American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-11, Issue-11, pp-96-109
www.ajer.org
Research Paper Open Access

# Physicochemical Characteristics of Activated Carbon Produced From Different Species (Hass & Reed) Of Nigerian Avocado Seeds

[1]Onwugbuta, N.E, [2]Ademiluyi, F.T., [3]Abam, T.K.S, [4]. Youdeowei, P.O.

*[1]Institute of Geoscience and Environmental Management, Rivers State University, Port Harcourt.*
*Dept of Environmental Management and Control, Rivers State University, Port Harcourt.*
*[2] Dept of Chemical/Petrochemical Engineering, Rivers State University, Port Harcourt.*
*Corresponding Email: nobleezebuchi@gmail.com*

***ABSTRACT***
*This study was aimed for the production of activated carbon from two different species of avocado Seeds(Hass and Reed).Physicochemical characteristics of activated carbons produced from two different species of avocado seeds which could be used for the adsorption of organic contaminants from wastewater was determined.The investigationof the effects of the activating agent onthe bulk density, ash content, moisture content, iodine number, percentage yield, percentage burn off, pore size distribution, specific surface area pH and Scanning Electron Microscopy (SEM) was done.In the course of this study, avocado seeds were carbonized at optimum temperature achieved at 270$^0$C with residence time of 150mins for both species. The pyrolysis of Hass and Reed species of avocado seeds at 270$^0$C under inert atmospheric conditions yielded 620g of Reed avocado char and 630g of Hass avocado char respectively; this represent63% and 62% of the original biomasses of Reed and Hass avocado seeds which were activated with Sulfuric acid of 0.2M at 600$^0$C to produce avocado seed activated carbon. The results of the analyses show that the bulk density range from 0.3g/cm$^3$ to 0.4g/cm$^3$; activated carbon exhibitedsurface areas of 525.725 m$^2$/gand 542.265m$^2$/g and micro pore volumes of2.70 cm$^3$/g and 3.669 cm$^3$/g. Ash content of Reed and Hass species of ASAC (5.32 % &5.84 %) reported in this study were good; this showed that there was enough time for total vaporization of the inorganic minerals in the carbon. The iodine number determined suggested that the iodine adsorption of Hass and Reed avocado seeds activated carbon prepared with 0.2M $H_2SO_4$ with 600$^0$C activation temperaturewere 2,424 g/kg and 2,375 g/kg which are comparable with the iodine number of commercial activated carbon.The avocado seed activated carbon and raw avocado seeds were further characterized by Scanning Electronic Microscopic and X-ray Diffraction; raw avocado seeds indicated rough surface structure with irregular shapes and a significant structure with dense agglomerated structures while the activated carbon had pores of smaller sizes with irregular shapes and fragment of particles basically mesoporous with lower microporous contribution. The XRD pattern of the Reed and Hass avocado seed activated carbon samples displayed broad and long features at 26$^0$ with weak diffracting peaks at 2Θ 20$^0$C, 25$^0$C, 30$^0$C, 35$^0$C, 40$^0$C, 45$^0$C, 50$^0$C, 55$^0$C,60$^0$C, 65$^0$C and 70$^0$C respectively.A significant percentage avocado seed activated carbon is needed for an economic viable production of activated carbon. Hence,activated carbon produced from Reed and Hass species of avocado seeds displayed a high percentage yield with quality physiochemical characteristics as superior as commercial activated carbon.*

***Keywords:*** *Activatedcarbon, carbonization, pyrolysis, avocado seeds, Hass, Reed,physicochemical, characterization.*

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Date of Submission: 06-11-2022 Date of acceptance: 20-11-2022

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## I. INRODUCTION

Over the years, activated carbon has been used as an adsorbent for the adsorption of a wide range of organic and inorganic contaminants from water and wastewater because of their well-developed micropores internal structures, high surface area of between 500-1500m$^2$/g and a large range of surface internal functional groups. Activated carbons of high surface area and porosity are prepared readily from available carbonaceous materials such as wood, coal, coconut shells, bamboo and other agricultural wastes by some activation process.

These carbonaceous precursors have the removal efficiency for inorganic and organic pollutants from water and industrial waste water streams(Zhao *et al;* 2011).

Activated carbon produced from agricultural wastes have economic potential and impacts on the environment. First, unwanted agricultural wastes are converted to useful adsorbents of high value. Second, activated carbon are widely used for the removal of organic and inorganic contaminants from the environment. Third, it reduces the importation of commercial activated carbon thereby impacting positively on the economy of the country (Abia*et al.*, 2003; Michuki 2015).

The use of low-cost adsorbent for the removal of TOC from produced water offers some benefits in solving environmental pollution problems.First, there is reduction in the volume of waste material and second, when the adsorbents are well harnessed, could be used in the treatment of industrial waste water at a low cost. These low-cost adsorbents are cheap and available locally from almond shell, hazelnut shell poplar; walnut, saw dust, rice husk, sugar cane bagasse, coconut bunch waste etc.

However, adsorption on low-cost adsorbent materials have been found to be most attractive due to its universal nature and ease of operation, inexpensiveness and as an economically viable technique for the removal of organic contaminants from wastewater. Adsorption on activated carbon is very important because it is the organic substances in particular that are dissolved and difficult to decompose, as they could be selectively removed by activated carbon (Ademiluyi *et al.,* 2009b).

However, existing technologies fail to eliminate small suspended oil particles and dissolved elements and most chemical methods of treatments have high initial and/or running costs and produce hazardous sludge. These treatments methods no longer suffice and there is need to supplement them by additional processing stage (Ahmadun*et al.,* 2009). Physical, chemical and biological treatment processes have been proven useful for the removal of TOC from industrial wastewater and they have their merits and demerits. These treatment methods have been found to have limitation in application, as they are either complex or not economical.

Activated carbon has been used widely for the removal of TOC due to its large surface area and different kinds of reactive surface sites. US Environmental Protection Agency cited activated carbon as one of the best technologies readily available for the removal of TOC from wastewater (Asenjo*et al.*, 2011).

