© JUN 2026 | IRE Journals | Volume 9 Issue 12 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I12-1718536

Preparation And Characterization of Activated Carbon Derived from Water Lily (*Nymphaea Ampla*) Roots

ABAH MOSES[1], ISHAQ SHAIBU ENEJI[2], PRECIOUS NNENNAYA AKPA-ONYEABOR[3], LUPER MAGARSHI[4]
[1, 2]Department of Chemistry, Joseph Sarwuan Tarka University, Makurdi, Benue State - Nigeria
[3, 4]Federal Polytechnic Wannune, Benue State-Nigeria

Abstract- Waterlily root-derived activated carbon was used to make powdered activated carbon. After 15 minutes of carbonization at 400 °C, the mixture was allowed to chill in ice before being chemically activated with 0.8 M ZnCl2 (zinc chloride). The mixture was agitated for an hour at 350 rpm and heated until a paste was formed.The paste was placed in a crucible, oven-dried at 105 °C, heated in a muffle furnace at 500 °C for one hour and thirty minutes, chilled in ice to help the sample retain its hardness (attrition), and rinsed with distilled water until the pH of the flushing water was between 5.7 and 6.2. After that, the wet sample was dried in an oven set at 105 °C for a whole day. The final product, known as WLR-AC, was stored in airtight plastic after being ground and filtered after drying. A few physicochemical parameters were measured for the adsorbent samples (WLR-AC and CAC). pH of 6.30 ± 0.10; 6.30 ± 0.10; moisture content (%) 4.98 ± 0.01; 5.62 ± 0.05; bulk density (Kg/m3) 250.00 ± 1.00; 278.00 ± 0.10; ash content (%) 6.43 ± 0.02; surface area (m2/g) 53.49 ± 0.02; carbon yield (%) 33.49 ± 0.00; and iodine number (mg/g) 299.15 ± 0.05. The results of the t-test statistical analysis revealed that there was no significant difference between the two activated carbons' properties for the following parameters: pH, bulk density (Kg/m3), pHpzc, and moisture content (%) for the WLR-AC samples. There was a notable variation in the activated carbons' iodine number (mg/g), surface area (m2/g), and ash content (%). The prepared activated carbon derived from biomass (waterlily roots) compared favorably well considering the surface properties with the commercial activated carbon, therefore can be use as an alternative for CAC.

Keywords: Activated Carbon, Characterized, Nymphaea Ampla, Carbonization, Bulk Density

I. INTRODUCTION

Activated carbon is a highly porous form of carbon that has undergone treatment to boost its surface area and adsorption ability. It is a great adsorbent for a wide range of heavy metals in both liquid and gaseous states due to its high degree of porosity and vast surface area (Ahmed et al., 2018).

In order to form a highly porous structure, natural materials including coconut shell, rice husk, orange peel, wood, water lily roots, fluted pumpkin stem waste, coal, and plantain peel are heated to high temperatures. However, because of its affordability and environmental sustainability, BDAC use has drawn more and more attention. Water lily roots and other biomass sources have shown promise as AC manufacturing predecessors. This substance is an appealing substitute for the conventional pre-cursors since it is cheap, plentiful, and renewable. Heavy metal adsorption onto activated carbon from different precursors has been studied in the past (Kumar et al., 2019; Chen et al., 2017; Singh et al., 2020).

The Egyptians, Greeks, and Romans employed ACs for medical and water purification purposes as early as 3000 BC (Kumar et al., 2019). These days, air conditioners are employed for a variety of purposes, such as industrial, medical, and water treatment (Singh et al., 2020). The creation of AC from agricultural waste is motivated by the fact that it is less costly, can be produced locally in underdeveloped nations, and effectively removes heavy metals (Loo et al., 1974; Madukasie et al., 2001).

Biomass Derived Activated Carbon (BDAC)

BDAC is a form of activated carbon made from organic resources like algae, forestry leftovers, agricultural waste, and other elements derived from plants. Through a variety of procedures, the biomass is transformed into activated carbon. Carbon compounds, one of nature's most amazing substances, have outstanding qualities like biocompatibility, corrosion resistance, and resistance to acids and bases. Furthermore, it may change into a variety of shapes and characteristics due to its sp electron orbital hybridization, such as an outstanding electrical conductor, an insulator and semiconductor, an opaque black material or an explicit transparent material, and more (Abu et al., 2021). With the introduction of coal and oil as well as the quick growth of contemporary industry, various forms of AC have arisen.

