Development of Micro Porous Materials (Activated Carbon) from Agricultural Products to be utilized for Environmental Remediation

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ORIGINAL RESEARCH

Abstract— This research explored the development of micro porous materials derived from agricultural products for environmental remediation applications. The innovative approach utilized biomass waste to create sustainable, high-performance, renewable materials with tailored properties. This agricultural materials are biodegrable as compared to the non-renewable and non degrable resources used in production of industrial activated carbon. Activated carbon (AC) was produced at varying temperature ranges of (400-600) ^{OC} in vector furnaces, after which it was impregnated using sodium hydroxide of 0.3ml. AC was then characterized in terms of moisture content, volatile matter, ash content, and fixed carbon, and the percentage yield was determined. The absorption rate of each produced AC was determined using a methylene blue adsorption test (MBAT). The characterization of both activated carbons produced gave moisture content as (14, 7.0%), volatile matter (11, 9.0%), ash content (2.0, 5.0%) and fixed carbon (72, 78 %), respectively. The result showed that above and below 600 °C, in below 60 minutes, both coconut husk and Periwinkle shell yield were produced. It can be deduced that the adsorption rate is higher in periwinkle shells than that of coconut husks, with 4.04%, 6.94% and 8.8% for 400, 500 and 600-degree centigrade, respectively. It can be inferred that the adsorption rates of both biomass employed are similar with slight vibration. The produced micro porous materials demonstrated excellent adsorption capabilities, making them ideal for removing pollutants from water and air. The findings offered a promising solution for a more sustainable and circular approach to environmental remediation, reducing waste and promoting eco-friendly technologies.

Keywords— Micro porous Materials, Adsorption, Activated carbon, Remediation, impregnated.

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1 INTRODUCTION

The quest for sustainable and eco-friendly solutions to environmental remediation has led to the exploration of innovative microporous materials derived from agricultural products. Environmental remediation has been a fundamental goal for sustainability since the evolution of industrialization and the increasing population. Micro porous materials, with their unique properties of high surface areas and excellent adsorption capacity, have shown great promise in addressing various environmental challenges such as water, air and soil pollutants.

So number of researchers have produced activated carbons as absorbents from renewable and cheaper industrial and agricultural by-products, like; bamboo (Ijaola *et al*, 2013), abattoir solid waste (Sangodoyin and Ajayi-Banji, 2013), locust bean husk (Ajayi-Banji *et al.*, 2015) cassava peel (Omotosho and Ewemoje, 2020), snail shells (Bolade and Sangodoyin, 2018), waste apricot Grimwood *et al*, 1975), wood (Yargicoglu *et al*, 2015), rattan sawdust (Foo *et al.,2014*), Coconut shell (Mopoung *et al.*, 2015) and coconut husk (Ajayi-Banji, *et al.*,2015), also more specifically Fatokun et al, 2021, developed adsorbent from *Cordia millenii* and *Gmelina arborea* wood species. However, the development of microporous materials produced from agricultural products in the context of this study, offers a groundbreaking approach to environmental remediation (Kotoula *et al.*, 2022; Wan Zhang *et al.*, 2022), by using periwinkle and coconut husk. These agricultural products, that is periwinkle shells and coconut husks, offer a promising approach to addressing various environmental challenges. These products are abundant and renewable biomass waste and possess unique properties that makes periwinkle shell is a significant, heavy byproduct that is left over when the edible portion of the periwinkle mollusk is removed, (Oyedoh & Ekesiobi 2023). Its shell wastes are frequently stacked in landfills and open fields, giving them an unsightly appearance, an unpleasant stench, and the opportunity for organisms that spread disease to grow. Over time, a number of substitute applications for shells have been developed in an effort to lessen their negative environmental effects. Among these is the process of turning periwinkle shells into activated carbon. For periwinkle shell activated carbon, periwinkle shells offer an incredibly affordable, abundant, long-lasting, and

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Section D- MATERIALS AND METARLLUGY/CHEMICAL SCIENCES & RELATED SCIENCE

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environmentally beneficial supply of carbon. (Oyedoh & Ekesiobi, 2023).