Therefore, themainobjectives of this study are; to produce activated and un-activated carbons from different species of avocado seeds with pyrolytic process in the laboratory, to characterize the activated carbon produced from avocado seeds using activating agent so that it could be used for the removal of organic contaminants from industrial wastewater

## II. Materials and Methods

### 2.1 Materials

The following materials and laboratory apparatus were used for this study: two species of avocado seeds (Hass & Reed) from Orlu Local Government Area of Imo State were used as precursor materials. Sulfuric acid was used as an activating agent, deionized water, locally fabricated pyrolytic reactor was used for carbonization of the avocado seeds with glass condenser to condense the product from pyrolysis, other materials used are Ohaus top loading Balance, electronic analytical weighing balance, electronic muffle furnace, fume cupboard, electronic oven, oven trays, refrigerator, Whitman filter papers, mortar, pistol, pH meter, beakers, measuring cylinder, volumetric flasks, spatula, 5 ml syringes, centrifuge, thermometer, temperature controlled water bath shaker, pipettes, funnels, weighing pans, desiccator, timer, sieve, ball mill ,Burettes, Conical Flasks,10ml pipette, laboratory glassware, and blender, etc.

### 2.2 Preparation of Activated Carbon

Avocado seeds of different species (Hass and Reed verities) were collected from different local fruits markets in Port Harcourt Rivers State, Nigeria and washed with deionized water. The known weight of avocado seeds was cut into small sizes and grind with hand grinder or high-power electric blender to approximately 2-3 mm, the resulting particles were dried in the laboratory electrical oven at 105 $^{0}$C for about 2-3 hours (Michuki 2015; Kassahun *et al.,* 2016). Figures 1 and 2 present Nigerian Hass and Reed Avocado Seeds**.**



**Figure 1:** Nigerian Hass Avocado Seeds. **Figure 2:** Nigerian Reed Avocado Seeds.

### 2.3 Carbonization Process

The Pyrolytic reactor system was set up and 1.00 kg of 2-3mm avocado particles was collected and weighed into a reactor for carbonization. The pieces of avocado seeds were pyrolyzed at a temperature of 270 ± 50C. Gases were emitted and condensed into a black oily liquid released from the pieces of avocado seeds which was collected with a calibrated measuring cylinder and it was constant for 30 minutes. The charred products formed during the process of carbonization was allowed to cool to room temperature. The charred products were crushed with mortar and pistol and sieved with a standard manual mesh size of 2.80mm. The percentage yield of carbonization was calculated from the weight of avocado seeds before carbonization (Wb) and the weight after carbonization (Wa). According to Yoshiyuki and Yutaka (2003), the percentage yield of carbonization is calculated as stated below:

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

### 2.4 Chemical Activation Process

50g of carbonized avocado seeds samples was weighed carefully and poured into beakers containing some known quantities of Sulfuric acid with concentrations of 0.2M in the ratio of 1:2 (g/vol). The samples were thoroughly mixed and impregnated for 4 hours till paste was formed. The samples were be transferred into the petri dishes and dried in the oven at 120$^0$C for 3 hours before they were placed in a muffle furnace and this was heated up to 600$^0$C for 1 hour. The activated carbon produced was removed from the muffle furnace then allowed to cool at room temperature and washed with distilled water to remove residual acids. The washing was completed at pH of 6-7 of the wash wastewaters. The activated carbons produced was oven dried at 120$^0$C for 4 hours and allowed to cool in a room temperature. The final products were kept in an air tight polyethylene bag for characterization and ready to be used (Ademiluyi & Braide 2012; Olatunji *et al.*,2017).

**Figure 3:** Hass AvocadoSeeds Before Carbonization**. Figure 4:** Reed Avocado Seed Before Carbonization.


**Figure 5:** Hass and Reed Avocado Seeds Activated Carbon**.**

### 2.5 Characterization of Activated Carbons Produced from Avocado Seeds

Many analytical techniques such as X-ray Fluorescence (XRF) Spectroscopy, Brunauer-Emmett-Teller (BET) Model, X-ray Diffraction(XRF) Analysis, Scanning Electron Microscopy (SEM), $N_2$ Isotherms, Fourier Transform Infrared Spectroscopy (FTIS), and surface area analyzer were used for the characterization of Avocado Seed activated carbon and this involves the determination of its properties such as pore volume, bulk density, moisture content, percentage burn off, ash content, benzene adsorption, particle size, iodine number and methylene blue (Ademiluyi *et al.*, 2007; Ololade 2017). ASTM methods was used to characterize (methylene blue number, bulk density, iodine number etc.) the activated carbons were produced from avocado seeds (Ademiluyi *et al.*, 2012).

#### 2.5.1 Determination of Ash Content

The ash content of the pyrolyzed avocado seeds activated carbon was determined by the use of the standard test method (ASTM D2866094). 10g of the activated carbon was measured and record as $D_i$ and it was put into the muffle furnace at the temperature of $600^0$C for an hour. It was removed from the muffle furnace and left to cool at room temperature before it was weighted and recorded as $D_f$.The percentage ash content will be determined using equation 3.6 Ash content, % = Weight of ash (g)/ Initial weight of sample (g) x 100%

Ash content $$\% = \frac{D_f}{D_i} \ x \ 100 \qquad (2)$$

Where; $D_i$ = Initial weight of sample and $D_f$= Final weight of sample (Anisuzzaman*et al.*, 2015; Olatunji *et al.*,2017).

#### 2.5.2 Determination of Bulk Density

The bulk density of the avocado seeds activated carbons were determined by weighing an empty measuring cylinder and the weight was recorded. Different samples of species of avocado seeds activated carbon were measured into a known weight of glass measuring cylinder and samples were compacted by tapping on the top of laboratory bench till the volume of the samples in the cylinders stopped reducing or decreasing. The volume and the mass of the sample were recorded (Yoshiyuki & Yutaka 2003; Olatunji 2017). The bulk density was calculated using equation 3.

$$\rho = Masss / Volume\, Occupied \ (\frac{g}{cm^3}) \qquad (3)$$

#### 2.5.3 Determination of Percentage Burn Off

10g of carbonized chars were accurately weighed and recorded as $W_a$and it was subjected to activation process at $600^0$C for an hour. The samples were removed from the muffle furnace and allowed to cool to a room temperature before it was weighted and recorded as $W_i$. The percentage burn off of the sampleswere determined using equation 4.

$$\% burn-off \; \frac{Wa - Wi}{Wa} \; x\,100 \qquad (4)$$

Where; Wa = Weight of char after pyrolysis,

Wi = Weight of carbon after activation

(Itodo*et al.,* 2010; Olatunji 2017).