Activated carbon is utilized extensively, and the raw materials used to make it vary. sources of raw materials used to make AC, such as coal, organic materials, plants, animals, and petroleum byproducts.

By reusing trash, AC built of biomass has significantly improved environmental protection and energy conservation. The International Energy Agency (IEA) defines "biomass" as a variety of creatures created by photosynthesis. There are two different meanings for it (Gao et al., 2019). All plants, microbes, and the waste they produce are included in the former, whilst inedible crops are referred to non the latter. Carbon compounds can generally be categorized into three groups:

i. Biomass derived activated carbon
ii. Mineral raw materials activated carbon
iii. Other raw materials activated carbon

The idea of waste and resource utilization is realized through the production of AC from biomass. Agricultural and forestry wastes, including wheat straw, fruit shell, wood, and other lignocellulose, as well as livestock manure, can be effectively managed through the harmless treatment of agricultural waste (Gao et al., 2018).

The primary AC raw materials fall into four categories: wood, coal, synthetic, and other AC types. Only biomass serves as the precursor material for biomass activated carbon (Anter et al., 2021; Salema et al., 2018).

Sources of Biomass for Activated Carbon Production

The biomass used to produce activated carbon comes from a variety of organic materials that are plentiful, renewable, and frequently regarded as waste. These sources fall into the following general categories: i. Agricultural residues: Byproducts produced during crop cultivation and processing are known as agricultural residues. These underutilized materials offer a cheap and sustainable feed-stock for the manufacturing of activated carbon. Important agricultural residues consist of:

(a) Rice Husk: One of the most popular biomass sources for the manufacture of activated carbon is rice husk. It generated activated carbon with superior adsorption and a large surface area.

(b) Corn Cobs: Another common agricultural waste that can be turned into activated carbon is corn cobs. The removal of heavy metals from water is one of the many uses for activated carbon made from corn cobs, which usually has a well-developed pore structure (Gupta et al., 2016).

ii. Forestry Waste: Materials from logging and wood processing are included in this category. These materials can be valorized by turning them into activated carbon, although they are frequently burned or allowed to decompose:

(a) Wood chips: Activated carbon is frequently made from wood chips derived from a variety of hardwoods and softwoods. Wood-based activated carbon is used to purify water and air because of its high micro porosity (Loannidou et al., 2017).

(b) Sawdust: Activated carbon from sawdust, a by-product of wood production, has a large surface area and is utilized in the food and beverage industry for purposes including purification and decolorization (Dias et al., 2017).

iii. Industrial By-Products: These can be used as feed-stock for the synthesis of activated carbon and are produced by a variety of manufacturing processes.

(a) Bagasse: The fibrous residue left over after sugarcane juice is extracted is known as bagasse. Because of its high lignocellulose content, which aids in the formation of a porous structure during activation, it is frequently utilized in the synthesis of activated carbon (Reza et al., 2016).

(a) Palm Kernel Shells: A byproduct of making palm oil are palm kernel shells. Highly microporous, activated carbon made from palm kernel shells is utilized in processes like wastewater treatment and gas purification that call for a high adsorption capacity (Menya et al., 2018).

iv. Dedicated energy crops: These are grown especially to produce biomass. These crops are selected because they can thrive on marginal ground and have a high yield.

(a) Miscanthus: Miscanthus is a perennial grass with a high biomass production rate. Miscanthus-derived activated carbon has a large surface area and is utilized in a number of environmental applications, such as water and air purification (Zhang and Zhao, 2016).

v. Aquatic biomass: Algae and water plants are examples of aquatic biomass, which is a viable and sustainable source of biomass for the synthesis of activated carbon.

(a) Algae: Algae are a renewable source of biomass because they grow quickly and can be grown in enormous quantities. Because of its large surface area, activated carbon made from algae can be employed in a variety of environmental applications, such as the removal of pollutants from water and the collection and storage of carbon (Loannidou et al., 2017).

(a) Water Hyacinth: An invasive aquatic plant that spreads throughout freshwater environments and frequently causes ecological issues is water hyacinth. It is possible to gather it and turn it into activated carbon, though. The resultant activated carbon effectively removes heavy metals and dyes from wastewater and has strong adsorption qualities (Subramanian et al., 2016).

vi. Industrial Biomass Waste: Byproducts from a variety of manufacturing and food processing sectors are included in industrial biomass waste. These resources, which are frequently plentiful, can be utilized to create activated carbon with particular qualities suited for industrial uses:

(a) Pineapple Peels: Packed in cellulose and lignin, pineapple peels are a by-product of the food processing industry. Heavy metals and organic contaminants are adsorbed from aqueous solutions using activated carbon made from pineapple peels (Patel et al., 2016).

vii. Agricultural Waste from Food Processing: This category comprises a variety of plant-based materials that are left over after food is produced and can be used to produce activated carbon.

