



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: <https://doi.org/10.22214/ijraset.2025.70163>

www.ijraset.com

Call:  08813907089

E-mail ID: ijraset@gmail.com

Generation and Characterization of Adsorbents Derived from Unmodified Peanut and Egg Shells

Abidemi Anthony Sangoremi

Department of Chemistry, Federal University Otuoke, Bayelsa State, Nigeria

Abstract: Efficient adsorbents equivalent to industrially obtainable activated carbon is drawing huge attention as a proficient precursor for adsorption process. The current study is zeroed on the generation and characterization of unmodified adsorbents from peanut shell (PNS) and Eggshell (EGS) by employing standard methods (ASTM and AOAC). The physicochemical characteristics were investigated up for both PNS and EGS adsorbents, and the outcome revealed the following biomass range: moisture content (15.20 ± 0.101 to 14.50 ± 0.110)%, volatile matter (11.20 ± 0.110 to 10.30 ± 0.011)%, ash content (9.10 ± 0.111 to 8.80 ± 0.110)%, pH (6.50 ± 0.010 to 6.40 ± 0.011) fixed carbon (66.40 ± 0.010 to 64.50 ± 0.110)%, particle size (300.00 ± 0.000) μm , bulk density (1.29 ± 0.000 to 0.540 ± 0.000) g/cm^3 , and surface area (750.00 ± 0.000 to 680.00 ± 0.100) m^2/g . Scanning electron microscope (SEM), and Fourier transform infrared spectrometer (FT-IR) were utilized to study the surface morphology and functional groups accordingly. The Electron dispersive X-ray spectrometer uncovered the elemental components of the adsorbents. The adsorbents had high fixed carbon contents and low inorganic, in conjunction with high surface area, making them valuable adsorbents. The FTIR examination revealed the presence of functional groups such as NH, C \equiv C, C=O, C-H and OH which are potential adsorption sites in addition to the well-developed pore structures from SEM studies. In contrast, EDX uncovered the presence of components like carbon, oxygen, calcium, magnesium and silicon in percent weights with PNS and EGS having carbon contents of 91.12 and 40.11% respectively. Generally, the study adsorbents possess the potential to be efficient and eco-friendly precursors for the adsorption process.

Keywords: Adsorbent, adsorption, activated carbon, biomass, FTIR, precursor,

I. INTRODUCTION

Agricultural wastes had been utilized effectively in current waste treatment plants for water filtration and detoxification treatment of polluted waters (Jacob *et al.*, 2017; Ajala and Ali, 2020), and effluent including waste treatment (Ajayi-Banji *et al.*, 2015; Marichelvan and Azhagurajam, 2018). Wastes produced from agro-wastes are numerous, they create irritation to the place where they are found. Agro-wastes are generally in enormous amount, a portion of these wastes are known for their hostile smell, and their rotted matter can modify soil pH (Bello *et al.*, 2017). Lately, different investigations have reported the preparation of adsorbents from the agro-wastes as a substitute for commercial activated carbons (ACs), which are expensive. Agro-waste materials have been proposed as conservative and eco-accommodating options for ACs (Oladoja *et al.*, 2014; Abdullahi *et al.*, 2022). The peanut shell (PNS) also known as groundnut shell, is the protective outer covering of the peanut (PN). It is a thin, hard, and fibrous material surrounding the edible peanut kernel (PNK). The PN is typically oval or elongated in shape and varies in colour from light tan to dark brown, depending on the variety of PN. It consists of two main parts: the outer shell and the inner seed coat. (Onawumiet *et al.*, 2021). The outer shell is tougher and more fibrous layer, while the seed coat is thinner and smoother layer that directly encloses the PNK. The shell serves as a natural protective barrier for the PNK, shielding it from environmental factors, pests and diseases. It helps to maintain the freshness and quality of the kernel inside. However, the shell itself is not consumed by humans as it is generally considered inedible due to its tough and fibrous nature (Ajala and Ali, 2020). The PNS have various uses beyond their roles in protecting the peanuts (PNs). They are commonly used as a good source of biomass fuel; they can be used as animal feed or as a component in livestock bedding material. In some cases, the shells are utilized for industrial purposes such as production of particle boards, mulch, and compost. PNS can also be used as an adsorbent in the adsorption phenomenon in the removal of dyes, heavy metals and other impurities from wastewater, and effluents including remediation of waste cooking oil (Onawumiet *et al.*, 2021). Further, an eggshell (EGS) is the outer covering of an egg, which is usually thin, fragile, and brittle. It is primarily composed of calcium carbonate, along with small amounts of protein and other minerals (Onawumiet *et al.*, 2021). The colour of an EGS varies, depending on the species of bird that laid it, but it is commonly white or off-white (Ahmed *et al.*, 2021). The EGS serves as a protective barrier that encases the egg's content, providing support and shielding the delicate internal structure.

Despite its delicate appearance, the EGs isquite strong and capable of withstanding the weight of an incubating bird sitting on it (Ahmed *et al.*, 2019a). However, it is still susceptible to cracking or breaking under pressure (Onawumiet *al.*, 2021). The surface of an EGS is covered with tiny pores that allow for the exchange of gases. These pores enable the developing embryos inside the egg to breathe by allowing oxygen to enter and carbon dioxidoexit. In terms of texture, the outer surface of an EGS can feel smooth, but it may also have a slight roughness or a grainy texture (Onawumiet *al.*, 2021). The texture can vary depending on the species of bird and individuals. Eggshells (EGSs) have been utilized for various purposes beyond their role in protecting the developing embryos. Theyare sometimes crushed into a fine powder and used as a calcium supplement or fertilizer. EGSs have also been employed in art and craft, as well as in traditional remedies and folk practices (Ahmed *et al.*, 2021). Finally, EGSs have been employed in various environmental remediation technologies such as theremoval of heavy metals, adsorption of radioactive meals, andadsorption of total nitrogen,fluoride and phosphorus from wastewater (Lu et al., 2017; Ahmed *et al.*, 2021; Onawumiet *al.*, 2021).