Coconut husk is an agricultural by-product, it is the mesocarp of coconut which consists of 33–35% of husk. The coconut husks are used as fuel for coconut processing, as a domestic fuel and as a source of fibre for rope and mats (*Yuliusman et al.*, 2020). Coconut husks are cheap and plen ontiful agricultural waste that can be better utilized by converting them into activated carbon (Ajayi-Banji, *et al.*, 2015). While there have not been many studies on coconut husk-based activated carbon, Yuliusman *et al.*, 2020 note that some have been done, including work on the adsorption of arsenic on carbon impregnated with copper and recent efforts on preparing activated carbon from coconut husk for the adsorption of basic dye. In spite of this, the most important characteristic of an activated carbon is its adsorption capacity or uptake which is highly influenced by the activated carbon preparation conditions. This is because activated carbon preparation variables such as activation temperature, activation time and chemical impregnation ratio will influence the pore development and surface characteristics of the activated carbon to produced ideal precursors for the production of microporous materials. These biomass wastes can be engineered to possess tailored properties, making them ideal for applications such as adsorption, catalysis, and filtration. The use of agricultural products in the production of microporous materials not only reduces waste but also provides a sustainable alternative to traditional materials, aligning with the principles of a circular economy (Ijaola *et al.*, 2020).

Engineers and Scientists further made a spirited effort to generate activated carbon from available raw materials like agricultural residues or by-products. (Baoyin *et al*, 2023). These materials are lignocellulosic biomasses that are mostly abundant and bio-renewable feedstock, which has great potential for sustainability, and its production can replace commercial activated carbon (Ijaola and Sangodoyin, 2020). The availability of many biomass for renewable energy source makes it fitting for conversion and pollution reduction *and* its usage can contribute to improving the environment. There is less trash on the earth when biomass is handled properly and used productively (Maulin & Pardeep, 2024). Using various thermal treatment techniques, such as gasification and pyrolysis, biomass is converted into syngas, biochar, and bio-oil. These days, energy-storing, cost-effective, and ecologically friendly materials are quite important for a wide range of environmental applications (Eustache *et al* 2020). On the other hand, by elevating human standards, the rapid use of biomass and biomass-derived material will contribute significantly to socio-economic and sustainable environmental development in the future. (Farooq and Muntaha, 2022).

The development of these materials has far-reaching implications for environmental remediation, including the removal of pollutants from water and air, soil remediation, and climate change mitigation. This innovative approach has the potential to revolutionize the way we address environmental challenges, offering a more sustainable and effective solution for a cleaner and healthier planet (Zhang *et al*., 2018). According to Hsi-Yen Wu, (2020) stated that Evaluating the full potential of biomass-derived carbon materials in various applications can not only maximize the value of the carbon products, but also promote the bio-based economy. This study focuses on the development of microporous materials from periwinkle shells and coconut husk and their utilisation in environmental remediation, exploring their potential to transform the field of environmental sustainability. By harnessing the potential of these innovative materials, we can create a more sustainable and effective solution for a cleaner and healthier planet.

2.0 MATERIALS AND METHODS

2.1 AGRICULTURAL WASTE COLLECTION AND PREPARATION

Coconut husk and periwinkle shells used in the development of microporous materials were collected from periwinkle and coconut vendors at the common ultra-modern market Akaba called Swali market in Yenegoa city council of Bayelsa State (Plate 1 &2). Prior to use, the samples of 5kg of coconut husk and periwinkle shells were thoroughly washed with clean water to remove dirt. To remove moisture, all samples were sun-dried for a period of one week and oven-dried for 24 hours.