(a) Orange Peels: Packed with cellulose and pectin, orange peels are a by-product of the juice industry. Heavy metals and organic pollutants can be effectively removed from water using AC derived from orange peels (Patel et al., 2016).

(b) Banana Peels: AC made from banana peels can be used to purify water since it has a high potential to adsorb organic contaminants.

Waterlily roots activated carbon (WLR-AC)
Aquatic plants known as water lilies (Nymphaea spp.) thrive in freshwater habitats like ponds, lakes, and sluggish streams. They are well-known for their floating leaves and lovely blossoms.

i. Surface Properties:
(a) Porosity: WLRAC may absorb a variety of contaminants because to its high levels of microporosity and mesoporosity.
(b) Functional Groups: Carboxyl, hydroxyl, and carbonyl groups are among the oxygen-containing functional groups that are frequently present on the surface of WLR-AC. These groups increase the carbon's adsorption capability by strengthening its interaction with heavy metal ions through processes like complexation and ion exchange.

ii. Heavy metal adsorption: Because of its wide surface area and surface functional groups, WLRAC has demonstrated considerable promise in adsorbing Cd2+ and Cr6+.
iii. Kinetics Isotherms: Heavy metal adsorption onto WLR-AC is consistent with the PSO kinetic model, suggesting chemisorption as the primary process. The Langmuir model frequently fits the adsorption

isotherms well, indicating monolayer adsorption on a uniform surface.

Eneji et al. (2016) studied WLR-AC and used activated carbon made from waterlily roots (Nymphaea ampla) to examine the adsorption of Cd^{2+} and Pb^{2+} ions from aqueous solutions. Adsorption capacities for Cd^{2+} and Pb^{2+} are 96.2 mg/g and 123.5 mg/g, respectively, according to the results. The porosity structure and the presence of oxygen-containing functional groups (such as hydroxyl and carboxyl groups) on the AC's surface were blamed for its high capacity.

The adsorption kinetics were consistent with a PSO model, indicating that chemisorption—in which the heavy metal ions bonded with the AC's surface functional groups—was the predominant mechanism. The Langmuir isotherm model fit the adsorption data well, suggesting monolayer adsorption on a homogenous surface with a maximum monolayer coverage of 123.5 mg/g for Pb^{2+}.

II. MATERIALS AND METHODS

Apparatus and Materials

Atomic Absorption Spectroscopy - AAS (MP-AES AGILENT 4200), Fourier Transformed Infra - Red (FT-IR, 630 by Agilent Technologies Ltd. USA) Spectroscopy, Dry Oven (DHG-9053A), , pH Meter (Milwaukee 101 pH meter), Hot plate (Ikamage RH, JANKE & KUNKEL. IKA Labortechnik), Furnace, Grinder and Sieve shaker, Crucibles, Mortal and Pistol, Analytical weighing balance (OHAUS), Watchman Filter Paper, Conical Flasks (250mL), Measuring Cylinders (1000mL, 100mL, 10mL), (stainless steel), Spatula, Glassware (Beakers-250mL, 500mL, Test tubes), (Water lily roots (Nymphaea ampla),

Chemicals and Reagents

Zinc Chloride ($ZnCl2$; purity: 98%), Hydrochloric Acid (HCl), Potassium Hydroxide (KOH), Nitric Acid (HNO_3), Standard iodine solution (0.1 N), Potassium iodide (KI), Sodium thiosulfate ($Na2S2O3$), Starch solution, Buffer solution, Distilled water.

Methods of Analysis

Sampling:

Water Lily roots: The aquatic hydrophyte (N. ampla) root was hand - harvested from River Benue behind abattoir, Wurukum- Makurdi Preparation and activation process of WLR-BDAC.

The method used by Eneji et al. (2016) was adopted for sample preparation without modification.

Sample Pre – treatment: The water Lily roots was washed and rinsed with distilled water, dried in the laboratory (Research laboratory in Chemistry Department; Joseph Sarwarm Tarka University, Makurdi – Benue State) under open air, to reduce the moisture contents, grind and sieved with < 2mm aperture.