II. MATERIALS AND METHODS

A. Agro-waste samples procurement

PNS samples wereobtainedfrom a farm settlement at Idi-Osan, Iragbiji, Boripe L.G.A, while the EGS were collectedfrom an eatery at Ogbonna region, Osogbo, Osun State, Nigeria. The samples were placed in polythene packs and brought to the herbarium for proof of identity at theLife Sciences research facility of FUOtuoque, Bayelsa State, Nigeria (Sangoremiet *al.*, 2024).

B. Sample preparation

The procedureofOnawumiet *al.* (2021) wasused.The samples were washed with steady water in the laboratory, and washed severally with distilled water to remove stones, dirt and trash. The samples were sun-dried for 24 hr and oven-dried at 105°C for 5 hr and allowed to cool in desiccators. The dried samples were squashed and sieved to 300 µm size with amechanical sifter and kept in a sealed glass container beforeusage.

C. Adsorbent Characterization

1) pH determination

Exactly 3 g of the adsorbent was measured and soakedin 30 ml of hot distilled water for 24 hr. The combination was mixed to guarantee good dilution and filtered. The pH of the filtrate was determined using a computerized pH meter, Jenway 3520 (Ebelegiet *al.*, 2022; Onawumiet *al.*, 2021; ASTM: D 3838).

2) Determination of moisture content

The moisture content (MC) wasdetermined by standard techniques ASTM D 2974 (2014). About2 g of the models was measured into a crucible. This was dried at 105 °C to consistent mass and kept in a desiccator. The percentage MC was determined mathematically (Boadu *et al.*, 2018)using the relationship below:

$$MC = \frac{C - D}{C - B} \times 100 \quad 1$$

D = Mass of crucible in addition to dried example

B = Mass of crucible (g)

C = Mass of crucible in addition to initial example (g)

3) Bulk density

The common procedure used in calculating the bulk density (BD)was weighing 5 g of the sample and placed on a pre-weighed 5 ml measuring cylinder (w_1). The cylinders were gently tapped to eliminate air spaces inside the samples in the cylinder to give a potential close pack (PBD). The volume required by the samples and the additional load of the cylinder wererecorded using a weighing balance as (w_2), (Ijaolaet *al.*2013, and Ebelegiet *al.* (2022).The mass BD was determined as:

$$BD = \frac{W_2 - W_1}{V} \quad 2$$

W1 = mass of cylinder (g)

V = size of the cylinder

W2 = mass of tests and cylinder (g)

4) Ash content profile

Ash content (AC) was calculated as per standard technique (Ebelegiet *al.*, 2022; ASTM: D 2866-94). Exactly 5 g of dried samples were measured into a crucible of a known weight and heated in a muffle furnace for 6 hr at 600 °C. Precisely when consistent weight was accomplished, the crucible was allowed to cool in desiccators. The mass of the ashed carbon was determined as the percentage of the initial sample.

$$AC = \frac{C - D}{C - B} \times 100 \quad 3$$

D = Mass of crucible + ashed sample (g)

C = Mass of crucible + initial sample (g)

B = Mass of the crucible (g)

5) Volatile matter

Volatile matter (VM) was determined by the standard techniques (ASTM D3175-11 and Ebelegiet *al.* 2022). Exactly 1g of the sample was taken in a pre-dried crucible and covered with a lid, and placed in a muffle furnace controlled at 950°C for 7 min. During heating, the crucible was promptly covered, cooled in desiccators and weighed. The sum weighed was taken as VM.

$$VM = \frac{C - D}{C - B} \times 100 \quad (4)$$

D = Mass of the crucible + volatile ample (g)

C = Mass of crucible + test sample (g)

B = Mass of the crucible (g)

6) Particle size

The particle size (PS) of the ground samples were examined. The samples were made by mean of an electric blending machine after which a sifter examination was done using Controls Miland-Italy D402-01 Matr 84000 109 sieve shaker at a rotation of 10-15 min with (300 μm) sieve.

$$\%C = \frac{A}{B} \quad (5)$$

A = Mass of carbon after sieve

B = Total mass of carbon

7) Surface Area

The surface area (SA) of the biosorbent was determined using the Sae's technique, (Ebelegiet *al.*, 2022) where 0.5 g of each sample was carefully weighed into 250 ml Erlenmeyer flask containing 25 ml of 0.1M HCl at pH 3.50. Thereafter, 1 g of NaCl was added to increase the pH to 4, and the mixture was titrated against a standard solution of 0.1M NaOH until pH 9 was achieved.

The volume expected to extend the pH from 4 to 9 was noted and applied in working out the SA utilizing Eq. (6).

$$SA \text{ (m}^2\text{/g)} = 32V - 25 \quad (6)$$

V = volume of NaOH used to increase pH from 4 to 9. The surface area of the biosorbent was resolved by using the Sae's technique, portrayed by Ebelegiet *al.* (2022) where 0.5 g of each sample was carefully weighed into 250 ml erlenmeyer flask holding 25 ml of 0.1M HCl at pH 3.50, after which 1 g of NaCl was enhanced to increase the pH to 4, the mixture was titrated against a standard solution of 0.1M NaOH until pH 9 was achieved.

The volume expected to extend the pH from 4 to 9 was noted and applied in working out the SA utilizing Eq. (6).

$$SA \text{ (m}^2\text{/g)} = 32V - 25 \quad (6)$$

V = volume of NaOH used to increase pH from 4 to 9.

Scanning electron microscopy/ energy dispersive X-ray spectroscopy (SEM/EDX/) analysis

The morphology of the samples and elemental configuration of PNS and EGS were obtained through SEM using a JSM-7610F (Tokyo, Japan). The hardware is a super-high goal Schottky Field emanation filtering electron microscopy joined with energy dispersive x-ray. The adsorbent surface was inspected with an amplifying lens worked at 10.0 kV. The samples were covered with a 10 nm thick layer of gold (Jabar *et al.*, 2020).

