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Characterization of Cocoyam Peels Biochar for Remediation of Crude Oil Polluted Soils

Ngozi Jane Maduelosi[1*], May Nwamaka Ighomuaye[1], and Emeka Emmanuel Joseph[2]

[1]Department of Chemistry, Faculty of Science, Rivers State University Nkpolu Oroworukwo, Port Harcourt, Nigeria.
[2]Department of Chemistry, Faculty of Science, Hezekiah University, Umudi, Imo State, Nigeria.

Email address:
*Corresponding author: ngozi.maduelosi@ust.edu.ng. +2348035811706
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ABSTRACT

Soil contamination is a growing environmental concern in Nigeria due to industrial, agricultural, and mining activities and this has posed serious ecological and health risks, yet conventional remediation methods remain costly and unsustainable. This study is significant because it provides a cost-effective and sustainable approach to tackling soil contamination by transforming cocoyam peels, an underutilized agricultural waste, into biochar for remediation purposes. In this study, cocoyam peels biochar (adsorbent) was produced and characterized using Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectrometer (FTIR). 10.0 g of the adsorbent was applied to 1000 g of crude oil-polluted soil. The physicochemical properties of the soil before and after remediation were determined using a multimeter. The FTIR result revealed the presence of the C=O, C–H, O=C=O, OH, and C=C functional groups. SEM showed a porous microstructure with well-developed cavities and micropores, providing an extensive surface area for pollutant binding. Results of physicochemical parameters obtained were; pH 5. 8, Electrical conductivity (EC) 2144 µS/cm, ambient temperature 29.0 °C, and Total dissolved solids (TDS) 1132 mg/L. Cocoyam peels biochar increased the activities of indigenous microbes which in turn reduced Total Petroleum Hydrocarbon (TPH) to 50 % thereby making it a promising, cost-effective, and sustainable material for the immobilization of pollutants in contaminated soils.

1. INTRODUCTION

Recently, rapid urbanization, intensive agriculture, and industrial expansion have polluted the soil, which is of environmental concern [1]. The mixed matrix of pollutants in such soils, examples heavy metals, pesticides, pharmaceuticals, per- and polyfluoroalkyl substances (PFAS), and microplastics; poses significant risks to the environment particularly soil health and agricultural productivity, complicating remediation efforts [2]. In addition to this, Climate change influences soil pollution dynamics, altering pollutant behavior, mobility, and environmental fate [3].

Biochar, a carbon-rich product from biomass pyrolysis is one of such emerging materials that holds promise for sustainable soil remediation. Biochar can adsorb and so sequester contaminants, improve soil fertility and structure, and even contribute to carbon sequestration, all with relatively low environmental impact [4]. Its multifunctional nature makes biochar a key element of a circular bioeconomy strategy for soil cleanup.

Cocoyam (*Colocasia esculenta*), a root crop widely grown in tropical regions, also produces considerable waste during processing and consumption. Chemically, cocoyam is a carbohydrate-rich tuber: its corm (edible root) is dominated by starch (often >85% of dry matter) and the 5 itself is essentially a lignocellulosic by-product. Recent analyses of cocoyam reveal that the peels have very low moisture (4–5%), ash (0.9–1.1%), and fiber (0.8–0.9%) contents, meaning they are overwhelmingly composed of carbohydrates [5]. In other words, roughly 93–94% of cocoyam peels' dry mass is carbon-rich organics (starch, cellulose, etc.). This composition suggests that cocoyam peels could yield a high-porosity, carbon-dense biochar upon pyrolysis [6]. The peel's low ash and mineral fraction is especially advantageous, as it means more fixed carbon in the biochar. Physically, cocoyam peels (like other tuber skins) consist of parenchyma cells rich in starch granules and some fibrous tissues. During pyrolysis, these features often create a matrix of micro- and mesopores in the char, enhancing surface area. Moreover, residual minerals (K, Ca, etc.) from the peels can contribute ash that provides liming and nutrient effects in the soil. Importantly, cocoyam peels are underutilized biomass; as it is not commonly exploited in industry, studying their potential valorization is a novel contribution to sustainable waste management [6]

Converting this residue into biochar not only reduces waste but also creates value-added products for soil management. Proper characterization using FTIR and SEM is essential to understand the functional groups and surface morphology responsible for adsorption. Such scientific evidence will validate cocoyam peels biochar as a reliable adsorbent for heavy metal remediation. The study therefore addresses both waste valorization and soil pollution challenges. It is expected to promote sustainable agricultural practices and contribute to the body of knowledge on biochar research. Ultimately, it would provide support for low-cost, eco-friendly solutions to environmental pollution in developing countries.