Carbonization: The sieved material was carbonized (heated in the absence of air) at 400◦C for 15 minutes.

Raw water Lily roots 400 ◦C, 15 minutes C + CO2 (carbonization) (1)

Activation (chemical activation process): 41.2576g of the carbonized materials was weighed out, and transferred into a beaker where it was impregnated with 500 mL of 0.8M $ZnCl2$, mixture stirred for 1 hour at a speed of 350rpm, heated until it formed a paste. The paste transferred into a crucible, oven dried at 105◦C and finally introduced into the muffle furnace and heated at 500◦C for 1 hour, 30 minutes. Sample withdrawn and cooled in ice to assist sample retain it hardness (attrition) before washing.

Post – treatment: After cooling, the activated carbon was rinsed several times with distilled water until the flushing water presented a pH range of between 5.7 and 6.2. The wet sample then dried at 105◦C for 24 hours in the oven. The dried product was grinded, filtered and the final product kept in air tight plastic container as activated carbon prepared from Nymphaea ampla roots labelled Nymphaea ampla roots activated carbon (WLR-AC)

Water lily plants

Nymphaea ampla roots

N. ampla roots activated carbon

Preparation of 0.8 M $ZnCl_2$

Exactly 54.512 g of $ZnCl_2$ was dissolved in de-ionized water in 500 cm3 volumetric flask and was made up to the mark with distilled water (Eneji et al., 2016).

Physicochemical Characterisation of Activated Carbon (BDAC and CAC)

Determination of pH

Exactly 1.0 g WLR-AC was weighed and transferred into a beaker. 100 mL of distilled water was measured and added to the beaker containing the 1.0 g of AC. The mixture was stirred for about 30 minutes and was allowed to stabilized; the pH was measured using a pH meter after the solution had settled (Eneji et al., 2016).

Determination of percentage moisture content (% MC)

A method used by Rengaraj et al. (2002) was adopted. 1.0g of WLR-AC, was weighed in duplicates and placed in washed, dried and weighed crucible. The crucibles were placed in an oven and dried at 105 ◦C to constant weight for 4 hours after which it was cooled in a desiccator and then weighed. The percentage moisture content (% MC) was computed as follows:

$$\text{MC (\%)} = \frac{\text{Loss in weight on drying (g)} \times 100}{\text{Initial sample weight (g)}} \qquad (2)$$

Determination of bulk density

This measures the amount of adsorbate the Carbon can hold per unit volume. The method used by Wuana et al. (2009) was adopted in the measurement of bulk density of WLR-AC. Exactly1.0 g of each of the dried AC was packed into a graduating measuring cylinder of size 100 mL, without applying excessive pressure to avoid compaction. The volume occupied by the sample in the cylinder was recorded. Care was taken to ensure there is no air gap within the packed carbon.

$$\text{Bulk Density} = \frac{\text{Mass of ACs (g)}}{\text{Volume it occupied in the cylinder (cm3)}}$$

(3)

Determination of Ash content

The standard test method for ash content -ASTM D2866-94 was used. A crucible was pre-heated in a muffler furnace to 500◦C, cooled in a desiccator and weighed. Exactly 1.0 g of WLR-AC was transferred into the crucible and re-weighed. The crucible containing the sample was placed in a muffler furnace and the temperature was allowed to rise to 500 ◦C. The crucibles were removed and allowed to cool in a desiccator to room temperature (30 ◦C) and reweighed again. The ash content was calculated using the equation.

$$\text{Ash (\%)} = \frac{\text{Ash weight (g)}}{\text{Oven dried weight (g)}} \times 100. \quad (4)$$

Determination Surface Area

Surface area (m2/g) of the AC was calculated adopting the methods used by Ogbeh et al. (2019). The diameter (assuming spherical shape) of the adsorbent was obtained by passing the crushed carbon through sieve size of 300 um and the external surface area was calculated by the relation

$$\text{Surface area (m2/g)} = 6/\text{Bd Pd} \quad (5)$$

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

Carbon yield

The yield is the quantity of the final product formed from the starting raw material on a scale of 100 and is dependent on temperature and time of activation (Abechi et al., 2013). The carbon yield was calculated using the formula:

$$\text{Carbon yield (\%)} = \frac{\text{weight of AC}}{\text{weight of raw biomass}} \times 100 \quad (6)$$

Determination of iodine number of ACs

It is a measure of the microporosity created during activation and is responsible for the large surface area of the activated carbon particles (Ekpete and Horsfall, 2011). Adsorbents with high iodine number / surface area perform better in the removal of small sized contaminants.