III. RESULTS AND DISCUSSION

A. Adsorbent pH

Scientific investigations showed that pH impacts the charge bulkiness around adsorbent/adsorbent particles (Ebelegiet *al.*, 2022; Sangoremiet *al.*, 2024). Subsequently, pH is a significant parameter that impacts the dissociation of active sites on the surface of adsorbents (Onawumiet *al.*, 2021). Tables 2 and 3 reveal that PNS and EGS have pH (6.50 0.010 and 6.40 0.011), and may be great adsorbent for anionic species. The pH for the prepared biomasses is within the range of those stated in the literature (Ajala and Ali, 2020) which suggests that the biomass was ideal for adsorption. The pH for the ideal take-up of metals and organic pollutants by most adsorbents is between pH 6.0-9.0 (Aji *et al.*, 2015; Sangoremiet *al.*, 2024).

B. Moisture Content (MC)

Research shows that moisture content (MC) increases directly with BD (Ebelegiet *al.*, 2022). Tables 2 and 3 reveal the range of MC (15.20 ± 0.1010 to $14.50 \pm 0.110\%$) which suggests that comparable to MC, EGS has an ideal adsorption efficiency over the PNS. Furthermore, adsorbents with low MC have a longer shelf-life usability than the ones with high MC. Consequently, biosorbents with high MC ought to be additionally exposed to gentle heating before they could be utilized as this would have diminished the MC, and subsequently upgraded a superior adsorption ability (Ebelegiet *al.*, 2022).

C. Volatile Matter

The VM amount is shown in Tables 2 and 3 in the scope of (11.20 ± 0.110 to $10.30 \pm 0.011\%$) for both PNS and EGS which was extensively high, conceivably because of the adsorbent source.

D. Ash Content

The outcome of AC uncovered that PNS was $9.10 \pm 0.111\%$, and EGS ($8.80 \pm 0.110\%$). Reports have it that elevated levels of AC diminish the overall effectiveness of adsorbents, subsequently, it decreases the efficiency of the adsorbents, as far as adsorbent regeneration is concerned. Accordingly, the outcomes acquired revealed the presence of an obvious level of ash in the adsorbents, and this could prevent their surface reactivity (Ebelegiet *al.*, 2022). Be that as it may, researchers have detailed AC values comparable to what was gotten in the current works (Boadu *et al.*, 2018).

E. Fixed Carbon

Tables 2 and 3 reveal that the values of FC for PNS and EGS are 64.50 ± 0.110 and $66.40 \pm 0.010\%$ respectively. The higher the FC, the better the adsorption capacity of the adsorbent, consequently, EGS would be a preferable adsorbent over PNS because of its higher FC. Reports have it that a decent adsorbent ought to have a $FC \geq 65\%$ (Olayiwola *et al.*, 2015). The FC values EGS adsorbent in the current work fall within the range of adsorbents as stated in the literature, while PNS was 0.5% lesser, by and large, the adsorbents synthesized are suitable for the adsorption process.

F. Bulk Density

Tables 2 and 3 presented the results of BD for PNS (0.540 ± 0.000), and EGS (1.29 ± 0.000 g/cm³). It is observed that EGS has a higher BD while PNS has the least. In this way, the BD values got for the adsorbents conformed to the values widely reported in the literature, making them suitable for adsorption (Ajala and Ali, 2020). Be that as it may, since BD is inversely correlated to the surface area, (SA) ($BD \propto 1/SA$), subsequently, the adsorbent with lower BD will have better adsorption efficiency. Hence, PNS shows improvement over EGS based on BD.

G. Surface Area

Tables 2 and 3 presented the surface area (SA) of 680.00 ± 0.100 m²/g for PNS, while EGS has 750.00 ± 0.000 m²/g. Consequently, EGS portrays a superior adsorbent in view of its higher SA which means the accessibility of more empty adsorption sites than PNS. Reports have that activation advances better porosity and high surface area (Onawumiet *al.*, 2021), and adsorbents with SA of 500-1500 m²/g are great for adsorption.

H. Particle Size

Particle size (PS) has a close relationship with SA. Decreased PS has direct connections to the progression of greater SA, enhancing more adsorption of empty sites within the adsorbents (Ebelegiet *al.*, 2022).

The worth of PS ($300.00 \pm 0.000 \mu\text{m}$), and other physicochemical properties of the adsorbents aligned to those detailed by different authors (Ajala and Ali, 2020; Sangoremiet *al.*, 2024).

Table 1: Standard threshold s for ACs

Parameter	SII No. 02587-79	SNI 06-3730-1995
Fixed Carbon (%)	Max -	Max 65
Volatile matter (%)	Max 15	Max 25
Ash content (%)	Max 2.5	Max 10
Iodine (mg/g)	Min 200	Min 750
Moisture (%)	Max 10	Max 15

Min: minimum, Max: maximu

Table 2: Physicochemical properties of Peanut shell (PNS)

S/no	Parameters	$\bar{x} \pm SE$
1	Moisture content (%)	15.20 ± 0.101
2	Volatile matter (%)	11.20 ± 0.110
3	Ash content (%)	9.10 ± 0.111
4	pH	6.50 ± 0.010
5	Fixed carbon (%)	64.50 ± 0.110
6	Particle size (μm)	300.00 ± 0.000
7	Bulk density (g/cm^3)	0.540 ± 0.000
8	Surface area (m^2/g)	680.00 ± 0.100

Table 3: Physicochemical properties of eggshell a(EGS)

S.NParameters	$\bar{x} \pm SE$	
1	Moisture (%)	14.50 ± 0.110
2	Volatile matter (%)	10.30 ± 0.011
3	Ash content (%)	8.80 ± 0.110
4	pH	6.40 ± 0.011
5	Fixed carbon (%)	66.40 ± 0.010
6	Particle size (μm)	300.00 ± 0.000
7	Bulk density (g/cm^3)	1.29 ± 0.000
8	Surface area (m^2/g)	750.00 ± 0.000