### 2.5.4 Determination of Iodine Number

1.00g of avocado seeds activated carbon of Reed and Hass species and concentration of activating agent was properly mixed with 30 ml of 0.1M of standard solution of iodine in a beaker and left for 24 hours and filtered with filter paper. 10 ml of the filtered solution of avocado seeds activated carbon samples was measured into a beaker, 2 drops of starch was added as an indicator into each of the solutions. The solution formed was titrated against 0.1M sodium thiosulphate until it became colorless and the initial and final readings was taken for each of the samples. The iodine number was calculated using equation 5.

$$\mathrm{I} = B - \frac{S}{B} x \frac{V}{W} x\; M\; x\, 126.91 \qquad (5)$$

Where; B = blank reading (ml), M = molarity, S = volume of iodine solution used (ml)
W = weight of activated carbon samples used (g), v = volume of iodine used (ml) (Olatunji et *al*; 2017; Evwierhoma*et al.,* 2018).

### 2.5.5 Determination of Percentage Yield

The percentage yield of avocado seed activated carbon was determined by weighing the mass of the original precursor and the mass of the activated carbon after activation process.

$$\%\ yeild\ = \frac{W_f}{W_f} x100 \qquad \text{Wi/Wf} \qquad (6)$$

Where; Wi = initial mass of dry impregnated sample,
$W_f$ = final mass of sample at the end of the activation process (Anisuzzaman *et al.,* 2015; Olatunji 2017).

### 2.5.6 Determination of Moisture Content

The moisture content in the avocado seed activated carbon was determined using SIRIM method (1984). 5.0g of avocado seed activated carbon was placed in an oven at 110$^o$C for 2 hours. The sample were allowed to cool in a desiccator and weighed repeatedly. The moisture content was calculated using equation below:

Moisture Content % =
(7)

$$\frac{Initial\ Weight\ (g) - Final\ Weight\ (g)}{Final\ Weight\ (g)}\ x\ 100\%\ (Dry\ Basis)$$

(Anisuzzaman*et al.,* 2015).

### 2.5.7 Determination of Pore Size Distribution and Specific Surface Area

The pore size distribution and specific surface area of avocado seed activated carbon were determined by the use of Brunauer Emmet and Teller (BET) method. The Brunuar Emmet and Teller (BET) surface area and pore size distribution were determined by nitrogen isotherm at 77.350K using Quanta Chrome Nova Win-Data Acquisition Auto-sorb Automated gas sorption instrument. Before the analysis, the avocado seeds activated carbon were out gassed under a vacuum at 110$^0$C for 12 hours. The surface area of the adsorbents was determined in line with the BET method at the relative pressure range of 0.05 to 0.3 (Anisuzzaman*et al.,*2015).

### 2.5.8 Determination of pH of Avocado Seed Activated Carbons

The pH determination of Hass and Reed species of avocado seed activated carbon were determined with the use of pH meter. 1.0g of avocado seed activated carbons were weighed into a 20ml Erlenmeyer flasks. 100ml of distilled water was added and heated to boil gentling. The solutions were allowed to cool to a room temperature before diluted with distilled water to 100ml. They were stirred and their pH were determined immediately (Anisuzzaman*et al.,* 2015).

### 2.5.9 Scanning Electron Microscopy (SEM) Analysis

Scanning Electron Microscopy (SEM) is an instrument that uses electron beam to scan over the surface of a sample that is coated with a metal of thin layer. The secondary electron will be collected by a detector which produces a three-dimensional image on the desk top screen (Anisuzzaman*et al.*, 2015). SEM was used to observe the pore structure, morphology and structural changes of avocado seeds activated carbon (Wang *et al.*, 2011; Anisuzzaman*et al.*, 2015). Avocado seed activated carbon was prepared and kept at the sample placement. Scanning Electron Microscopy (SEM) (JEOL JSEM-5610LV, Japan) will be running to determine the characteristics of the adsorbents.

## III. RESULTS AND DISCUSSION

### 4.1 Characterization of Activated Carbon from Avocado Seeds

### 4.1.1 Physicochemical Characteristics of Avocado Seeds Activated Carbon

Physicochemical characteristics of activated carbons produced from two different species of avocado Seeds are shown in Tables 1,2 and 3 Show that the characterizations of different species of avocado seed activated carbon used for the adsorption of organic contaminants from wastewater; bulk density, ash content, moisture content, methylene & iodine number (which measures the level of activity and the content of micro pore content of avocado seed activated carbon) show high degree of activation which is in agreement with the studies carried out by (Olatunji *et al.*, 2017), Kassahun *et al.*, (2016) on preparation and characterization of activated carbon from Avocado Pear Seed with $H_2SO_4$, $HNO_3$, $H_3PO_4$ Activating agents; removal of phenol from water with activated carbon synthesized from avocado kernel seed.

**Table 1:** Textural Properties of Hass and Reed Avocado Seeds Activated Carbon.

| Parameters | HASS ASAC | REED ASAC |
|---|---|---|
| Pore volume (nm/g) | 0.136 | 0.190 |
| Pore Dimeter (nm) | 2.647 | 2.740 |
| Micro Pore Volume (cc/g) | 2.70 | 3.669 |
| Surface Area ($m^2$/g) | 530.442 | 542.265 |
| Micro Pore Surface Area ($m^2$/g) | 525.723 | 657.294 |
| Average Pore Width (nm) | 6.435 | 5.555 |

**Table 2:** Physicochemical and Proximate Analysis of Hass and Reed Avocado Seeds Activated Carbon (ASAC)

| Parameters | Hass ASAC | Reed ASAC | Referenced activated Carbon |
|---|---|---|---|
| Bulk density (g/m3) | 0.4 | 0.3 | 0.2-0.6 Ademiluyi &Ujile (2013); Long &Criscione (2003). |
| Moisture Content (%) | 5.6 | 4.69 | 2.70-15 Ademiluyi &Ujile 2013; Melcalf& Eddy (2003) |
| Ash Content (%) | 14.32 | 14.79 | |
| Ph | 7.8 | 7.9 | |
| Iodine Number (g of iodine/kg of C) | 2,424 | 2,375 | 500-1200 Ademiluyi &Ujile (2013); Long &Criscion (2003) |
| Porosity | - | - | |
| Average Particle Size (µm) | 300 | 300 | |