2.2 CARBONIZATION OF SAMPLES AND IMPREGNATION

The coconut husks and periwinkle shells were to get the initial mass prior to carbonization, which was done at varying temperatures ranging from 400-600^{o}C in the Vecstar furnace, and it was at this point of the carbonizations stage that the first pores of the activated carbon were produced, which is the macrospores. The mass of the carbonated samples was also taken to know the effect of carbonizations temperatures on the samples. After carbonizations, the carbonized samples were broken into smaller particle sizes, such as capsule sizes, and then it was impregnated separately in a 0.3M sodium hydroxide solution for 24 hours. This helps to improve the porosity of the carbon during the activation process. Later, the samples were screened from the solution using a sieve, followed by thermal activation in an electric furnace.

The samples were introduced into the furnace separately for the activation using different temperatures, ranging from (500 to 700)^{o}C at standard set point mode. Thus, the mesopores and micro pores of the activated carbon were

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also formed at this stage. Then, the activated carbons were washed with warm water for a trace of sodium hydroxide removal and dried in an oven at 105⁰C per hour for total moisture removal.

In the process of production, some of the process parameters were kept constant, whereas others varied. The constant parameters include the mass of the precursor and the concentration of sodium hydroxide (NaOH) in the impregnation process. The variable parameters were carbonizations temperature, activation time and activation temperatures. The carbonisation temperatures range from (400-600ᵒC), activation temperatures range from (500-700)ᵒC, and the activation time ranges from (30-90 minutes).


Plate 1: Coconut Husk


Plate 2: Periwinkle shells

2.3. PROXIMATE ANALYSIS OF PRODUCED ACTIVATED CARBONS

The properties of the activated carbons were characterized by following standard procedures as; the moisture content, the volatile matter, the ash content, and the fixed carbon.(cite reference or source)

The American Society for Testing and Materials (ASTM D2867 – 09) oven-drying test method was used to determine the moisture content. The carbon samples were precisely weighed during the separation process and placed within a dry, airtight capsule with a specified weight. After opening the capsule, the lid was put on and the oven was preheated to between 145 and 155ᵒC. After the samples were taken out of the oven and dried to a consistent weight, they were placed in a desiccator to cool to room temperature while the capsule was sealed. Once more, the closed capsule was precisely weighed. The sample's moisture content is represented as the percentage weight difference. Environmental development through human standards advancement

The percentage of volatile matter in the activated carbon samples was determined by the standard method using the American Society for Testing and Materials (ASTM D5832 – 98). A known weight crucible with a lid was filled with around 1.0 g of the sample. For 7 (seven) minutes, 8the covered crucible was heated to 950⁰C in a muffle furnace. The weight of the covered crucible was then noted after it had been allowed to cool to room temperature in a desiccator. The percentage of volatile matter was considered to be equal to the percentage of weight loss.

Weighing the dried activated carbon samples to the closest 0.1 mg allowed for the determination of their ash concentrations. It was placed inside the known-weight crucible. When consistent weight was reached, the ashes were deemed to have been completed. The crucible was placed in the muffle furnace at 650ᵒC. After allowing the crucible to cool to ambient temperature in a desiccator, the American Society for Testing and Materials (ASTM D2866 – 94) was used to determine the percentage weight of the remaining sample, which was then regarded the ash content.

The fixed carbon is a calculated value, and it is the result of the summation of the percentage of moisture, ash, and volatile matter subtracted from 100.

Fixed carbon (%) = 100 – (moisture, % + ash, % + volatile matter, %)

Regarding the yield, each sample was assumed to weigh 5 kg before carbonization was carried out. This was done using an electronic balance. After activation and carbonization, samples were reweighed and reported as follows:

Yield = (Weight after carbonisation/Weight before carbonisation) x 100. All samples calculated at varying times and temperatures were obtained

2.4 DETERMINATION OF ADSORPTION RATE USING METHYLENE BLUE TEST

Methylene Blue Adsorption Test (MBAT) was employed to determine the activated carbon absorbance level on both coconut and periwinkle shells. These experiments were carried out in the Chemical Engineering Analytical Lab of the Federal University, Otuoke Bayelsa State, Nigeria.