2. MATERIALS AND METHOD

2.1. Sample Collection, Preparation, and Analyses

Fresh cocoyam peels were sourced from Mile 3 market in Port Harcourt, Nigeria. The peels were carefully washed and rinsed with distilled water to eliminate soil and impurities, followed by air-drying for seven days. To ensure uniform and complete dryness, they were oven-dried at 105 °C until a constant weight was achieved. The dried material was ground into fine powder using a mechanical grinder and sieved to obtain a homogenous particle size suitable for pyrolysis. 17 grams of the pretreated cocoyam peels were placed into ceramic crucibles with lids and subjected to pyrolysis in a muffle furnace under limited oxygen conditions. The pyrolysis process was carried out at a temperature of 500 °C for 3 hours [7]. After cooling to room temperature, the biochar was sieved and stored in an air- tight container. FTIR and SEM analyses were carried out to determine its functional groups and micropore surface area.

A crude oil-polluted soil sample was collected from Biara, Gokana local government area in Rivers State. 1kg of polluted soil was weighed into a plastic reactor. The sample was left for three days for acclimatization and afterwards treated by applying 10 g of the produced biochar in the polluted soil sample reactor using the modified method of [8]. The soil sample was monitored for a period of one month after which it was air–dried, ground, sieved with a 2 mm mesh, and stored in labelled polythene bags under room temperature. The treated soil sample was used for the determination of TPH, pH, TDS, and EC. Also, TPH of the untreated polluted soil sample was determined.

3. RESULTS AND DISCUSSION

3.1. Fourier Transform Infrared Spectroscopy Characterization of Cocoyam Peels Biochar

Table 1 shows the FTIR fingerprint region and functional groups of cocoyam peels biochar. Prominent absorption bands were observed at 984 cm^{-1} (C–O or Si–O vibrations), 1364 cm^{-1} (C–H or O–H bending), 1558 cm^{-1} (C=C stretching), 1894cm^{-1} (C=O overtone), 2117 cm^{-1} (C≡C or C≡N), 2341 cm^{-1} (O=C=O), 2960 cm^{-1} (aliphatic C–H), and 3034 cm^{-1} (aromatic C–H). Figure 1 displayed the FTIR spectrum, showing the distinct peaks corresponding to the identified functional groups.

Table 1. *FTIR Wavenumbers (cm^{-1}) and the corresponding Functional Groups in Cocoyam (Colocasia esculenta) peels Biochar*

Serial No.	Wavenumber (cm^{-1})	Functional Group
1	984	C–O stretching or Si–O vibrations
2	1364	C–H bending ($–CH_3$, $–CH_2$) or O–H bending of phenolic group
3	1558	C=C stretching (aromatic ring vibrations) or N–O asymmetric stretch
4	1894	C=O overtone or aromatic combination bands
5	2117	Possible C≡C (alkyne) or C≡N stretching
6	2341	O=C=O stretching (CO_2 adsorbed on surface)
7	2960	C–H stretching (aliphatic $–CH_3$, $–CH_2$)
8	3034	=C–H stretching (aromatic C–H)