Fourier transform infrared spectroscopy (FT-IR) analysis

Figures 1 and 2 showed the spectra of PNS and EGS, while Tables 4 and 5 revealed the functional configuration. The spectra uncovered functional groups that are probable sites for adsorption. For both PNS and EGS adsorbents, the bands representing the peaks were seen at 3657.76, 3657.16, 2924.18, 1712.85, 1519.96, 995.30 cm^{-1} , and 3896.34, 3811.47, 3703.15, 3510.56, 3124.79, 2337.80, 1658.84, 1442.52, 972.16 cm^{-1} separately. The peaks at 3896.34, 3811.47 and 3703.15 cm^{-1} represent the stretching of OH, and the peaks at 3510.56, 3124.79, 2337.80, 1658.84, 1442.52, 972.16 connote N-H, C-H, $\text{C}\equiv\text{C}$, $\text{C}=\text{O}$, CH_3 , C-H stretch separately in the EGS adsorbent. The bands at 3657.76 and 3657.16 cm^{-1} address the N-H extending, while the peaks at 2924.18, 1712.85, 1519.96 and 995.30 cm^{-1} signify CH, $\text{C}=\text{O}$, $\text{C}=\text{C}$ and NH_2 extending separately in PNS adsorbent. The adsorbents' functional groups not only influence the adsorption process, but in addition, govern the adsorption phenomenon.

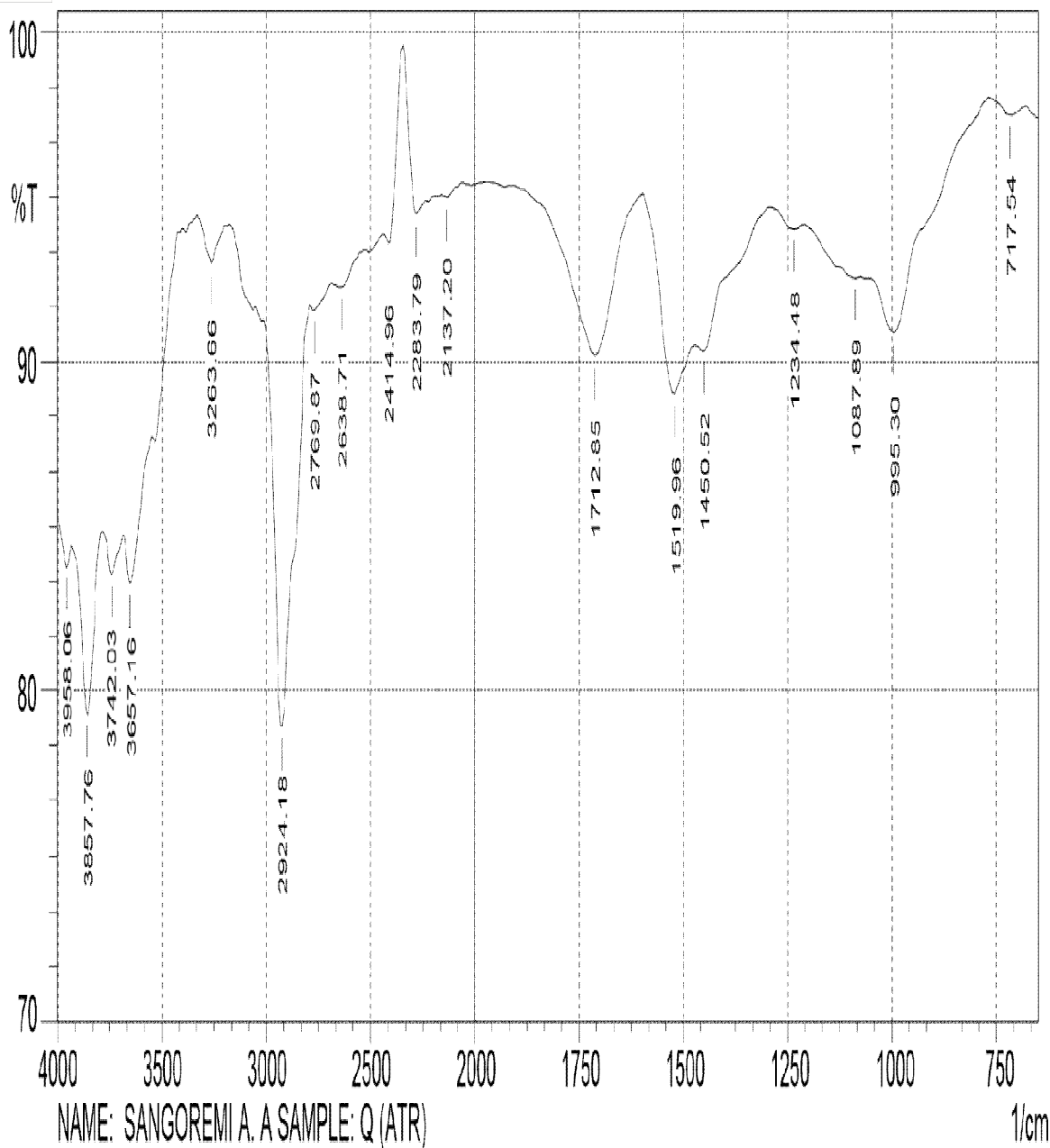


Figure 1: FTIR Spectrum of peanut (PNS)

Table 4: The FTIR spectrum of peanut shell

S. N	Wave number (cm ⁻¹)	Bands (cm ⁻¹)	Functional group
1	3657.76	> 3500	N-H stretch
2	3657.16	> 3500	N-H stretch
3	2924.18	2960 - 2700	CH stretch
4	1712.85	1730-1700 (s)	C=O stretch
5	1519.96	1550-1475	C=C stretch
6	1450.52	1510-1450	CH ₃ or CH ₂
7	995.30	1000-665 (s)	NH ₂