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3 RESULTS AND DISCUSSION

TABLE 1. Characterizations of activated carbon using proximate analysis

S/NO	Raw Materials	Total Mass (g)	Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)
1	Coconut Husks	1.0	14	11	2.0	72
2	Periwinkle Shells	1.0	7.0	9.0	5.0	78
3	Standard From Literatures	1-0 and	15	15	0.5-5	Depends on precursor

Proximate analysis is a method used to estimate quantities of substances present in a mixture, especially solid-liquid material, by analyzing them according to their characteristics. These are moisture content, volatile matter, ash content, and fixed carbon, which were present in the activated carbons obtained from periwinkle shells and coconut husks. The results in Table 1 show the characterizations of both activated carbons produced as moisture content was given as (14, 7.0%), volatile matter (11, 9.0%), ash content (2.0, 5.0%) and fixed carbon (72, 78 %) respectively. Above and below 600 °C, and below 60 minutes, both coconut husk and Periwinkle shell yield reduces, as indicated in (Figures 1 and 2).

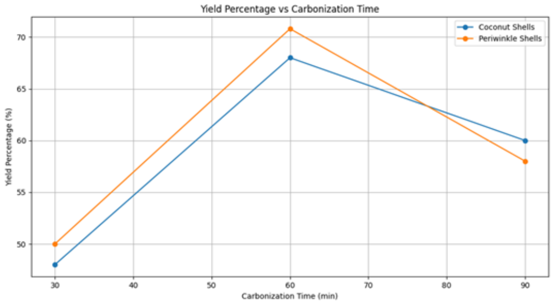

Fig: 1 Percentage yield point as a function of time

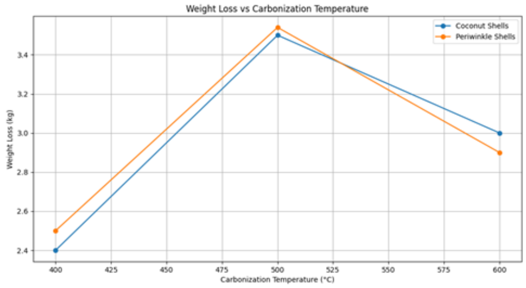

Fig 2: Percentage yield point as a function of temperature

Table 2 weight loss during carbonizations

S/NO	Raw Material	Time (min)	Carbonization Temp. (oC)	Activated Temp. (°C)	Reagent (NaOH) (M)	Initial Weight (kg)	Final Weight (kg)	Weight Loss (kg)	Yield (%)
1	Coconut Husks	30	400	500	0.3	5	2.4	2.60	48
		60	500	600	0.3	5	3.50	1.50	68
		90	600	700	0.3	5	3.00	2.00	60
2	Periwinkle Shells	30	400	500	0.3	5	2.5	2.50	50
		60	500	600	0.3	5	3.54	1.46	70.8
		90	600	700	0.3	5	2.90	2.10	58

Table 2 indicates that, weight loss during carbonization stopped increasing with temperature at a specific time and temperature. Weight loss was minimal at the optimal temperature of 700oC. This is because a longer carbonization period allowed enough time for some of the carbon to oxidize and for some of the volatile matter that was still present to escape. Activation time and temperature have a major impact on increasing yield. The result shows the effects of temperature and time on carbonizations and activation with respect to yield, as shown in Figures 1 and 2.At 600 °C at 60 minutes, coconut husk records a maximum yield of 68% while Periwinkle at 71% respectively.

Figure 3 is a perfect result on weight with respect to carbonizations temperature, which took exactly the same trend of below 600 °C and above and below 60 minutes, and both coconut husk and Periwinkle shell yield reduced. On the other hand, Figure 4 shows the initial and final weight loss of coconut husk and periwinkle shell as precursor materials used for the preparation of the activated carbon.

