



Extraction and Characterisation of Bio-Oil from Common Selected Biomass in Nigeria

¹Alexander Ikechukwu Ajai, ¹Abdullahi, Mohammed Mohammed, ¹Simon Olonkwoh Salihu,
^{*1,4}Saheed Mustapha, ^{1,4}Jimoh Oladejo Tijani, ^{2,4}Ambali Saka Abdulkareem,
^{1,4}Muhammad Muhammad Ndamitso, ¹Labake Ajoke Fadipe, ³Rasheed Olakitan Oyewale



¹Department of Chemistry, Federal University of Technology, Gidan Kwano Campus, Minna, Niger State, Nigeria.

²Department of Chemical Engineering, Federal University of Technology, Gidan Kwano Campus, Minna, Niger State, Nigeria.

³Department of Crop Production, Federal University of Technology, Gidan Kwano Campus, Minna, Niger State, Nigeria

⁴Nanotechnology Research Group, Center for Genetic Engineering and Biotechnology, Federal University of Technology, Minna, Niger State, Nigeria.

*Corresponding Author's email: saheed.mustapha@futminna.edu.ng

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ABSTRACT

Agricultural residues, and plant oils sourced from various origins, can be used for the production of value-added bio-products and provide alternatives for integrated pest management approaches among other applications. However, there is limited comparative information on physicochemical or functional properties of oils from lignocellulosic and lipid-rich biomass. This study extracted and characterized oils from rice husk, corn cob and neem seed collected in Minna Niger State, Nigeria with focus on physicochemical traits and functional group composition. Rice-husk, corn-cob and neem seed oils had densities of 1.02, 1.16 and 0.91 g mL⁻¹ and pH values of 2.80, 2.24 and 5.87 respectively while moisture contents (MC) were 23.70, 39.70 and 1.10% and acid values (AV) of 118.3, 143.0 and 4.48 mg KOH g⁻¹, respectively. Neem seed oil had the highest yield of 41.25% followed by corn-cob (26%) and rice-husk (20%). Functional group analysis by FTIR showed that lignocellulosic bio-oils had oxygenated and hydroxyl groups while neem oil had more lipid and ester groups. The study established differences in the chemical make-up of the oils based on source material and extraction approach. Neem seed oil has potential as a lipid-rich product while rice-husk and corn-cob oils appear to have more acidic and oxygenated constituents. The findings could help promote the use of local resources for production of bioproducts and bioenergy but requires further chemical characterization and assessment of end-use applications such as biopesticides and biodiesels.

CITATION

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INTRODUCTION

The worldwide need for sustainable agriculture in recent years has prompted the search for renewable substitutes

to synthetic pesticides. Agricultural residues, especially corn cobs, and rice husks possess the potential for energy and chemical generation via pyrolysis. Due to their

availability, underutilization, and high concentrations of lignocellulosic biomass, corn cobs make an excellent candidate for bio-oil feedstock with prospective pesticidal usefulness (Bello et. al., 2025). Agricultural residues such as corn cobs, rice husks, and wheat straw are rich in lignocellulosic biomass, which can be converted into valuable bio-based products. Corn cobs and rice husks are generated in large quantities during maize harvesting and rice processing and are often underutilised or discarded. Valorisation of these biomasses through thermochemical conversion processes like pyrolysis can yield bio-oil, biochar, and syngas (Zhang et. al., 2020).

Natural plant-derived compounds, such as bio-oils extracted from agricultural biomass (e.g., rice husks, corn cobs, and palm kernel shells), represent a promising and underutilized reservoir of bio-insecticides. Many plant groups contain bioactive constituents—such as alkaloids, terpenoids, and flavonoids—with insecticidal, repellent, or growth-inhibitory properties. These compounds are generally biodegradable, less toxic to non-target organisms, and compatible with integrated pest management (IPM) systems. The use of plant resources also promotes biodiversity and supports sustainable rural economies. Moreover, such bio-based pesticides are specific in their action, non-harmful to beneficial species, and capable of overcoming pest resistance associated with synthetic pesticides (Mishra et. al., 2020). They can effectively target pests without disrupting the ecosystem due to their short residual periods, which minimize bioaccumulation (Shayan and Iqra, 2023).