Preparation of Iodine Solution: A standard iodine solution (usually 0.1 N), was prepared
by dissolving iodine in a potassium iodide solution.

Adsorption Test: A known amount of AC was added to the iodine solution, and the mixture is stirred to allow adsorption of the iodine onto the activated carbon.

Titration: After a specific contact time, the remaining iodine concentration in the solution was determined by titration with sodium thiosulfate using starch as an activated carbon, with higher iodine numbers indicating greater microporosity and surface area.

The iodine number is calculated using the following formula:

$$\text{Iodine Number (mg/g)} = \frac{(B - S)\ X\ N\ X\ 126.93}{\{W\}} \quad (7)$$

where: B = Volume of sodium thiosulfate used for blank titration (mL),
S = Volume of sodium thiosulfate used for sample titration (mL),
N = Normality of the sodium thiosulfate solution (N),
(126.93) = Molecular weight of iodine (g/mol),
W = Weight of the activated carbon sample (g)

Student's t – test analysis

The student's t – test analysis of the mean values of the surface properties of activated carbon derived from water lily roots (WLR-AC) was compared with those of commercial activated carbon (CAC). This was done by formulating a null hypothesis that: there is no significant difference between the surface properties of WLR-AC and CAC.

$$t = (X_{1-X2}) / \sqrt{(S^2/N_1 + S^2/N_2)} \quad (8)$$

where:
X1 = mean value of water lily roots activated carbon
X2 = mean value of commercial activated carbon
N1 = number of measurements of water lily roots activated carbon
N2 = number of measurements of commercial activated carbon
S = standard deviation from the mean
DF = Degree of freedom

To test the null Hypothesis (H_o), the experimental t-values (tcal) for any degree of freedom at confidence level of 95% is compared with the tabulated t-values (ttab).

If the tabulated t-values (ttab) > the experimental t-values (tcal), H_o is accepted, and there is no significant difference between the surface properties of WLR-AC and CAC

If the tabulated t-values (ttab) < the experimental t-values (tcal), H_o is rejected, and there is significant difference between the surface properties of WLR-AC and CAC

III. RESULTS AND DISCUSSION

Physicochemical properties

Table 1 displays the average values of the physicochemical characteristics. using their respective standard deviations. It describes the biomass-derived activated carbon's applicability for a specific process by demonstrating its large-scale use.

Table 1: Mean Values of Physicochemical Parameters of ZnCl2 Activated Carbon

S/NO	Parameters	WLR-AC	CAC
1	pH	6.30 ± 0.10	6.1 0± 0.10
2	Moisture content (%)	4.98 ± 0.01	5.62±0.05
3	Bulk density (Kg/m^3)	250.00 ± 1.00	278.00 ± 0.10
4	Ash content (%)	6.43 ± 0.02	2.84 ± 0.01
5	Surface area (m^2/g)	533.33 ± 0.04	479.62 ± 0.02
6	Carbon yield (%)	33.49 ± 0.00	-
7	Iodine number (mg/g)	299.15 ± 0.05	274.68 ± 0.02

Results are given as mean ± S.D (triplicate measurements)
WLR-AC: Water lily Roots Activated Carbon
CAC: Commercial Activated Carbon

pH

The preparation techniques, the treatments the adsorbents underwent, the chemically active oxygen-containing functional groups on the surface, and the in-organic matter contents all affect the pH of the activated carbon generated from biomass. The pH range for the majority of activated carbons is 6 to 8 (Ekpete et al., 2010). Water lily root activated carbon and commercial activated carbon were found to have pH values within the specified range, at 6.30 ± 0.10 and 6.1 0± 0.10, respectively. Table 1 below shows that the pH is in the following order: WLR, AC, and CAC.

Percentage moisture content (% MC)

The moisture content, which indicates the porosity in the activated carbon's structure, is the quantity of water that is present in the carbons. The adsorptive activity of activated carbon will be diminished if its moisture content is high (Sugunadevi et al., 2002). In this investigation, the moisture content of WLR-AC and CAC was found to be 4.98 ± 0.01 (smaller than the value of 5.0±0.00 reported by Eneji et al. (2016) for NAAC) and 5.62±0.05, respectively, with WLR-AC having a lower value than CAC. According to table 1 below, the moisture content as a percentage fall between CAC > WLR and AC.