**Table 3: Element Composition of Hass and Reed Avocado Seed Activated Carbon**

| Element Composition | HASS ASAC | REED ASAC |
|---|---|---|
| Carbon | 67.83 | 50.28 |
| Potassium | 8.4 | 13.52 |
| Sulphur | 7.61 | 7.53 |
| Aluminum | 1.21 | 7.18 |
| Silver | 0 | 1.79 |
| Phosphorus | 2.04 | 4.49 |
| Calcium | 0.7 | 2.8 |
| Oxygen | 7.97 | 5.67 |
| Chlorine | 0.39 | 1.93 |
| Silicon | 0.89 | 1.43 |

| | | |
|---|---|---|
| Magnesium | 0 | 0.58 |
| Iron | 1.03 | 0.35 |
| Titanium | 0 | 0.61 |
| Sodium | 0 | 0 |
| Zinc | 0 | 0 |
| Nitrogen | 1.92 | 0 |

### 4.1.2 Specific Surface Area of Avocado Seed Activated Carbon

Table 1 shows that textural properties of HASS and REED avocado seeds activated carbon. It displays the external surface area, surface area, micropore area, total pore volume, micropore and mesopore volumes. It can be noted that the textural features of REED are higher than HASS; for instance, the pore volume (0.190 nm/g: 0.136nm/g), pore diameter (2.740nm:2.647nm), micro pore volume (3.669cc/g: 2.70 cc/g), Surface area (542.265 $m^2$/g: 530.442 $m^2$/g) and micro pore surface area (657.294 $m^2$/g: 525.723 $m^2$/g). This suggest that avocado seed activated carbon surface area and pore volume play vital role during the adsorption of contaminants from wastewater. This is in agreement with the previous study carried out by Anderson *et al.*, (2017); they reported that avocado seed activated carbon were composed of mesopore of diameter within 2-50nm, total surface area of 1,433$m^2$g-$^1$, mesopore surface area of 279.1$m^2$ $g^{-1}$ and external surface area of 1,153$m^2$ $g^{-1.}$

The value of the specific area of the two species of avocado seeds activated carbon are comparable to the value reported by Leite*et al.*, (2017) who produced avocado seed activated carbon of high specific surface area in the range of 1,122 $m^2$ g-$^1$ to 1584 $m^2$ g-$^1$ intheir study of activated carbons produced from avocado seed; optimization and application for the adsorption of several emerging organic compounds.

The activated Reed and Hass species of avocado seeds surface areas were 525.725 $m_2$/g and 542.265$m^2$/g as well micro-pore volume of 2.70 $cm^3$/g and 3.669 $cm^3$/g respectively. This combination of micro-meso pores has yielded avocado seeds activated carbon with a significant aqueous adsorption capacity.

### 4.1.3 Bulk Density of Avocado Seed Activated Carbons

Bulk density is one of the very vital properties of activated carbon as it measures the quantity of contaminants the activated carbon can hold per unit volume. The higher the bulk density the better the quality of activated carbon; this is because of more volume that are available for adsorption. It was observed that the bulk density of Hass and Reed avocado seeds activated carbons are in agreement with what was reported by (Ademuliyi&Ujile 2013; Olatunji *et al.*, 2017) and that of commercial activated carbon. The bulk density of Hass and Reed was within the range of (0.3-0.4g/$cm^3$).

### 4.1.4 Iodine of Avocado Seed Activated Carbons

Iodine number is one of the techniques used to determine the adsorption capacity of activated carbons. It measures the micropore content of the activated carbon by the adsorption of iodine from the solution. From the result of this study, it is observed that the iodine number for Hass (2,424 g/kg) was higher than the iodine number for Reed (2,375 g/kg). These agree with commercial activated carbon iodine number range from 300 to 1200g/kg and above which is great. Other studies carried out by (Olatunji *et al.*, 2017) on adsorptive property of avocado seeds activated carbon suggests that avocado seed is a great source of raw material for the production activated carbon of high removal efficiency. This high adsorptive property is attributed to the activation with 0.2M sulfuric acid with activation temperature at 600$^0$C owing to the extensive degradation of volatile matter and high micropore content on the activated carbon surface. More so, high iodine number for Reed and Hass indicates that iodine number is an important parameter used for the characterization of the performance of activated carbon; this suggest high degree activated which is in agreement with the study by (Aziza *et al.*,2008; Itodo*et al.*, 2010; Olatunji *et al.*, 2017).

### 4.1.5 Product Yield of Activated Carbon Produced from Avocado Seeds

Figure 4.1 shows the percentage Activation yield of Reed and Hass species of Avocado seeds. As shown in Figure 6, the pyrolysis of 1.00kg Hass and Reed species of avocado seeds at 270$^0$C under inert atmospheric conditions as shown in Figure 1 yielded 620g of Reed avocado char and 630g of Hass avocado char respectively; this represents 62 % and 63% of the original biomasses of Reed and Hass avocado seeds.