Pyrolysis is a thermochemical process which treats organic biomass in an oxygen-limited environment to produce bio-oil, biochar, and syngas. Bio-oil, contains complex mixture of antimicrobial and pesticidal phenolic, aldehydic, and other oxygenated compounds (Novita et. al., 2025).

The conversion of corn cobs and rice husks into useful bio-oils mitigate waste management issues while offering a sustainable alternative to toxic pesticides (Casoni et. al., 2022). Bio-oils obtained from the corn cobs and rice husks have been found to contain bioactive ingredients that disrupt the normal processes of insect growth and reproduction. These naturally occurring substances could be incorporated into integrated pest management (IPM) schemes, which focus on non-chemical methods of controlling pests to minimise the chances of pesticide resistance and pollution (Domazetovska et. al., 2023).

Bio-oils obtained from pyrolysis have the potential to act as insect growth regulators. Such qualities are useful in reducing the rate of increase and ultimately the population of pests without the associated adverse environmental impact of other pest control methods (Bruce et. al., 2022). Therefore, this study focused on the extraction and characterization of bio-oils from selected biomass for their active potentials as possible alternatives for sustainable

pest management which this study intends to achieve could help in mitigating the various challenges associated with the use of synthetic pesticides by acting as safer pesticide alternatives, enhance eco-friendly farming, and contribute to food security and consumer safety. It will also help address the issue of food export rejection in international markets, thereby boosting the national economy. Furthermore, the application of such eco-friendly biopesticides in agricultural practices will reduce the carcinogenic health risks associated with synthetic pesticides. This will also contribute to achieving several United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 6 (Clean Water and Sanitation), and SDG 15 (Life on Land)

MATERIALS AND METHOD

Sample Collection and Pretreatment

Biomass materials were obtained from different locations within the city of Minna. Corn cobs were collected from local farmers in Gidan Kwano, Minna, while rice husks were obtained from rice processing mills in Bosso, Minna. Neem fruits sourced from the Bosso area of the Minna metropolis. The corn cobs and rice husks were sun-dried and pulverized using a laboratory mortar and pestle and stored for further analysis. The neem seeds were sun-dried, after which they were deshelled to obtain the kernels. The collected kernels were pulverized using a laboratory mortar and pestle and stored in a polyethylene container for further analysis.

Extract of Oil

Bio-Oil Extraction from Rice Husks and Corncobs

The method reported by Abatyoug et. al., (2022), was used for the extraction of bio-oil from pretreated agricultural biomass. The pyrolysis process was carried out under inert conditions using a three-neck flask fitted with a cooling condenser, a thermocouple, and gas inlet and outlet pipes on the remaining necks. The reactor was loaded with 5000 g of pulverized rice husk biomass and pressurized using a nitrogen gas cylinder. It was then heated to approximately 450 °C and maintained for a specified retention time to generate condensable gases. The condensable gases produced were collected in a container placed at the end of an ice-cooled condenser connected to the reactor. The resulting condensate, a mixture of water and bio-oil, was purified by separating it from tar: the bio-oil obtained from condensation was left to settle for one week. The upper liquid layer was then collected and transferred to a distillation device. Distillation was conducted at approximately 150°C. The distillate was collected, and the distillate was filtered using activated zeolite. This filtration process was intended to remove hazardous substances, such as tar, and obtain completely safe active substances.(Novita et.

al., 2025). The same procedure was also adopted to extract bio-oil from rice husks.

Extraction of Oil from Neem Seeds

The neem seeds will be deshelled after sun drying and pulverised using a laboratory pestle and mortar. The neem powder weighing 200 g was loaded into the thimble and inserted into the Soxhlet chamber. Meanwhile, a round-bottom flask was filled with 1000 mL of petroleum ether and set up for the Soxhlet extractor. Subsequently, the distillation process commenced. Upon completion of the extraction process, both the solvent and the extractor were transferred onto a water bath to facilitate the evaporation of the solvent. (Sulaiman et. al., 2024) The concentrated extract was stored for further analysis