Bulk Density

The quantity of adsorbate that the adsorbent (activated carbon) can store per unit volume is known as bulk density (Kg/m3). The initial raw ingredients determine the values. In this investigation, the bulk densities for WLR-AC and CAC were 250.00 ± 1.00 and 278.00 ± 0.1, respectively. This is comparable to the NAAC value of 260.10±0.00 found by Eneji et al. (2016), and it is all greater than the minimum requirement of 250.00 kg/m3 for application in the removal of contaminants or heavy metals in waste water (AWWA 1991). The bulk density falls between CAC and WLR-AC.

Percentage Ash Content

Ash contents is the residue that remains after the carbonaceous portion is burnt off, this is considered as an impurity. Percentage ash content is an indication of the quality of the activated carbon. It is in the range of 2 - 10% (Yang and Lua, 2003).

Low value of ash contents shows that the inherent carbon in the starting materials is high (Karthikeyan and IIango, 2008). Activated carbon with high percentage ash content is undesirable because it reduces the adsorption capacity and mechanical strength of the activated carbon (Soleimani et al., 2007).

Good quality activated carbon should have a low percentage ash content. In this study the percentage ash contents of WLR – AC and CAC were found to be 6.43 ± 0.02 and 2.84 ± 0.01 accordingly. This falls within the accepted range, and in the order of WLR – AC > CAC.

Surface Area

The AC's surface area (m2/g) was determined using Ogbeh et al. (2019)'s methodology. Crushed carbon was passed through a 300 um screen to determine the adsorbent's diameter (assuming spherical shape), and the external surface area was computed using the formula Surface area (m2/g) = 6/Bd Pd.

Carbon yield

The amount of the finished product made from the initial raw material is known as the carbon yield (%), and it is stated as a percentage. Temperature and activation time have an impact (Abechi et al., 2013). For the manufacture of activated carbon to be practical and profitable, a large yield is required; Following carbonization and chemical activation, a remarkable yield of 33.49 ± 0.0% was achieved. This figure is greater than the yield of 30.49 ± 0.2% for NAAC (Eneji et al., 2016), but lower than the yield of 46.08 ± 0.0% for tarmarind wood activated carbons (Salhu et al., 2010).

Iodine number

The micro-porosity produced during activation, which gives the activated carbon particles their enormous surface area, is measured by the iodine number (mg/g) (Ekpete and Horsfall, 2011). Small-sized pollutants were more effectively removed by activated carbon with a high iodine value. The iodine numbers for WLR-AC and CAC in this study are 299.15 and 274.68 (mg/g), respectively. These values are lower than the 335.02 (mg/g) for NAAC found by Eneji et al. (2016), but higher than the 244.90 (mg/g) found for fluted pumpkin stem waste activated carbon by Ekpete and Horsfall (2011).

Table 2: texp. of the various Surface Properties of WLR – AC and CAC

Parameters	Carbon type	Mean	SD	df	$t_{cal.}$	t_{tab}	Decision
pH	WLR	6.30	0.10	4	2.45	2.776	Not significant
	CAC	6.10	0.10	-	-	-	-
Moisture (%)	WLR	4.98	0.01	4	-21.70	2.776	Not Significant
	CAC	5.62	0.05	-	-	-	-
Bulk Density (Kg/m^3)	WLR	250	1.00	4	-48.90	2.776	Not Significant
	CAC	278	1.00	4	--		
Ash content (%)	WLR	6.43	0.02	4	278.29	2.776	Significant
	CAC	2.84	0.01	4	-	-	-
Surface area (m^2/g)	WLR	533.33	0.04	4	2081.78	2.776	Significant
	CAC	479.62	0.02	4			
Carbon yield (%)	WLR	33.49	0.00	-	-	-	-
Iodine Number (mg/g)	WLR	299.15	0.05	4	789.03	2.776	Significant
	CAC	274.68	0.02				

Student's t – test analyses: The surface properties of the activated carbon derived from water lily roots was compared with the commercial activated carbon.

The statistical t – test analyses were carried out to determine if there was any significant different between the properties obtained for WLR-AC and CAC. A 95% level of confidence corresponding to 0.05 level of significant was chosen and the calculated texp and ttab. are given in Table 2. From the Table 2 above, it was found that, the activated carbon samples, texp < ttab for the following properties; pH, Moisture contents (%), and Bulk Density (Kg/m3).

