong, J. Recent Advances in Capture of Carbon Dioxide 125 Using Alkali-Metal-Based Oxides. Energy Environ. Sci. 2011, 4, 3805.
24. Yang, R. T. Adsorbents: Fundamentals and Applications; John Wiley & Sons, 2003.
25. Zevenhoven, R.; Kilpinen, P. Flue Gases and Fuel Gases. In Control of Pollutants in Flue Gases and Fuel Gases; 2001; p 2.1-2.12.