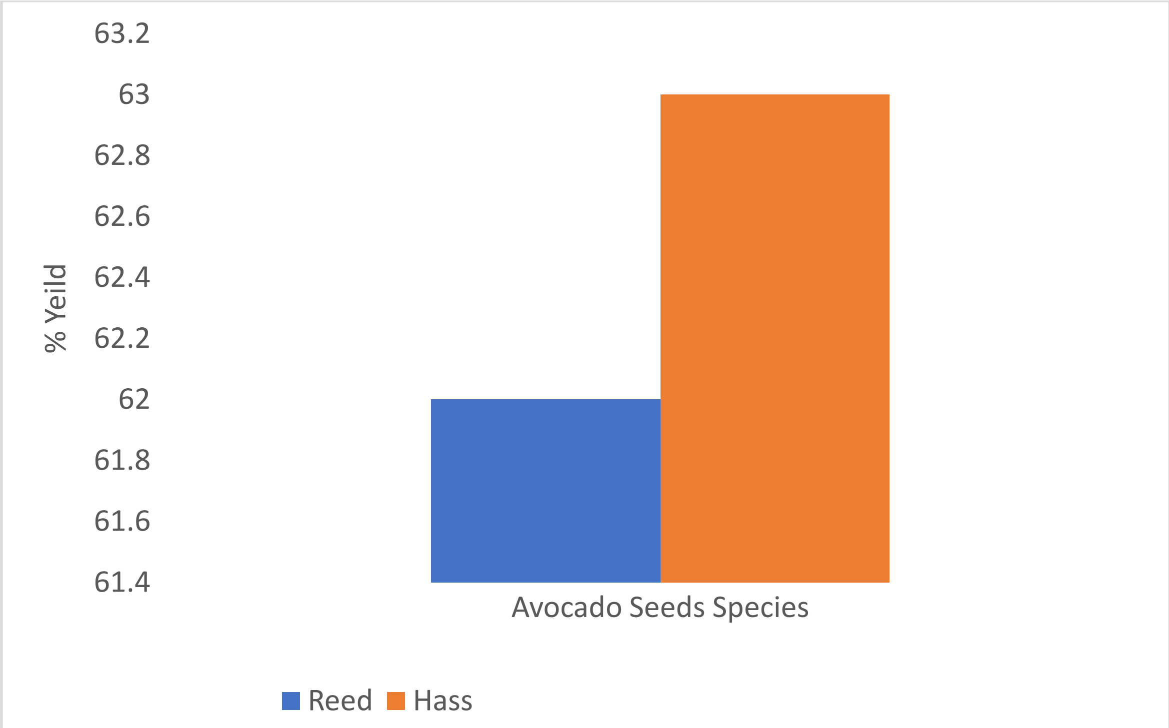



**Figure6: Percentage Activation Yield for Reed and Hass Species of Avocado seeds**

The pyrolysis of Hass and Reed species of avocado seeds were carried in a reactor at the temperatures ranging from 0 to 270$^0$C and heating rating of 5$^o$C/minutes. Figures 7 and 8 show product temperature and liquid oil yields and these describe the pyrolysis of different species of avocado seeds using different operating conditions. The quantity of char and bio-oil were measured with weighing balance and calibrated measuring cylinder (Durak&Tevfik 2015). This is in agreement with the study carried out by Sanchez *et al.*, (2016) on the transformation of residual avocado seed; they reported liquid oil yield of 53–56 wt% of the original biomass and 70–75 wt% of water; they stated that the liquids exhibited small carbon contents about 16 wt%) with high heating value of about 3 MJ/kg.

High quality activated carbons were produced by the pyrolysis of avocado seeds with optimum temperature achieved at 270$^0$C and residence times of 150minutes for both species. This is in agreement with the study carried out by (Sanches*et al.*,2017) on the granular activated carbons from avocado seeds and (Olatunji *et al.*, 2017) on the preparation and characterization of avocado pear seeds using different activating agents. A significant percentage avocado seed activated carbon is needed for an economic viable production of activated carbon. Activated carbon produced from Reed and Hass species of avocado seeds displayed a high percentage yield which is