This shows that there is no significant difference between the mean value of pH, Moisture contents (%), and Bulk Density (Kg/m3) of the activated carbon samples derived from water lily roots (WLR-AC) and the commercial activated carbon (CAC).

There is a significant difference in the properties of Ash content (%), Surface area (m2/g), and Iodine Number (mg/g) of the activated carbons. Regardless of the significant differences that existed for some of the properties between the water lily roots activated carbon and the commercial, the water lily roots (WLR-AC) can still be used as an alternative to the traditional CAC.

CONCLUSION

The prepared water lily roots activated carbon (WLR-AC) favorably contrasted with the commercial activated carbon (CAC). The pilot study to develop a national potential for the production of activated carbon will among several benefits contribute to the measures for reducing the environmental degradation caused by dumping of Agricultural waste.

REFERENCES

[1] Abu, S., and Maitra, S. (2022). Preparation and characterization of bamboo-derived activated carbon (BDAC) for water treatment. Journal of Water Process Engineering, 47, 102722. DOI: 10.1016/j.jwpe.2022.102722

[2] Abu, S., Khan, M. E., and Chowdhury, Z. Z. (2022). Biomass-derived activated carbon (BDAC) for environmental remediation: A review. Journal of Environmental Chemical Engineering, 10(2), 107344.

[3] Antar, M., Lyu, D., Nazari, M., Shah, A., Zhou, X., & Smith, D. L. (2021). Biomass for a sustainable economy: An overview of world biomass production and utilization. Renewable and Sustainable Energy Reviews, 139, 110691. doi: 10.1016/j.rser.2021.110691. Additional information:Journal ISSN: 1364-0321.

[4] Dias. J. M., Alvim-Ferraz, M.C.M., Almeida, M.F., Rivera – Utrilla, J., & Sanchez – Polo, M. (2017). Waste Material for Activated Carbon preparation and its use in aqueous – phase treatment: A review journal of Environmental Management, 85(3), 833-846. https://doi.org/10.1016/j.jenvman.2017.07.015

[5] Sugunadevi SR, Sathishkumar M, Shanthi K, Kadiruvelu K & Pattabhi S 2002. Removal of direct T-blue-R from aqueous solution on to carbonized sugarcane bagasse waste. Indian J. Envtal protection, 22: 500 – 505

[6] Karthikeyan G & Ilango SS 2008. Adsorption of Cr (VI) on Activated Carbons Prepared from Indigenous Materials. E–J. Chem., 5(4): 666 – 678.

[7] Abechi, S. E., Gimba, C. E., Uzairu, A., and Dallatu, Y. A. (2013). Preparation and characterization of activated carbon from palm kernel shell by chemical activation. Research Journal of Chemical Sciences, 3(7), 54-61.

[8] Eneji, I. S., Sha'Ato, R., Wuanna, R. A., and Kagbu, J. A. (2016). Kinetic and thermodynamic studies of cadmium and lead adsorption on activated carbon from water lily (Nymphae ampla) roots. Journal of Environmental Science and Technology, 9(2), 143–154. environmentally relevant conditions, J. Environ. Manage., 2021, 277, 111472.

[9] Ekpete O.A. Horsfall M. Jnr. And Tarawou T., potential of fluted and commercial activated Carbon for phenol removal in aquous solution. ARPN. Journal of Engineering and applied sciences, 5, 39-47 (2010)

[10] Ekpete AO & Horsfall M Jnr. 2011. Preparation and Characterization of Activated Carbon \ derived from Fluted Pumpkin Stem Waste (Telfairia occidentalis). Res. J. Chem. Sci., 1(3): 10 – 15

[11] Ahmed, M. J., and TheyDan, S. K. (2018). Adsorption of heavy metals onto activated carbon from rice husk. Journal of Environmental Chemical Engineering, 6(4), 4629–4638

[12] Chen, C. X., Chen, L., et al. (2017). Thermodynamic and kinetic studies of chromium dsorption onto activated carbon from water lily roots. Journal of Environmental Science and Health, Part B, 52(10), 2721–2728. Journal ISSN: 0360-1234.

[13] Gao, K., Chen, X., and Sun, W. (2018). Biomass energy: Current status and future prospects. Energy and Environmental Science, 11(10), 2822–2833. doi: 10.1039/C8EE00831G

[14] Gao, K., Sun, W., and Chen, X. (2017). Definition and classification of biomass. Renewable and Sustainable Energy Reviews, 77, 1010–1021. doi: 10.1016/j.rser.2017.04.074.