Determination of the Physicochemical Properties of the Extracted Bio-Oil

The following physicochemical properties (pH, viscosity, moisture content, and specific gravity) of the extracted bio-oil (corn cob and Rice husk) and Neem seed oil from were analysed.

pH Value

The pH of the extracted bio-oil was determined using a digital pH meter. The pH meter was kept at the standby position first, then calibrated with the pH 7 and pH 4 standard buffer solutions. The electrode of the pH meter was then inserted into the test solution, and the temperature knob was set at 0°C to control the temperature of the test solution. Then read the scale on the pH meter after the pointer needle (Sari et. al., 2023)

Moisture Content

The oven-dry method was used to analyse the moisture content of the bio-oils. An empty evaporation dish was weighed and 5g of each of the oil samples was added, reweighed and recorded as W_1 . The triplicate of each oil sample was weighed and placed in an oven for one hour at a temperature of 105 °C until a constant weight was obtained among the triplicate samples. After the drying, samples were re-weighed and cooled in desiccators, and recorded as W_2 (Okidhika and Ekpote, 2023). The percentage moisture contents of the various bio-oil samples were evaluated using Equ. (1).

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

Where W_1 = weight of dish plus weight of oil before drying and W_2 = weight of dish plus weight of oil after drying

Density Determination

The density of jatropha onion oil has been measured by using this relation 2 (Nura et. al., 2023). The mass of crude oil was measured using digital balance machine and its volume using graduated cylinder and calculated using the following equation;

$$\text{Density of oil} = \frac{\text{Mass of crude oil (g)}}{\text{Volume of crude oil (mL)}} \quad (2)$$

Determination of Saponification Value

The method reported by Okidhika and Ekpote (2023) was used to analyse acid values. The acid number of oil is the number of milligrams of potassium hydroxide needed to neutralise the free fatty acid in 1g of oil sample. 5 cm³ of diethyl ether and 5 cm³ of ethanol were measured and poured into a 250 cm³ conical flask, and 0.5 cm³ of (1%) phenolphthalein was added to the solution. Two grammes of oil samples were measured and added to the conical flask and titrated with 0.1 mol/dm³ KOH. Constant agitation of the conical flask was ensured as the titration was going on until a pink colouration persisted for about 15 seconds. The amount of KOH expended to achieve the endpoint was recorded and computed as follows;

$$\text{Acid value} \left(\frac{\text{mgKOH}}{\text{g sample}} \right) = \frac{\text{Volume of KOH used} \times 5.61}{\text{Weight of oil sample used}} \quad (3)$$

Evaluation of the Structural Compositions and Functional Groups of the Extracted Bio-Oil

The oil extracts were characterised using Fourier Transform Infrared Spectroscopy (FTIR) Analysis. The FTIR spectrum was recorded to establish the prominent functional groups present in the oil extracts. A small quantity of the oil sample was placed on the diamond crystal of an Attenuated Total Reflectance (ATR) accessory. The spectra were recorded on an FTIR spectrophotometer from 4000–400 cm⁻¹ with 4 cm⁻¹ resolution.

RESULTS AND DISCUSSION

Physicochemical properties of oils

The physicochemical properties of the extracted bio-oils, as presented in Table 1 varied markedly with feedstock composition, extraction behaviour, and lipid hydrolysis. Rice-husk, corn-cob, and neem seed oils had densities of 1.02, 1.16, and 0.91 g mL⁻¹, respectively, with the lignocellulosic-residue-derived oils having much higher densities than neem seed oil. The relatively low density of neem oil is very close to the 0.91 g mL⁻¹ reported by Zing et. al., (2026), thereby supporting the present result. On the other hand, higher densities of the rice-husk and corn-cob products may come from oxygenated compounds, residual water, and other polar constituents formed or retained during lignocellulosic biomass conversion.