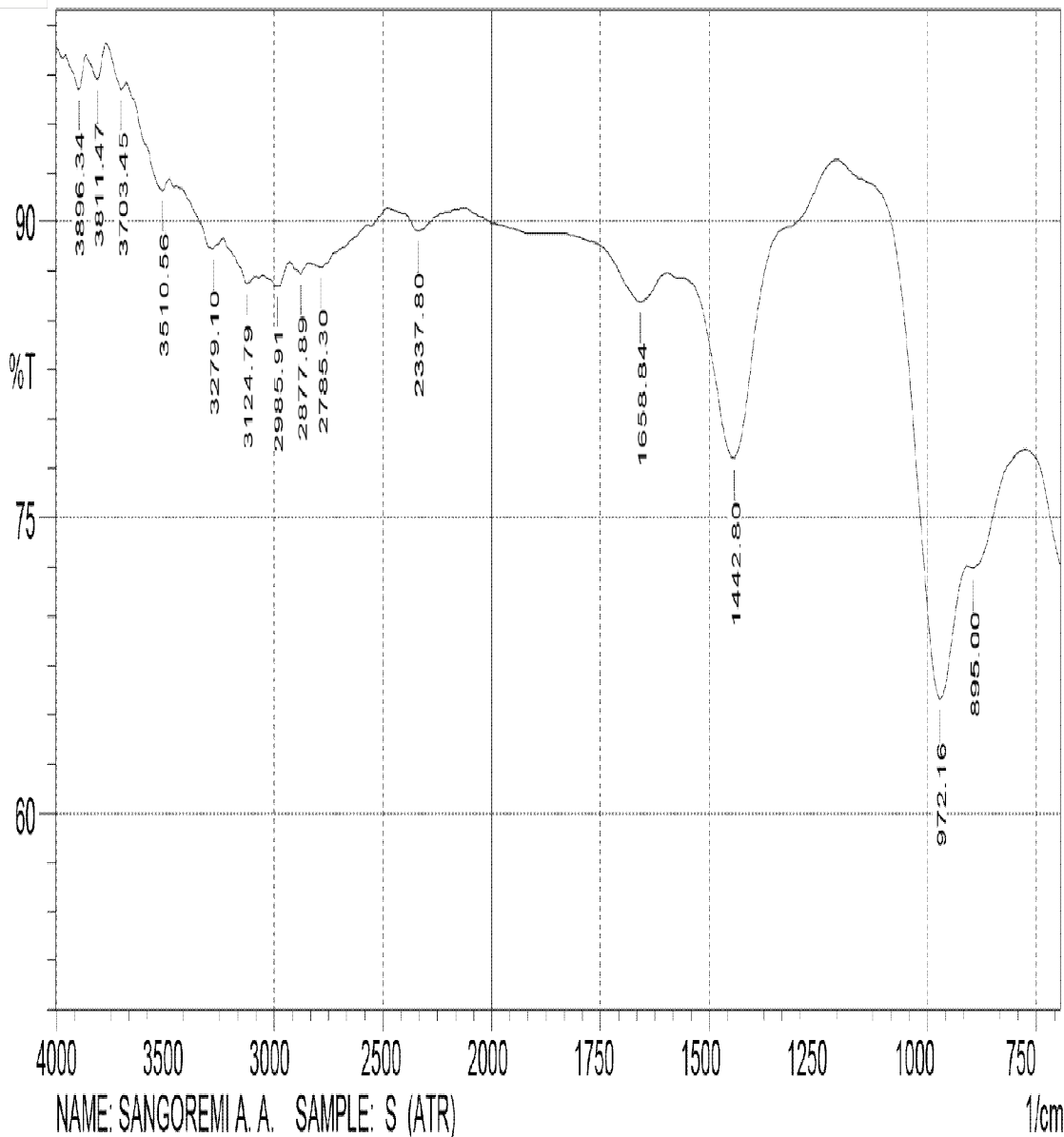


Figure 2: FTIR Spectrum of eggshell (EGS)

Table 5: FTIR spectrum interpretations of eggshell adsorbent

S. No	Wave number (cm ⁻¹)	Frequency (cm ⁻¹)	Functional group
1	3896.34	> 3500	O-H
2	3811.47	> 3500	O-H
3	3703.15	> 3500	O-H
4	3510.56	> 3500	NH stretch
5	3279.10	3300 - 2500	NH
6	3124.79	3300 - 2500	C-H
7	2337.80	2376 - 2248	C≡C
8	1658.84	1680 - 1620	C=O stretch
9	1442.52	1510 - 1450	CH ₃ (methyl group)
10	972.16	1000 665 (s)	C-H out of plane bending vibration.

Scanning Electron Micrographs (SEM)

Figures 3 and 4 showed the Scanning electron micrographs (SEM) of PNS and EGS adsorbents individually. The surface morphology of the samples clearly shows that the surface pores were well developed, and smooth with regular pore structures which are prerequisites to good adsorption efficiency. Other researchers made similar reports (Ebelegiet *al.*, 2022). The accessibility of pores and internal surfaces is fundamental for successful adsorption. In this way, the porous properties of the synthesized biomass assist in the adsorption process. These pores give a decent SA for impurities removal, and remediation of waste oils (Ebelegiet *al.*, 2022).