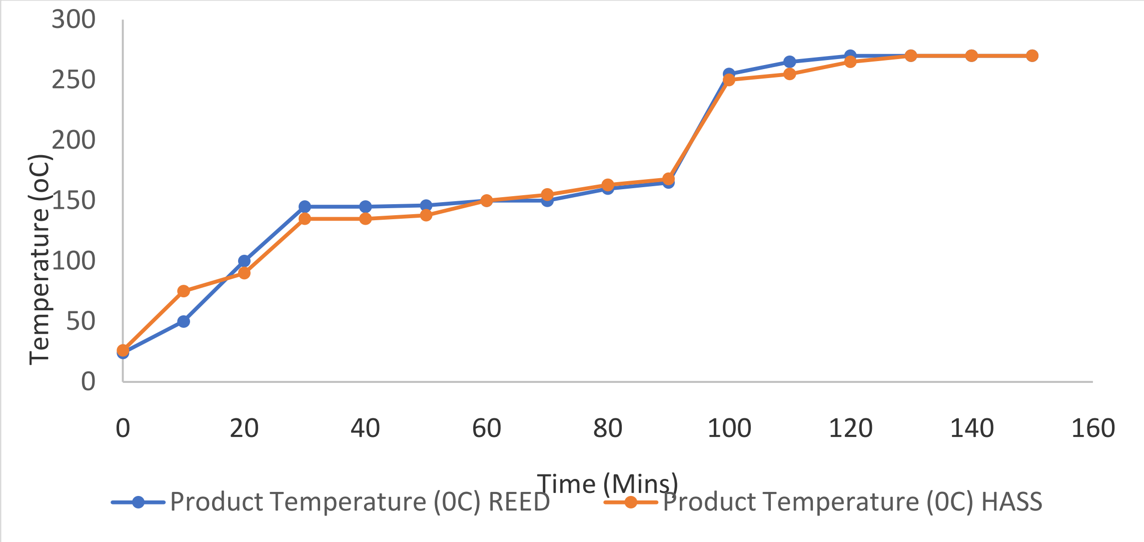



**Figure 7:** Product Temperature for the Pyrolysis of Hass and Reed Avocado Seeds

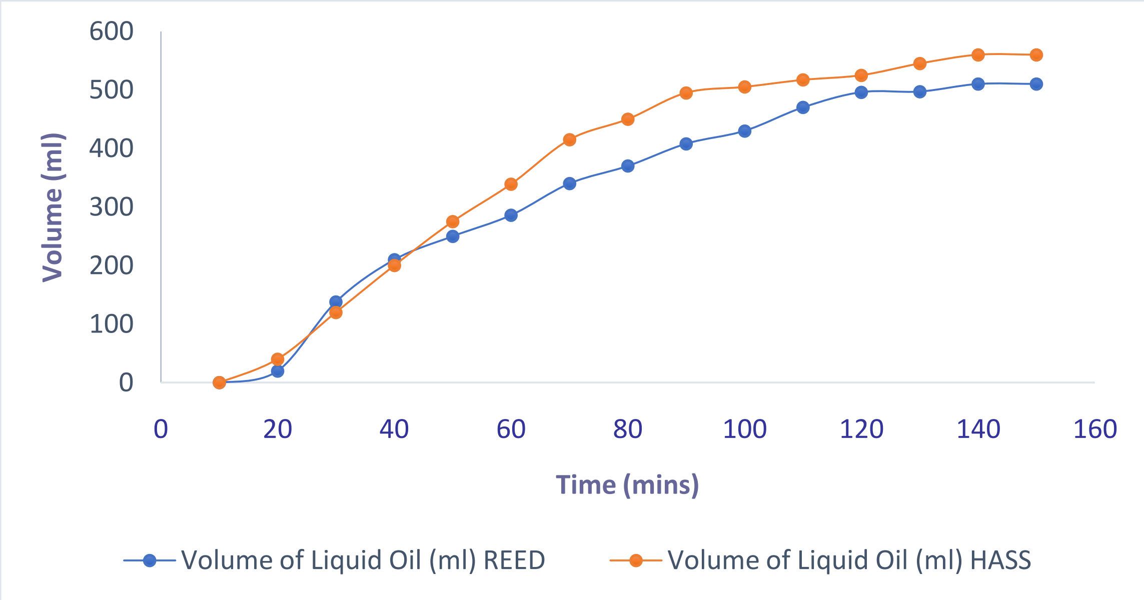



**Figure 8:** Liquid oil Yield for the Pyrolysis of Hass and Reed Avocado Seeds.

### 4.1.6 Ash Content of Activated Carbon from Avocado Seed

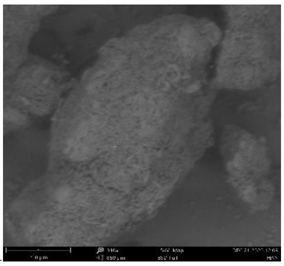
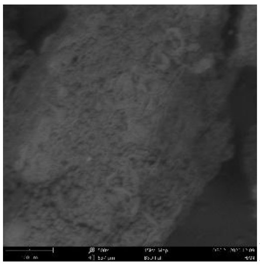
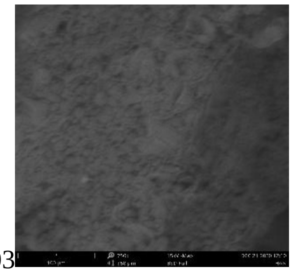
Ash content is amongst the physiochemical properties of activated carbon that influence the adsorption capacity of activated carbons; this is a measure of the level of activity, the content of micro pore of the activated carbon and has a direct relationship with porosity. Bansode*et al*., (2003), stated that ash content of activated carbon was dependent on the ash content of the parent material and the measure of inorganic impurity (activating agent) trapped in the structure of the carbon and the time of activation. In this study, the ash content of Reed and Hass species of avocado seeds activated carbon were good (5.32 % &5.84 &); this agrees with the avocado seed activated carbon ash content value of 2.4% reported by (Arukwe*et al*., 2012); 2.760 % for Nigerian bamboo activated carbon by (Ademiluyi &Ujile 2013); 4.97% for ASAC treated with HCl (Kassahun *et al*., 2016) and 5.58% for ASAC (Muluh*et al.*, 2017). Ash contents of Reed and Hass avocado seed activated carbons (5.32 % &5.84 %) reported in this study suggest that there was enough time for total vaporization of the inorganic minerals in the carbon. This is in agreement with the previously avocado pear seeds activated carbon ash content value of of between 4% and 5% reported by (Kassahun *et al.*, 2016; Muluh*et al*., 2017; Ololade*et al*., 2017). Consequently, the high ash content value reported in this study is within the range of ash contents of agricultural waste activated carbon and other commercial activated carbons (≤ 8%) (Ademiluyi &Ujile 2013; Anisuzzaman*et al.*, 2015; Olatunji *et al*., 2017).

### 4.1.6 Scanning Electron Microscopy (SEM) Analysis of Inactivated and Activated Reed and Hass Avocado Seed Carbon

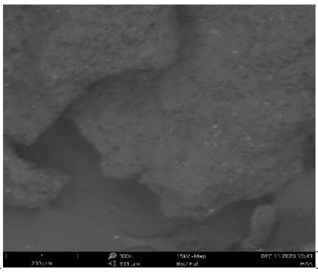
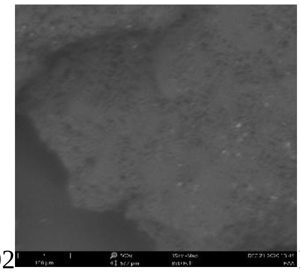
The surface morphology of different species of avocado seeds before and after activation were characterized using scanning electron microscopy (SEM) JSM-6060LV JEOL LTD., Japan). The scanning electron microscopy of the inactivated and activated species of avocado seed are presented in figures HAN001-003, HA001-003, REAN001-003 & REA001-003 respectively of 100µm, and 200µm at 300x, 500x, and 750x magnifications. The size of the avocado seed activated carbon and inactivated avocado seeds were between 100µm, and 200µm. The purpose of scanning electronic microscopy investigation was to assess the porosity of the adsorbent created during pyrolysis and activation. Activated carbon porosity that is highly developed will increase the specific surface area, hence, this will lead to the number of available active site that may be fixed upon by the molecules of organic contaminants (Tagne*et al.*, 2019). These images suggest that biomass which occur naturally are induced by pyrolysis and activation and this have led to the development of adsorbent porosity and the bursting the pores that occurred naturally (Tagne*et al.*, 2019). Figures 9-12: HAN001-003, HA001-003, REAN001-003 & REA001-003 show some pores found on the surfaces of the inactivated and activated carbons. SEM images of

Reed and Hass of raw avocado seeds indicate rough surface structure with irregular shapes and a significant structure with dense agglomerated structures which may be because of the molecules covering its surfaces partially while the SEM images of Reed and Hass avocado seed activated carbon display smoother surface texture. This is because the porous surface of raw avocado seed is filled with surfactant. The modification of adsorbent with sulfuric acid has resulted to increase in the surface area from 381.762$m^2/g$ (HAN) to 525.725 $m^2/g$ (HAA) and 371.958$m^2/g$ (REN) to 542.265$m^2/g$ (REA) respectively. The avocado seed activated carbon have pores of smaller sizes with irregular shapes and fragment of particles. Clearly observed is an agglomeration of nanoscale particles with spherical shapes and homogenous linear structure with very large surface area. The Reed and Hass materials were basically mesoporous with lower microporous contribution. Table3 shows the composition of elements in the activated carbon used in this experimental study. The characterization report shows that carbon, oxygen, potassium, silver, calcium, zinc, phosphorus, Sulphur etc. are major constituents.

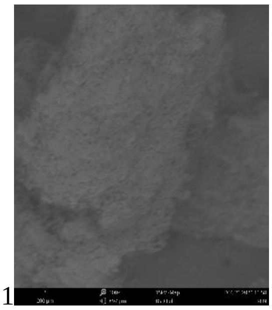
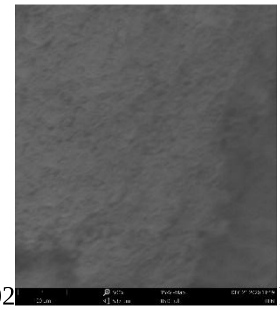
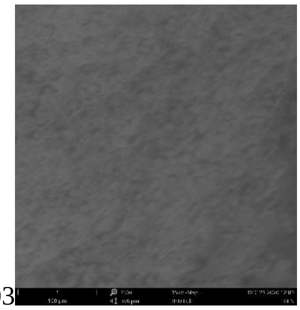
The Reed and Hass ASAC has mesopore with average pore width of 6.929 nm and 6.435nm and micropore surface areas of 568.714$m^2/g$ and 525.723 $m^2/g$ respectively as seen in Table 3. This is in agreement with the established International Union of Pure and Applied Chemistry (IUPAC) activated carbon mesopores that range from 2-50nm of the right size that is suitable to adsorb many organic and inorganic contaminate from aqueous solutions. Koehlet (2017),reported that activated carbon macropores of more than 50 nm in width would have low adsorption capacity while activated carbon micropores with width less than 2 nm are critical for the adsorption of small contaminant molecules; although they are very important in the determination of adoption kinetics with the particles of the adsorbent. The larger the pores of adsorbent are, the more transport path they provide for contaminants molecules to diffuse in the mesopores and micropore which adsorption occur (Koehlet 2017).