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The results show varying differences, though very minor differences.

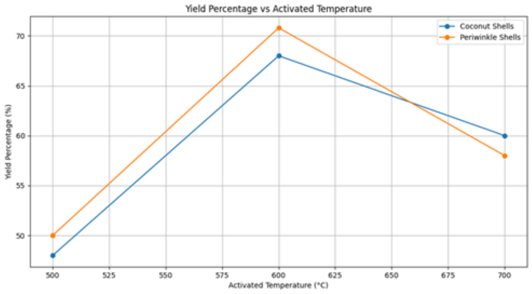

Fig 3: Percentage yield point as a function of temperature

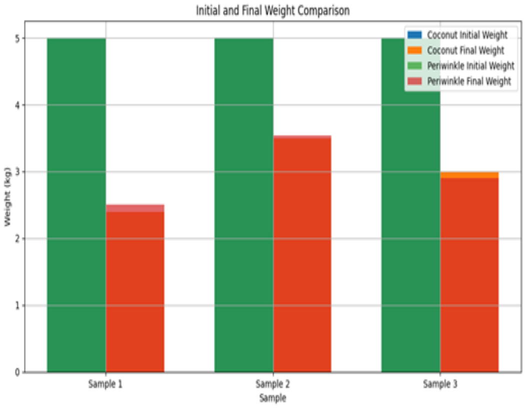

Fig 4: Comparative analysis of initial and final weight of produced activated carbon

3.1 ADSORPTION CAPACITY OF PRODUCED ACTIVATED CARBON

TABLE 3. Adsorption capacity of Produced activated carbon at different Activation Temperature

Table 3 shows the adsorption rate of produced activated carbon from coconut husk and periwinkle shells at different activation temperature rates at constant time. It can be deduced that the adsorption rate is higher in periwinkle shells than that of coconut husk, with 4.04%, 6.94% and 8.8% for 400, 500 and 600 degree centigrade, respectively. From the deduction, it can be inferred that the adsorption rates of both biomass employed are similar with little vibration, but the Methylene Blue was adsorbed easily unto the accessible hydrophobic site within the adsorbent or activated carbon matrix for 60 min. These could have resulted from the chemical interaction between the Methylene Blue and the adsorbent surface. It can then be implied that the pore structure of the adsorbents used for these experiments consists of macro pores, transitional pores (mesopore) and micro pores. From the results in Table 3, it is evident that the periwinkle shell sample gave better yield and adsorption rate than the coconut husk sample when the time was kept constant at 60 minutes at varying activated temperatures of 400 °C, 500 °C and 600 °C, respectively.

4 CONCLUSION

This experimental work's findings demonstrate that the chemical activation approach can be used to create activated carbon with comparatively large surface areas and pore volumes from agricultural waste products like coconut husks and periwinkle shells. The carbonizations temperature and activation time and temperature played a vital role in the production of the activated carbons. High carbonizations temperature gives high energy costs coupled with low carbon yields. Furthermore, the effects of activation temperature and activation time on the surface area of the samples were examined using the methylene blue test on absorbance.

S/NO	Raw material	Activation time (min)	Activation temperature (°C)	Adsorption (mg/g)
1	Coconut husks	60	400	1.90
			500	2.68
			600	2.4 4
2	Periwinkle Shells	60	400	1.98
			500	2.88
			600	2.4 6

When compared, the periwinkle shell sample gives a better yield and adsorption rate than the coconut shell sample, though the variation was small. However, activated carbon samples from both samples show a good adsorption rate, which can be improved. It is evident that the coconut husk precursor has higher moisture content and volatile matter than that of the periwinkle shell, while the ash content and fixed carbon are less than that of the periwinkle shell precursor based on 1.0g used. However, as compared to other pieces of literature based on standards, both samples were under the specified range, and figures based on 1.0g were used as sample mass

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