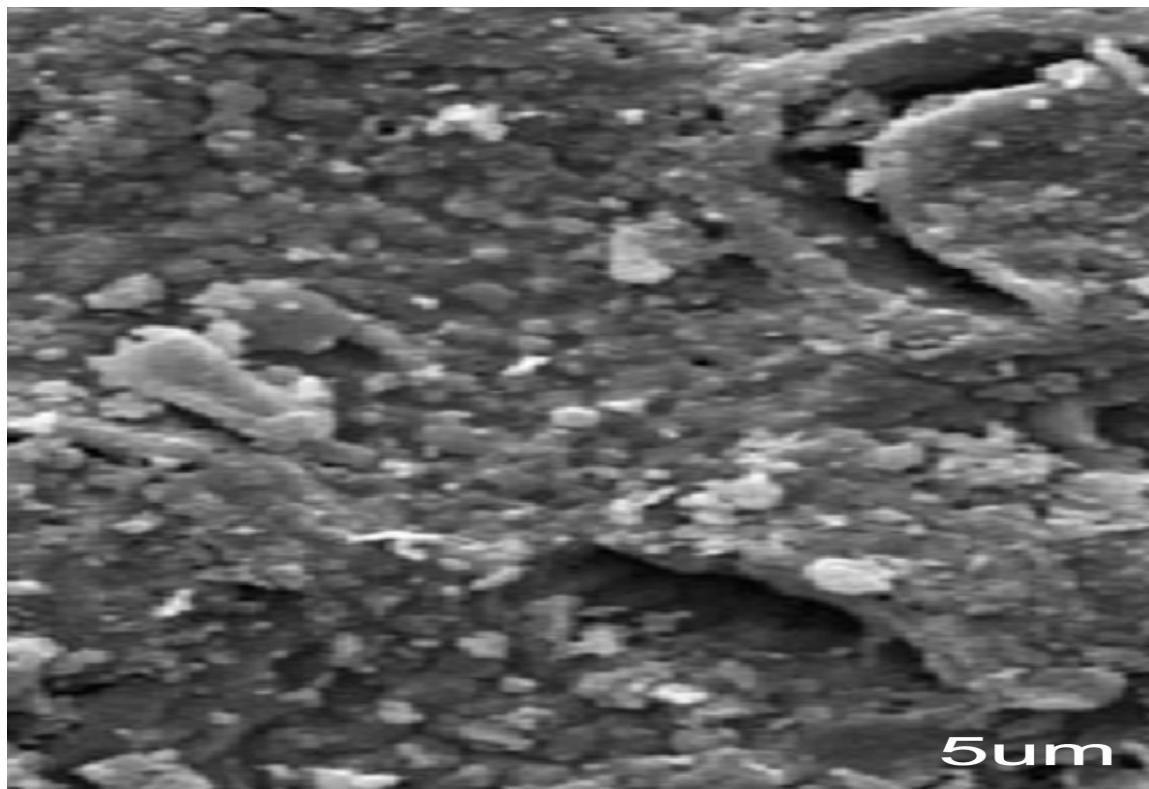


Figure 3: SEM micrograph peanut shell adsorbent

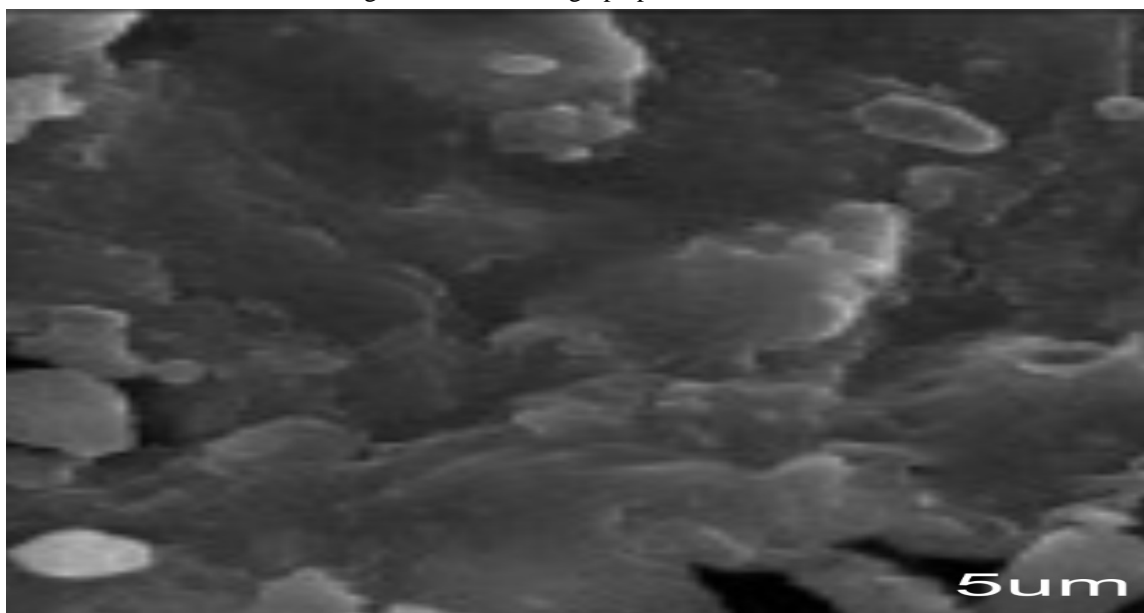


Figure 4: SEM micrograph eggshell adsorbent

Electron Dispersive X-ray Spectroscopy (EDX)

The EDX study is a technique for elemental examination in Figures 5 & 6 showed the EDX spectra of PNS and EGS adsorbents, while Tables 6 and 7 showed the elemental configuration of the adsorbents individually. The carbon contents for PNS and EGS are 91.12 and 45.41% respectively. Additional elements present according to percent atomic weight comprise: Mg (0.55%), O (42.92%), Ca (1.28%), N (5.64%), P (1.63, 1.28%) (Ushedoet *al.*, 2022).