HAN001

HAN002

HAN003


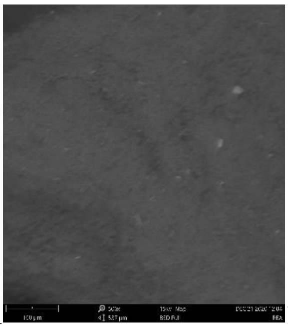
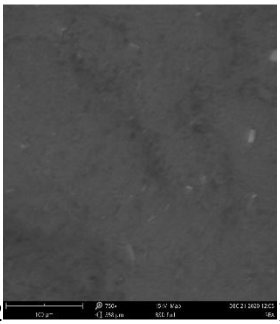
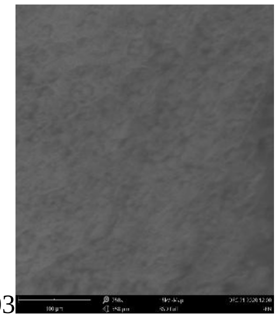
**Figures 9:** HAN001, HAN002 and HA003: ScanningElectronMicroscopy (SEM) Images of Inactivated Hass Avocado Seeds at different magnifications.

HA001  HA002  HA00 

**Figures10:** HA001, HA002 and HA003: Scanning Electron Microscopy (SEM) Images of Activated Hass Avocado Seeds at different magnifications.

REN001  REN002  REN003 

**Figures 11:** REN001, REN002 and REN003**:** Scanning Electron Microscopy (SEM) Images of Nonactivated Reed Avocado Seeds at different magnifications.

REA001  REA002  REA003 

**Figures 12:** REA001, REA002 and REA003**:** Scanning Electron Microscopy (SEM) Images of Activated Reed Avocado Seeds at different magnifications.

### 4.1.7 X-ray Diffraction (XRF) for Hass and Reed Species of Avocado Seeds Activated Carbon

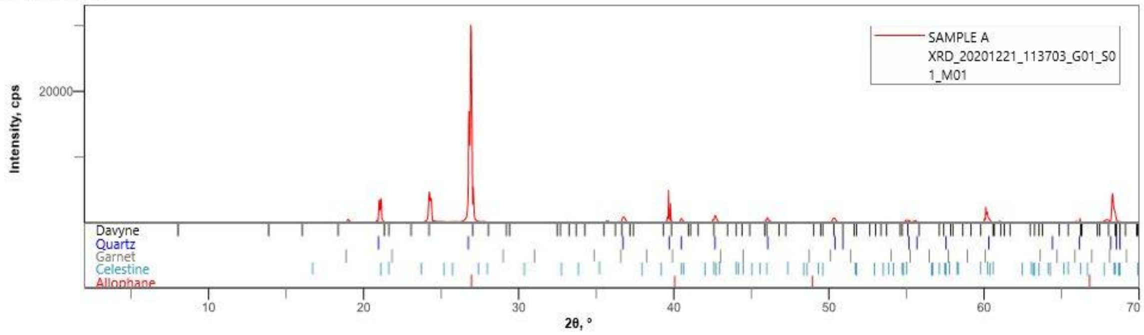
X-ray diff ractometer (XRD) was used to determine the properties of Reed and Hass species of avocado seeds activated carbon. X-ray Diffraction (XRD) study was carried on a Philips X'Pert X-ray diffractometer using Cu Kα radiation (λ = 0.15406 nm). The XRD pattern of the Reed and Hass avocado seed activated carbon samples are shown in Figures 4 and 5. Results showed that the modification of the adsorbents with acid led to structural changes of the surface of the adsorbents. The Reed and Hass avocado seed activated carbon displayed broad and long features at $26^0$ with weak diffracting peaks at 2ϴ $20^0$C, $25^0$C, $30^0$C, $35^0$C, $40^0$C, $45^0$C, $50^0$C, $55^0$C,$60^0$C, $65^0$C and $70^0$C respectively. These demonstrate amorphous structures with low degree of interlayer condensation.

**Quantitative analysis report**

General information

| | | | |
|---|---|---|---|
| Analysis date | 2020-12-21 12:53:06 | Measurement start time | 2020-12-21 11:38:09 |
| Analyst | Administrator | Operator | Administrator |
| Sample name | SAMPLE A XRD | Comment | |
| Measured data name | C:\Users\Rigaku pc\Desktop\ANALYSIS\OGA\21-12-20\SAM... | Memo | |

**Multiple Profile**




Path: C:\Users\Rigaku pc\Desktop\ANALYSIS\OGA\21-12-20\SAMPLE A XRD Solution.rmrsln

Solution

**Plot of results**

SAMPLE A XRD20201221_113703_G01_S01_M01

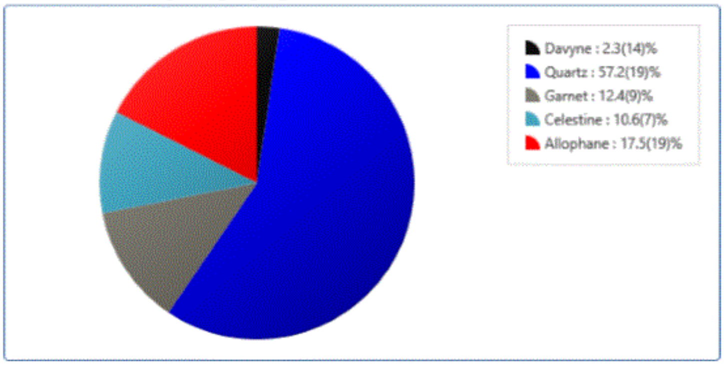



Table of results

| Dataset / Weight Fraction, wt% | Value, Unit | Davyne | Quartz | Garnet | Celestine | Allophane |
|---|---|---|---|---|---|---|
| SAMPLE A XRD_20201221_113... | 0 | 2.3(14) | 57.2(19) | 12.4(9) | 10.6(7) | 17.5(19) |