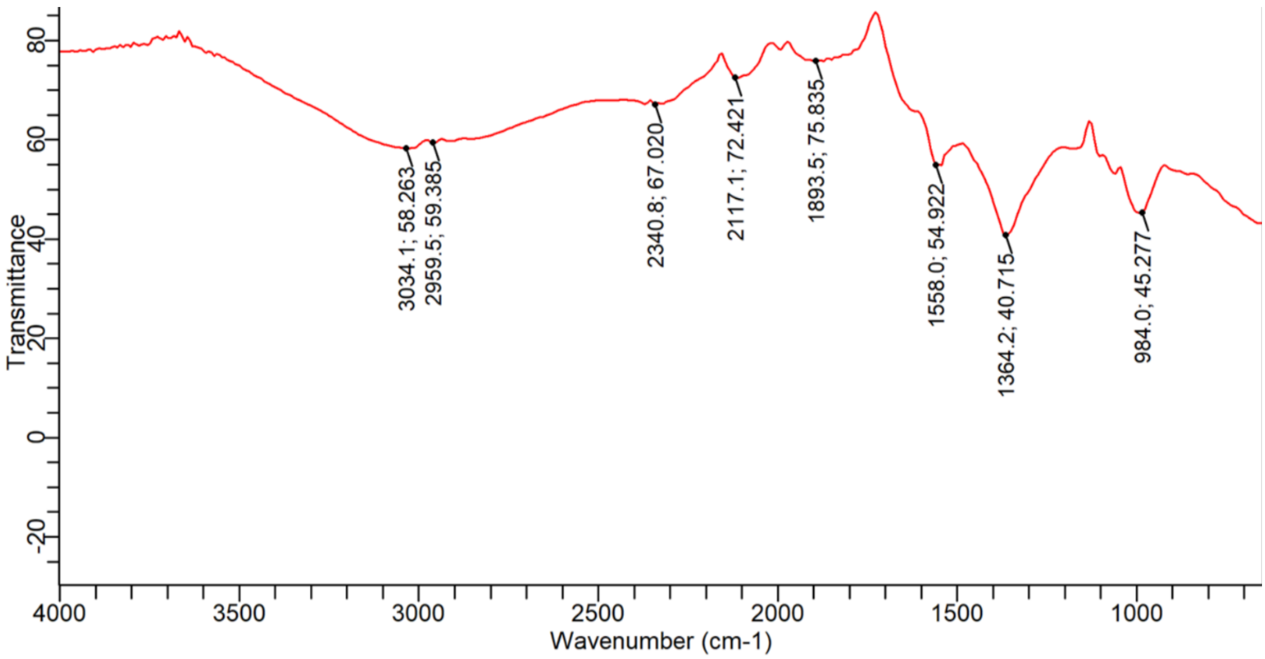


Figure 1. *FTIR Spectrum of Cocoyam Peels Biochar*

The present study investigated the structural, surface, and physicochemical properties of biochar derived from cocoyam (*Colocasia esculenta*) peels, to evaluate its potential for application in polluted soil remediation.

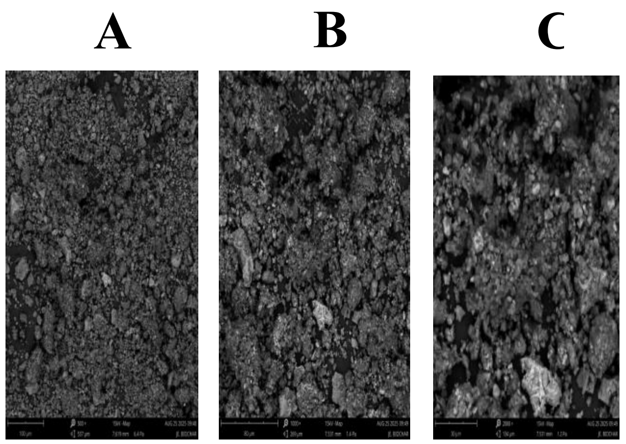
3.2. Fourier Transform Infrared spectroscopy Characterization

The FTIR analysis revealed prominent absorption bands at 984, 1364, 1558, 1894, 2117, 2341, 2960, and 3034 cm^{-1} (Table 1). These correspond to functional groups such as C–O/Si–O, C–H, O–H, C=C, C=O, C≡C, O=C=O, and aromatic/aliphatic C–H bonds respectively (Figure 1). The presence of these functional groups is critical for determining the adsorption behavior of the biochar.

The FTIR result showed similarity to the FTIR results of some biochar samples used in previous studies. [9-10] reported similar findings for cocoyam-derived bioflocculants in wastewater treatment. The abundance of hydroxyl peaks in the present study therefore suggests strong potential of cocoyam peels biochar in removing metals from crude oil contaminated soil samples. The C=O groups provide active sites for complexation with metal ions. [11] observed that taro stem biochars with abundant carbonyl groups showed enhanced Pb and Zn immobilization in contaminated soils. Thus, the functional groups detected here reinforced the adsorption capacity of the biochar from cocoyam peels. The aliphatic C–H and aromatic C–H peaks indicate the presence of both saturated and unsaturated hydrocarbons. These are probably remnants of incomplete carbonization, which is expected in low-to-moderate pyrolysis temperatures. While aliphatic groups contribute less directly to adsorption, their presence indicates that cocoyam peels biochar retains some reactive carbon chains, potentially enhancing surface heterogeneity. Interestingly, a peak at 2341 cm^{-1} indicated adsorbed CO_2 on the biochar surface. This is a common observation in biochars with high porosity and surface reactivity, as atmospheric CO_2 readily binds to basic sites on the surface [12]. It suggests that cocoyam peels biochar can interact dynamically with gases, which may enhance its role in carbon sequestration and soil CO_2 buffering.