The pH values further highlight the significant differences in the chemical characteristics of the bio-oils. Rice-husk bio-oil (pH 2.80) and corn-cob bio-oil (pH 2.24) showed strongly acidic characteristics, while neem seed oil was considerably less acidic with a pH of 5.87. This trend is consistent with their acid values of 118.3, 143.0, and 4.48 mg KOH g⁻¹, respectively, indicating a substantially higher concentration of acidic constituents in the rice-husk and corn-cob bio-oils. The particularly high acid value of corn-

cob bio-oil corresponds to its lowest pH, suggesting a greater abundance of free fatty acids and other oxygenated acidic compounds. In contrast, the very low acid value of neem seed oil is consistent with its near-neutral pH and indicates a comparatively low content of free acidic components. The particularly high acid value of corn-cob bio-oil indicates a greater contribution from acidic oxygenated compounds, possibly arising from more extensive hydrolysis and thermal decomposition of lignocellulosic components. On the other hand, the acid value of neem seed oil is comparable to that reported for waste neem seed oil by Zuhane et. al., (2025), who obtained $3.64 \text{ mg KOH g}^{-1}$. However, the acid value of $4.48 \text{ mg KOH g}^{-1}$ in the present study is slightly higher. The relatively low acid and free-fatty-acid contents reported for neem seed oil strongly favor direct alkaline transesterification, highlighting its substantially different chemical characteristics from the more oxygenated and acidic rice-husk and corn-cob bio-oils.

Moisture content provides another significant difference among the bio-oils. Corn-cob bio-oil showed the highest moisture content (39.7%), followed by rice-husk bio-oil (23.7%), while neem seed oil contained only 1.1% moisture. The significantly higher moisture levels in the lignocellulosic biomass-derived bio-oils may reflect the presence of residual water generated or retained during thermochemical conversion, while the very low moisture content of neem seed oil indicates comparatively little water incorporation. High moisture can negatively affect fuel quality by reducing effective heating value, increasing storage instability, and influencing viscosity and combustion characteristics. As such, neem seed oil clearly has an advantage where low moisture content is desired for energy and fuel applications. Compared to this, the very low moisture content of neem oil is typical of a more conventional extracted vegetable oil. However, this value is significantly different from the 7.78% moisture content reported for rice-husk-derived silica by Zing et. al., (2026). However, since the reported values refer to

fundamentally different materials, this comparison should only be considered as a general indication of differences in moisture levels rather than as an assessment of material quality or composition.

The acid value and pH together show that corn-cob bio-oil is the most acidic of the three samples, showing the lowest pH (2.24) and the highest acid value ($143.0 \text{ mg KOH g}^{-1}$). Rice-husk bio-oil also shows substantial acidity, but slightly less than that of corn-cob, with a pH of 2.80 and a correspondingly lower acid value. Neem seed oil is considerably less acidic, as evidenced by the near-neutral pH of 5.87. The high acidity of the lignocellulosic bio-oils is probably due to the presence of organic acids and other oxygenated compounds generated during biomass conversion. On the other hand, the significantly lower acid value of neem oil indicates a better suitability for direct utilization and processing that require relatively mild downstream treatment. This finding is consistent with Zuhane et. al., (2025), who showed that neem seed oil could undergo alkaline transesterification without prior acid-esterification pretreatment. However, they also indicate that the resulting biodiesel needs further consideration of acid value and oxidative stability to ensure fuel quality and storage performance.

The oil yields were 20% for rice-husk bio-oil, 26% for corn-cob bio-oil, and 41.25% for neem seed oil, identifying neem seed as the most productive feedstock under the present extraction conditions. The significantly higher yield obtained from neem seed is chemically consistent with its naturally high lipid content, while rice husk and corn cob are mostly lignocellulosic biomass with comparatively lower extractable lipid fractions. Notably, the present neem seed oil yield is considerably higher than the approximately 20.30% reported by Zing et. al., (2026) and approximately 20% reported by Zuhane et. al., (2025). Such variation can be attributed to differences in seed maturity, moisture content, particle size, extraction solvent, extraction temperature and duration, solid-to-solvent ratio, and oil-recovery efficiency.