**Figure 13:** XRD Patterns of Reed Avocado Seed Activated Carbon

Path: C:\Users\Rigaku pc\Desktop\ANALYSIS\OGA\21-12-20\SAMPLE A XRD Solution.rmrsln

Solution

**SAMPLE A XRD_20201221_113703_G01_S01_M01-Evaluatio report (SAMPLE A XRD_20201221_113703_G01_S01_M01)**

General information

| | | | |
|---|---|---|---|
| Analysis date | 2020-12-21 12:53:06 | Measurement start time | 2020-12-21 11:38:09 |
| Analyst | Administrator | Operator | Administrator |
| Sample name | SAMPLE A XRD | Comment | |
| Measured data name | C:\Users\Rigaku pc\Desktop\ANALYSIS\OGA\21-12-20\SAM... | Memo | |

Qualitative Analysis Results

| Phase name | Formula | Figure of merit | Phase reg. detail | Space Group | DB Card Number |
|---|---|---|---|---|---|
| Davyne | ( Na , Ca )8 Al6 Si6 O24 ( Cl ,... | 2.999 | Import(PDF-4 Minerals 2020... | 173 : P63 | 00-050-1578 |
| Quartz | Si O2 | 1.373 | Import(PDF-4 Minerals 2020... | 152 : P3121 | 01-086-2237 |
| Garnet | 3 ( Ca , Fe , Mg ) O · ( Al , Fe... | 3.345 | Import(PDF-4 Minerals 2020... | 230 : Ia-3d | 00-002-0981 |
| Celestine | Sr S O4 | 3.386 | Import(PDF-4 Minerals 2020... | 62 : Pnma | 00-003-0437 |
| Allophane | Al2 O3 ·2 Si O2 ·3 H2 O | 1.462 | S/M(PDF-4 Minerals 2020 R... | | 00-038-0449 |

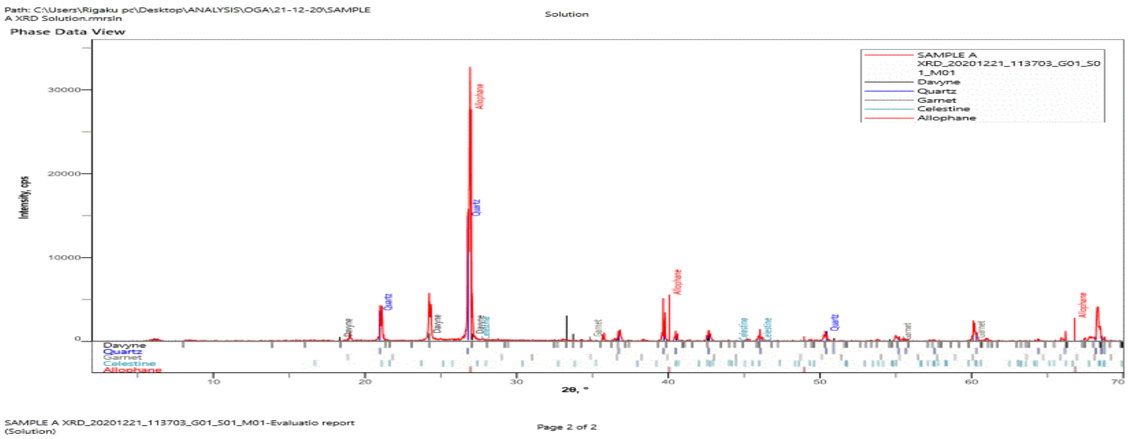



**Figure 14:**XRD Pattern of Hass Avocado Seed Activated Carbon

Figures 13&14 show the XRD profiles of Reed and Hass avocado seeds activated carbon. All the diffraction peaks at 2Ө $20^0$C, $25^0$C, $30^0$C, $35^0$C, $40^0$C, $45^0$C, $50^0$C, $55^0$C,$60^0$C, $65^0$C and $70^0$C were index from 1000 to 3000 plane respectively which are in relationship with the monoclinic crystal phase.

This analysis suggests that the functional groups of Qavyne2.3 (14wt%), Quartz 57.2 (19wt%), Garnet 12.4 (9wt%), Celestine10.6 (7wt%) and Allophane 17.5(19wt%) were found in the Reed and Hass avocado seeds activated carbon. The functional groups present on the surface of avocado seed activated carbon are indicators to other factors which influence and determine the adsorption of organic contaminants from industrial waste water. Though, the surface functional groups have influence on the adsorption of organic contaminants form wastewater, the carbon and oxygen groups are the most important and influencing groups. This is in agreement with the study carried out by (Nazar*et al*., 2015). Consequently, the inorganic and organic elements detected in the avocado seed activated carbon samples affect the mechanism of adsorption of contaminants in distinct manner. It has been reported that the adsorption of organic and inorganic elements from the aqueous solution is greatly influence by the presence of the carbon and oxygen surface groups (Viswanathan Varadarajan& Neel 2008). However, different inorganic elements and organic groups found on the avocado's seeds activated carbon surfaces may be attributed to the chemical composition of the activated carbon samples (Nazar*et al*., 2015).

## IV. CONCLUSION

Activated carbon of a high quality, high surface area and low cost was produced at low temperature from avocado seeds with the activation of $H_2SO_4$ at 0.2M impregnation ratio. The characterization of avocado seed activated carbon involves the determination of its properties such as pore volume, bulk density, moisture content, burn off, ash content, % yield, benzene adsorption, particle size, and iodine number. The activated Reed and Hass species of avocado seeds exhibited surface areas of 525.725 $m^2$/g and 542.265$m^2$/g and micro-pore volume of 2.70 $cm^3$/g and 3.669 $cm^3$/g. This combination of micro-meso pores yielded avocado seeds activated carbon with a significant aqueous adsorption capacity.More so, high iodine number for Reed (2,375 g/kg).and Hass (2,424 g/kg) indicated that iodine number was an important parameter used for the characterization of the performance of activated carbon.Ash content of Reed and Hass species of ASAC (5.32 % &5.84 %) reported in this study were good; this showed that there was enough time for total vaporization of the inorganic minerals in the carbon. SEM images suggested that biomass which occurred naturally were induced by carbonization and activation and this have led to the development of adsorbent porosity and the bursting of pores that occurred naturally.

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