3.3. Scanning Electron Microscopy Analysis of Cocoyam Peels Biochar

Figure 2 below presents the SEM images of cocoyam biochar at 100 µm, 80 µm, and 30 µm magnifications, respectively. At 100 µm, the biochar surface appears rough with visible cavities. At 80 µm, more pore channels and irregular voids are observed. At 30 µm, the morphology shows well-defined micropores and a highly porous structure. These images confirm the surface heterogeneity and pore development of cocoyam peels biochar at different magnifications.



(A) Surface Morphology of Cocoyam peels Biochar (100 µm)	(B) Surface Morphology of Cocoyam peels Biochar (80 µm)	(C) Surface Morphology of Cocoyam peels Biochar (30 µm)

***Figure 2.** Scanning Electron Micrographs of Cocoyam Peels Biochar at different magnifications*

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SEM imaging at 100, 80, and 30 µm magnifications (Figure 2) reveals a heterogeneous surface morphology characterized by pores, cavities, and irregular voids. At 100 µm, the surface appeared rough and cracked, while at 80 µm, distinct pore channels emerged. At 30 µm, the morphology showed well-defined micropores, suggesting enhanced porosity and surface area. These results align with general expectations for tuber peel biochars, which typically develop porous architectures during pyrolysis due to the decomposition of starch and cellulose [13]. In cocoyam peels biochar, the high carbohydrate content likely contributes to significant pore development, as starch granules decompose to form channels and cavities. Porosity is a critical property for adsorption-based remediation, as it increases the available surface area for pollutant binding. The presence of micropores (less than 2 nm) and mesopores (2–50 nm) is particularly valuable, as these provide access for heavy metals and small organic molecules. [13] emphasized that SEM analysis of biochars consistently shows that higher pyrolysis temperatures produce finer, more interconnected pores, thereby enhancing sorption potential. Although the pyrolysis temperature for cocoyam peels biochar in this study was moderate, the development of distinct micropores suggests substantial adsorption capacity.

Similar observations have been made for cassava peels biochar, where higher magnifications revealed complex pore structures favorable for remediation [14]. Potato and plantain peel biochars have also been reported to possess high porosity, contributing to their efficiency in immobilizing Cd and Zn from contaminated soils [15]. Thus, the SEM results of cocoyam peel biochar fit well within the pattern of tuber-derived biochars, reinforcing its suitability for pollutant immobilization.

3.4. Physicochemical Properties of Cocoyam Peels Biochar

Table 2 below shows the physicochemical properties of cocoyam biochar. The pH was 5.8, indicating a slightly acidic nature. The electrical conductivity (EC) was 2144 µS/cm, while the measured total dissolved solids (TDS) were 1132 mg/L, reflecting the presence of soluble salts and mineral residues. The temperature at the time of measurement was 29 °C, representing ambient conditions. These values provide the baseline chemical characteristics of the biochar sample.

Table 2. *Physicochemical Properties of Cocoyam Peels Biochar*

Parameter	Value	Unit	Remarks
pH	5.8	-	Slightly acidic, typical of low-temp biochar
Electrical Conductivity (EC)	2144	µS/cm	Indicates high soluble salt content
Total Dissolved Solids (TDS)	1132	mg/L	Reflects mineral residue in biochar
Temperature	29	°C	Ambient during measurement

The Physicochemical analysis of soil treated with cocoyam peels biochar revealed a pH value of 5.8, an electrical conductivity of 2144 µS/cm, and total dissolved solids of 1132 mg/L, with a measurement temperature of 29 °C (Table 2). These values provide important insights into the nature of the biochar and its suitability for environmental remediation.

The slightly acidic pH observed is consistent with findings in some low-temperature biochars, which often retain acidic functional residues due to incomplete volatilization of organic compounds during pyrolysis [15]. In comparison, biochars derived from cassava and potato peels have been reported to be more alkaline, particularly when pyrolyzed at temperatures above 400 °C [16, 14]. The acidity of cocoyam biochar can be attributed to the relatively low ash and mineral content of cocoyam peels, as reported by Ohuoba *et al*. (2019), who noted that the peels are dominated by carbohydrates (>90%) and contain minimal ash (<1%). This means that fewer basic cations such as Ca^{2+}, K^{+}, and Mg^{2+} are retained in the char, thereby limiting its alkalinity.