Table 1: Some Physicochemical Properties of Rice Husk, Corn Cob and Neem Seed Oils

Properties	Rice- Husk	Corn Cob	Neem Seed
Density (g mL^{-1})	1.02	1.16	0.91
pH at 28.6	2.80	2.24	5.87
Moisture content (%)	23.70	39.70	1.10
Acid value	118.3	143	4.48
Yield (%)	20	26	41.25

FTIR results

The FTIR spectra in Fig. 1 show distinct differences in chemical composition of the oils derived from rice husk, corn cob and neem. For rice husk oil, the broad band at 3312 cm^{-1} corresponds to O–H stretching and suggests the presence of hydrogen-bonded hydroxyl-containing species. This assignment agrees closely with that of Cai et.

al., (2019), who reported O–H stretching of rice-husk bio-oil at $3450\text{--}3421 \text{ cm}^{-1}$ and associated this region with water, alcohols, acids and phenols. The difference between 3312 cm^{-1} in the present sample and $3421\text{--}3450 \text{ cm}^{-1}$ reported by Cai et. al., (2019) reflects differences in the concentration and hydrogen-bonding environment of hydroxyl-containing compounds, particularly as hydrogen

bonding can broaden and shift O–H absorptions. Similarly, Bisen et. al., (2025) associated the broad 3600–3200 cm^{-1} region of rice-husk-derived pyro-oil with O–H stretching of phenolic, alcoholic and water-containing species. Therefore, 3312 cm^{-1} provides firm evidence of oxygenated constituents in rice husk oil.

The 1636 cm^{-1} band of rice husk oil falls within the reported area for C=C and/or carbonyl-related vibrations. Cai et. al., (2019) identified the 2000–1500 cm^{-1} region as encompassing C=C or C–O stretching and compounds such as aldehydes, ketones and acids, with an observed absorption around 1630 cm^{-1} linked to double-bond-containing structures and oxygenated compounds. Therefore, assignment of 1636 cm^{-1} to C=C stretching and/or molecularly associated water is reasonable, although FTIR is unable to definitively distinguish the relative contributions of these overlapping assignments. The 1382 cm^{-1} band agrees well with the 1380–1350 cm^{-1} region reported by Cai et al. (2019) for CH_3 bending vibrations, while the 1277 and 1015 cm^{-1} absorptions fall within the broad C–O stretching region (1300–1000 cm^{-1}) associated with alcohols, phenols and ethers. Bisen et al. also associated the 1300–1000 cm^{-1} region with C–O stretching from ethers, esters, alcohols and phenolic compounds. The band around 750 cm^{-1} also lies within the low-wavenumber region where C–H deformation and aromatic C–H vibrations can occur, consistent with the reported assignments for rice-husk bio-oil.

The corn cob oil shows a somewhat different spectral pattern. Its broad 3370 cm^{-1} band is assigned to O–H stretching and agrees with the 3400–3200 cm^{-1} region reported by Martins-Vieira et al. (2023) for corn-cob bio-oil. The latter authors attributed intense absorptions in this region to hydrogen-bonded –OH groups associated with alcohols, organic acids and phenols. Padilla et al. (2019) similarly reported an O–H band at 3459 cm^{-1} , identifying this as associated with phenols, alcohols and carboxylic acids in corn cob. The slightly lower position observed at 3370 cm^{-1} may therefore reflect differences in hydrogen-bonding and the proportion of hydroxyl-containing constituents.

The 2975 cm^{-1} absorption in the present corn cob oil is characteristic of aliphatic C–H stretching and agrees well with the 3000–2850 cm^{-1} region reported by Martins-Vieira et. al., (2023) for aliphatic structures. Padilla et al. (2019) report a corresponding band at 2943 cm^{-1} , confirming the

occurrence of aliphatic structures in corn cob biomass. The 1673 cm^{-1} band also falls within the region associated with unsaturated and carbonyl-containing structures. Martins-Vieira et. al., (2023) reported absorptions between 1750 and 1650 cm^{-1} for carbonyl-related vibrations that were associated with aldehydes, carboxylic acids and ketones, whereas Padilla et. al., (2019) identified 1659 cm^{-1} as C=C stretching. Therefore, the 1673 cm^{-1} band in the present oil is consistent with unsaturated and/or oxygenated compounds rather than being uniquely indicative of C=C bonds. The 1451 and 1357 cm^{-1} bands correspond well with the C–H deformation region reported by Martins-Vieira et. al., (2023), while the 1220 cm^{-1} band is consistent with C–O-containing compounds. The 2088 cm^{-1} feature, however, should be treated with caution, given that the provided literature does not establish a particular functional-group assignment for this exact band in corn-cob oil. Therefore, treating it as a weak or overlapping contribution rather than definitive evidence of a triple bond is scientifically sound.