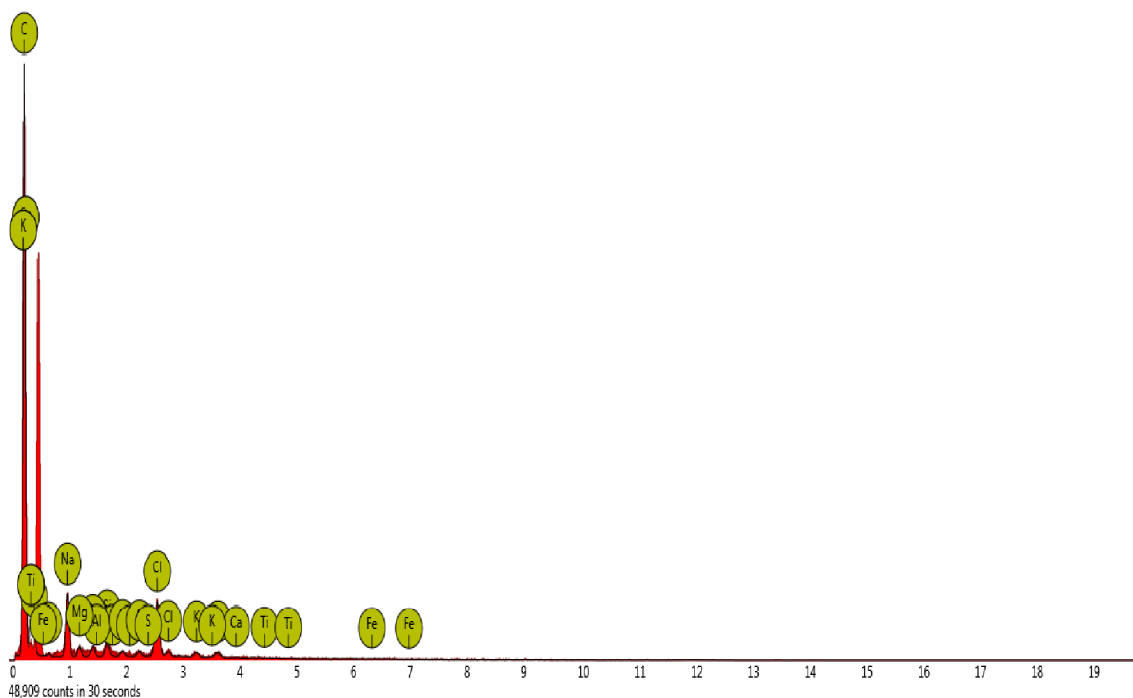


Figure 5: EDX adsorption spectrum of peanut shell

Table 6: Elemental composition of peanut shell

Element	Symbol	Name	Atomic Conc.	Weight Conc.
6	C	Carbon	91.12	79.15
15	P	Phosphorus	4.66	10.44
19	K	Potassium	1.63	4.60
20	Ca	Calcium	0.77	2.23
14	Si	Silicon	0.79	1.61
11	Na	Sodium	0.30	0.50
16	S	Sulfur	0.11	0.25
17	Cl	Chlorine	0.11	0.28
13	Al	Aluminum	0.23	0.46
12	Mg	Magnesium	0.28	0.49
22	Ti	Titanium	0.00	0.00
26	Fe	Iron	0.00	0.00

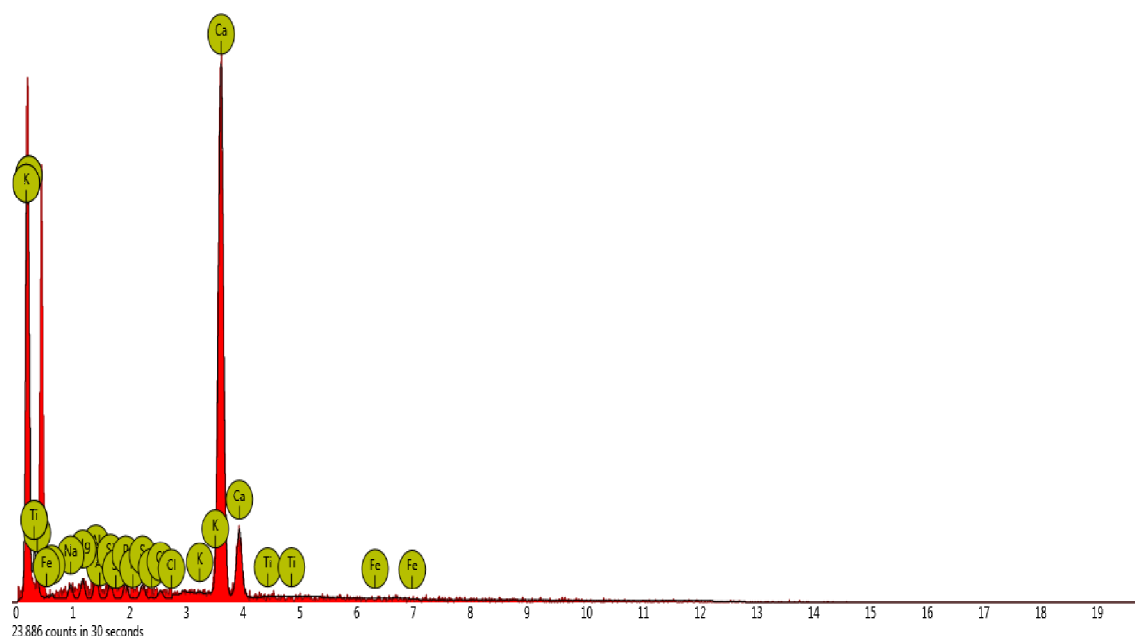


Figure 6: EDX adsorption spectrum of eggshell

Table 7: Elemental composition of eggshell

Element	Symbol	Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	45.41	44.66
6	C	Carbon	40.11	39.67
19	K	Potassium	5.28	4.09
13	Al	Aluminum	2.19	2.00
12	Mg	Magnesium	2.00	1.91
11	Na	Sodium	2.00	1.69
16	S	Sulfur	1.25	1.21
15	P	Phosphorus	1.28	1.20
17	Cl	Chlorine	0.38	0.33
14	Si	Silicon	1.33	1.20
26	Fe	Iron	0.00	0.00
22	Ti	Titanium	0.00	0.00

IV. CONCLUSION

The adsorbents generated, PNS, and EGS focused in this work supposedly had moderate MC, and optimal pH alongside high fixed carbon including high SA that are pointers to outstanding adsorbents. The FTIR showed the presence of functional groups (COOH, OH, C=O, NH) that are plausible adsorption sites. The SEM results revealed the surface structure of the adsorbents (PNS and EGS) to possess the incredible features of an ideal adsorbent. The general features showed that the prepared adsorbents could be viewed as outstanding and effective precursors for the adsorption process.