[15] Gupta, V. K. (2016). Sources of biomass for activated carbon production. In Activated Carbon: Properties, Applications, and Production Processes (pp. 17-34). Springer, Cham. DOI: 10.1007/978-3-319-28607-3_2 BookISBN: 978-3-319-28606-6 (Print)978-3-319- 28607-3

[16] Madukasie, T. I., & Dai, X. (2001). Preparation of activated carbon from agricultural waste. Journal of Environmental Science and Health, Part B, 36(5), 483-493.

[17] Menya, E., Olupot, P. W., Storz, H., Lubwama, M., and Kiros, Y. (2018). Production and performance of activated carbon from rice husks for removal of natural organic matter from water: A review. Chemical Engineering Research and Design, 129, 271–296. doi: 10.1016/j.cherd.2017.11.028

[18] Patel, M., Kumar, R., and Verma, P. (2016). Conversion of waste fruit peels into value-added activated carbon for heavy metal removal. Environmental Progress & Sustainable Energy, 35(3), 849–856. doi: 10.1002/ep.12304.

[19] Singh, J., Kumar, P., & Sharma, S. (2020). Applications of activated carbon: A review. Journal of Environmental Science and Health, Part B, 55(1), 39-55. doi: 10.1080/03601234.2019.1704533

[20] Singh, K., and Singh, V. K. (2020). Thermodynamic and kinetic studies of nickel adsorptiononto activated carbon from fluted pumpkin stem waste. Journal of Hazardous Materials, 389, 122155.doi: 10.1016/j.jhazmat.2020.122155. Journal ISSN: 0304-3894,

[21] Wuana RA, Okieimen FE, Adejo SO & Mbasugh, PA 2009. Single and competitive aqueous phase adsorption of calcium and magnesium ions onto rice husks carbon. Journal of Chemical Society of Nigeria, 34(1): 97 – 109

[22] Wuana RA, Sha'Ato R & Iorhen S 2015. Aqueous phase removal of loxacin using adsorbents from Moringa oleifera pod husks. Advances in Environmental Res., 4(1): 49 - 68

[23] Kumar, P., Kumar, A., and Sharma, S. (2019). A review on the history, production, and applications of activated carbon. Journal of Environmental Science and Health, Part B, 54(1), 1-15. doi: 10.1080/03601234.2018.1553636

[24] Ioannidou, O., Zabaniotou, A., & Antonakou, E. V. (2021). Water purification using biochar-derived activated carbon: A review. Journal of Environmental Chemical Engineering, 9(5), 105831. doi: 10.1016/j.jece.2021.105831.

[25] Ioannidou, O., Zabaniotou, A., Antonakou, E. V., & Lappas, A. A. (2017). Production of activated carbon from lignocellulosic biomass for low-cost CO2 capture. Journal of Analytical and Applied Pyrolysis, 123, 117–131. doi: 10.1016/j.jaap.2017.02.003

[26] Rengaraj S., Seung – Hyeon M. and Sivabalm S., Agricultural solid waste for the removal of organics; adsorption of phenol from water and wastewater by palm seed coat activated carbon, waste Management, 22, 543 -548 (2002)

[27] Reza, M. T., Andert, J., Wirth, B., Busch, D., Pielert, J., Lynam, J. G., & Mumme, J. (2016). Production and characterization of activated carbon and biochar from hydrothermally carbonized biomass. Bioresource Technology, 209, 396404. https://doi.org/10.1016/j.biortech.2016.03.115;

[28] Soleimani.M & Kaghazchi T 2007. Agricultural waste conversion to activated carbon by chemical activation with phosphoric acid. Chem. Engineering Techn., 30: 649 – 654

[29] Subramanian, S., Venkatachalam, P., and Challappan, S. (2016) Sustainable production of activated carbon from water hyacinth for the

removal of organic pollutants in water. Journal of Environmental Chemical Engineering, 4(3), 2934-2941.https://doi.org/10.1016/j.jece.2016.05.21

[30] Salema, A. A., and Ani, F. N. (2018). Raw materials for activated carbon production. Journal of Environmental Chemical Engineering, 6(4), 3839–3853. doi: 10.1016/j.jece.2018.05.029

[31] Zhang Z., and Zhao, Y. (2016). Recent advances in biomass-derived activated carbons for electrochemical energy storage. Progress in Natural Science: Materials International, 26(5), 429-437. https://doi.org/10.1016/j.pnsc.2016.08.009;