Although alkaline biochars are often desirable for remediating acidic soils and immobilizing heavy metals through precipitation reactions, slightly acidic biochars also play a vital role in remediation. An acidic medium can favor adsorption processes, especially for certain metals that form complexes with oxygen-containing functional groups. Therefore, the pH of cocoyam peels biochar suggests that its remediation mechanism may rely more on surface complexation and functional group interactions than simple liming effects.

The high EC (2144 µS/cm) and TDS (1132 mg/L) values indicate the presence of soluble inorganic salts and mineral residues in the biochar. These results are consistent with studies of other tuber biochars. [15] reported that potato peels biochar had elevated EC values due to rich potassium and phosphorus content, both of which are released as soluble salts during pyrolysis. Similarly, cassava peel biochar has been shown to retain high concentrations of exchangeable cations such as K^{+}, Ca^{2+}, and Mg^{2+}, contributing to increased EC and TDS [16]. In cocoyam peels biochar, these salts are likely derived from residual starch-associated minerals and trace elements in the peels.

From a remediation perspective, elevated EC and TDS indicate that the biochar can contribute nutrient cations to the soil, potentially improving fertility and microbial activity [17]. While excessively high EC may cause soil salinity issues if applied in large quantities. Thus, while cocoyam peels biochar provides nutrient-enriching potential;

its application rates should be carefully controlled to avoid adverse salinity effects.

The temperature of 29 °C recorded during measurement reflects ambient conditions and does not directly influence interpretation. However, it confirms that the physicochemical assessments were carried out under stable laboratory conditions, avoiding temperature-related artifacts in pH or EC measurement.

3.5. Total Petroleum Hydrocarbons

Table 3 below reports the Total Petroleum Hydrocarbons in crude oil-polluted soil before and after treatment as 937 and 4748 ppm respectively.

Table 3. *Total Petroleum Hydrocarbons*

Parameter	Value (ppm)	Remarks
Initial TPH	9379	Above the permissible limit of 5000
Final TPH	4748	Within the permissible limit

The TPH result showed 50% degradation, from 9379 ppm to 4748 ppm, which was slightly below the intervention value of 5000 ppm [18]. Therefore, cocoyam peels biochar is a potential material for the remediation of soil.

4. CONCLUSION

This study investigated the potential of cocoyam (*Colocasia esculenta*) peels biochar as an adsorbent for polluted soil remediation through structural and physicochemical characterization. FTIR analysis confirmed the presence of key functional groups such as carbonyl, and aromatic structures, which are responsible for adsorption and complexation of heavy metals. SEM imaging further revealed a porous microstructure with well-developed cavities and micropores, providing an extensive surface area for pollutant binding.

The physicochemical parameters results revealed that the biochar possessed a slightly acidic pH (5.8), relatively high electrical conductivity (2144 µS/cm), and total dissolved solids (1132 mg/L), indicating the presence of soluble salts and mineral residues that may enhance soil nutrient status.

The TPH result showed 50% degredation with the period of one month.

These findings demonstrated that cocoyam peels biochar combines beneficial chemical and structural characteristics that make it a promising, low-cost, eco-friendly, and sustainable material for the immobilization of pollutants in contaminated soils. Hence, recommended for soil remediation.

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Conflict of Interest Declaration

The authors declare no conflict of interest.

References

[1] Zhang, Z., Han, J., Zhang, Y., Sun, Y., Sun, Z. & Liu, Z. (2023). Connotation, status, and governance of land ecological security in China's new urbanization: Recent advances and prospects. *Environmental Science and Pollution Research*, 30, 119654–119670.

[2] Liu, X., Sathishkumar, K., Zhang, H., Saxena, K. K., Zhang, F. & Naraginiti, S. (2024). Frontiers in environmental cleanup: Recent advances in remediation of emerging pollutants from soil and water. *Journal of Hazardous Materials Advances,* 16, 100461. https://doi.org/10.1016/j.hazadv.2024.100461

[3] Biswas, B., Qi, F., Biswas, J. K., Wijayawardena, A., Khan, M. A. I. & Naidu, R. (2018). The fate of chemical pollutants with soil properties and processes in the climate change paradigm. A review. *Soil Systems, 2*(3), 51. https://doi.org/10.3390/soilsystems2030051

[4] Cheng, S., Chen, T., Xu, W., Huang, J., Jiang, S. & Yan, B. (2020). Application research of biochar for the remediation of soil heavy metals contamination: A review. *Molecules*, 25(14), 3167. https://doi.org/10.3390/molecules25143167

[5] Ohuoba, A. N., Onwuka, G. I. & Omodamiro, R. M. (2019). Effects of drying methods on physico-chemical properties of hydrocolloids isolated from peel flour of some selected root and tuber crops. *International Journal of Biochemistry Research & Review,* 27(1), 1–8.