REFERENCES

- [1] Abdullahi, A., Tsafe, A.I., Liman, M.G., & Ibrahim, N. (2022). Characterization and Modification of Activated Carbon Generated from Annogeissus leiocarpus. Caliphate Journal of Science and Technology, 2:151-159.
- [2] Ahmed, T.A.E., Kulshreshtha, G., & Hinke, M. (2019a). Value-added uses of eggshell and eggshell membranes "in Eggs as functional food and Nutraceuticals for human Health, ed. J.Wu (London). Journal of Royal Society of Chemistry 2019, 359-397.

- [3] Ahmed, TAE., Suso, HP., Maqbool, A., & Hinckle, MT. (2019b). Processed eggshell membrane powder: bio-inspiration for an innovative wound healing product. *Journal of Material Science Engineering* 95, 192-203.
- [4] Ahmed, TAE., Wu, L., Younes, M., & Hincke, M. (2021). Biotechnological Application of Eggshell: Recent Advances. *Frontiers in Bioengineering and Biotechnology*, 6 (2021):675364. <https://doi.org/10.3389/fbioe.2021.675364>
- [5] Ajala, LO & Ali, EE. (2020). Preparation and Characterization of Groundnut Shell-Based Activated Charcoal. *Journal of Applied Sciences and Environmental Management*, 24(12):2139-2146.
- [6] Ajayi-Banji, A., Sangodoyin, A., & Ijaola, O. (2015). Coconut husk Char Biosorption in Heavy Metal Diminution from Contaminated Surface Water. *Journal of Engineering Studies and Research*, 21 (4):7-13.
- [7] ASTM D2866-94 (2014). Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils, ASTM international, West Conshohocken, PA, USA, www.astm.org.
- [8] ASTM D2974 (2014). Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils, ASTM international, West Conshohocken, PA, USA, www.astm.org.
- [9] ASTM D3175-11 (2014). Standard Test Methods for volatile matter determination, ASTM international, West Conshohocken, PA, USA, www.astm.org
- [10] ASTM D3838 (2014). Standard Test Methods for pH determination in biosorbent samples, ASTM international, West Conshohocken, PA, USA, www.astm.org.
- [11] Bello, OS, Awojuyigbe, ES., Babatunde, MA. & Folaranmi, FE (2017). Sustainable conversion of agro-wastes into useful adsorbent. *Applied Water Science*, 7:3561-3571.
- [12] Boadu, K.O., Joel, O.F., Essumang, D.K., & Ebuomwan, B. (2018). Comparative Studies of the Physicochemical Properties and Heavy Metals Adsorption Capacity of Chemical Activated Carbon from Palm Kernel, Coconut and Groundnut Shells. *Journal of Applied Science Environmental Management*, 22(1):1833-1839.
- [13] Ebelegi, AN., Toneth, EL., & Bokizibe, MA. (2022). Determination of Physicochemical Properties of Biosorbents Synthesized from Watermelon Rind Using Microwave Assisted Irradiation Procedure. *Open Journal of Physical Chemistry*, 12:19-30.
- [14] Ijaola, OO., Ogedengbe, K., & Sangodoyin, AY. (2013). On the efficacy of activated carbon derived from bamboo in the adsorption of water contaminants. *International Journal of Engineering Inventions*, 2(4):29-34.
- [15] Jabar, JM., & Odusote, YA (2020). Removal of Cibacron blue 3G-A (CB) dye from aqueous solution using chemophysically activated biochar from palm empty fruit bunch fiber. *Arabian Journal of Chemistry*, 13:5417-5429.
- [16] Jacob, AG., Okunola, OJ, Uduma, AU., Tijjani, A. & Hamisu, S. (2017). Treatment of waste water by activated carbon developed from *Borassus aethiopicum*. *Nigerian Journal of Material Science and Engineering*, 6 (1):103-107.
- [17] Lu, G., Qu, L., Lin, Z., Dang, Z., Yang, C., & Xie, Y. (2017). A kind of method using the acid agricultural land soil of eggshell heavy metal pollution to carry out improving. State Intellectual Property Office of the People's Republic of China, CN106269841A. Inventor; south China University of technology, assignee. 1-10.
- [18] Marichelvan, MK., & Azhagurajan, A. (2018). Removal of mercury from effluent solution by using banana corm and neem leaves activated charcoal. *Environmental Nanotechnology. Monitoring and Management* 10, 360-365.
- [19] Nandiyanto, ABD, Oktiani, R., & Ragadhita, R. (2019). How to Read and Interpret FTIR Spectroscopy of Organic Material. *Indonesian Journal of Science and Technology*, 4(1):97-118.
- [20] Oladoja, NA., Adelagun, ROA., Ololade, IA Anthony, ET., & Alfred, MO. (2014). Synthesis of nano-sized hydrocalumite from a Gastropod shell for aqua system phosphate removal. *Separation and Purification Technology* 124, 186-194.
- [21] Onawumi, OO., Sangoremi, AA. & Bello, OS. (2021). Production and Characterization of Groundnut and Egg Shells Activated Carbon (AC) as Viable Precursors for Adsorption. *Journal of Applied Science and Environmental Management*, 25(9):1707-1713.
- [22] Sangoremi, AA., Onawumi, OO., & Bello, OS. (2024). Modification and Characterization of Biosorbent Developed from Coconut Shell. *International Journal of Basic Science and Technology* 10:91-101.
- [23] Sangoremi, AA., Adeyeye, JA., & Isaac, IU. (2024). Adsorptive Kinetic Mechanisms of Bromocresol Green Dye Removal from Wastewater Using Modified Groundnut Shell Adsorbent. *Science World Journal* 19 (4): 1049-1054.
- [24] Ushedo, TR., Adeyemi, OG., Adewuyi, A., & Lau, W. (2022). Synthesis of N, N(1,3-Phenylene) dimethanimine. A useful resource for the removal of free fatty acid in waste vegetable oil. *Scientific African* 16, e01188. <https://doi.org/10.1016/j.sciaf.2022.e01188>



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)