[6] Daza-Orsini, S. M., Medina-Jaramillo, C. & López-Córdoba, A. (2025). Physicochemical characterization of starch and cellulose nanofibers extracted from *Colocasia esculenta* cultivated in the Colombian Caribbean. *Polymers*, 17(17), 2354. https://doi.org/10.3390/polym17172354

[7] Ideriah, T. J. K., Ighomuaye, M. N., Boisa, N. & Cookey, G. A. (2025). Preparation and Characterization of Magnetite Nanoparticles and Biochar from Unripe Banana Peels from Biara in Rivers State, Nigeria. International Journal of Research and Innovation in *Applied Science,* 10 (3), 118 -133.

[8] Adeniyi, A. S., Ehirim, E. O. & Wordu, A. A. (2020). Degradation of Crude Oil Polluted Soil Using Magnetic Nano-Particles. *Global Scientific Journal,* 8(2), 933-977.

[9] Banerjee, S., Mukherjee, S., Laminka-Ot, A., Joshi, S. R., Mandal, T. & Halder, G. (2016). Biosorptive uptake, of Fe^{2+}, Cu^{2+}, and As^{5+}, by activated biochar derived from *Colocasia esculenta*: Isotherm, kinetics, thermodynamics, and cost estimation. *Journal of Advanced Research,* 7(5), 597–610.

[10] Shende, A. P. & Chidambaram, R. (2023). *Cocoyam powder extracted from Colocasia antiquorum as a novel plant-based bioflocculant for industrial wastewater treatment: Flocculation performance and mechanism. Heliyon, 9*(4), e15228. https://doi.org/10.1016/j.heliyon.2023.e15228

[11] Vuong, T. X., Nguyen, D. P., Nguyen, V. H. N., Pham, T. T. H. & Nguyen, T. T. T. (2025). Immobilization of lead and zinc in contaminated soil using taro stem-derived biochar and apatite amendments: A comparative study of application ratios and pyrolysis temperatures. *RSC Advances,* 15(19), 11975–12000.

[12] Tong, S., Yuqi, Z. & Qiang, W. (2020). Recent advances in chemical admixtures for improving the workability of alkali-activated slag-based material systems. *Construction and Building Materials,* 261, 121647. https://doi.org/10.1016/j.conbuildmat.2020.121647.

[13] Amalina, F., Abd Razak, A. S., Krishnan, S., Sulaiman, H., Zularisam, A. W. & Nasrullah, M. (2022). Biochar production techniques utilizing biomass waste-derived materials and environmental applications – A review. *Journal of Hazardous Materials Advances,* 7, 100134. https://doi.org/10.1016/j.hazadv.2022.100134

[14] Ben, F. & Olubambi, P. A. (2024b). In-situ reinforcement of AA6063/Al_2O_3 hybrid composite: Comparative wear and hardness evaluation of *Manihot esculenta* and green *Plantago major* particulates. *Discover Applied Sciences,* 6, 280, 1–19.

[15] Vilakazi, S. P., Muchaonyerwa, P. & Buthelezi-Dube, N. N. (2023). Characteristics

and liming potential of biochar types from potpine bark and pine bark. *PLOS ONE, 18*(2), e0282011. https://doi.org/10.1371/journal.pone.0282011

[16] Grema, I., Hamissou, M., Esaie, K. & Appiah, K. (2023). Valorization of cassava peelings into biochar: Physical and chemical characterizations of biochar prepared for agricultural purposes. *Scientific African, 20,* e01737. https://doi.org/10.1016/j.sciaf.2023.e0 1737

[17] Adekiya, A. O., Agbede, T. M., Olayanju, A., Ejue, W. S., Adekanye, T. A., Adenusi, T. T. & Ayeni, J. F. (2020). Effect of biochar on soil properties, soil loss, and cocoyam yield in sandy-loamical sandyloam Alfisol. *The Scientific World Journal,* 2020, 9391630. https://doi.org/10.1155/2020/9391630

[18] Department of Petroleum Resources (DPR-EGASPIN, 2002) "Environmental Guidelines and Standards for the Petroleum Industry in Nigeria "DPR:Lagos Nigeria.