Neem oil exhibits the greatest evidence of long-chain lipid structures of the three oils. The intense bands at 2912 and 2838 cm^{-1} correspond to asymmetric and symmetric C–H stretching of $-\text{CH}_2/-\text{CH}_3$ groups. This agrees with Zuhane et. al., (2025) who reported C–H stretching of neem seed oil in the 3000–2850 cm^{-1} region. The pronounced nature of these bands compared to the rice husk and corn cob spectra supports the interpretation that neem oil contains a greater contribution from aliphatic hydrocarbon chains, as expected for a lipid-rich seed oil. The 1733 cm^{-1} band of neem oil is particularly significant as it falls within the characteristic carbonyl region of fatty-acid-derived compounds. The present assignment to C=O stretching associated with ester functionalities is consistent with the ester-carbonyl region reported by Zuhane et. al., (2025) who identified ester C=O absorption in neem seed oil and biodiesel. Agu et. al., (2025) also identified oxygen-containing ester-related features in neem oil, including C–O stretching bands at 1112.531 and 1308.414 cm^{-1} . The strong 1145 cm^{-1} band observed here therefore provides added evidence of ester-containing, oxygenated lipid structures. Furthermore, the 1440 cm^{-1} absorption agrees with the C–H deformation region reported for neem-derived materials, while the band near 703 cm^{-1} is compatible with low-wavenumber hydrocarbon-chain deformation.

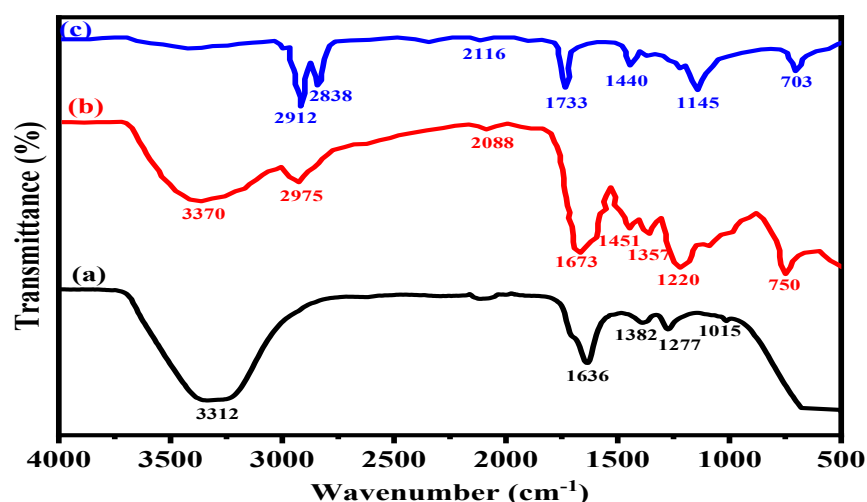


Figure 1: FTIR Spectra of (a) Rice Husk Oil (b) Corn Cob Oil (c) Neem Oil

CONCLUSION

The study established that feedstock type significantly influences the physicochemical and chemical properties of oils derived from rice husk, corn cob, and neem seed. The major difference was observed between lignocellulosic-residue-derived oils and neem seed oil. The former two feedstocks resulted in oils with comparatively greater acidity and moisture contents (pH: 2.80 and 2.24) and acid values (118.3 and 143.0 mg KOH g⁻¹) than neem seed oil (pH: 5.87; acid value: 4.48 mg KOH g⁻¹). Neem seed also gave the highest oil yield (41.25%), surpassing corn cob (26%) and rice husk (20%). The observed differences were attributed to the biochemical nature of the feedstocks, with lipid-rich neem seed yielding oil with distinctly superior quality than predominantly lignocellulosic rice husk and corn cob.

The FTIR analysis further revealed significant differences in terms of composition among the oils. Indeed, rice-husk and corn-cob oils showed significant hydroxyl, C–O, unsaturated, and carbonyl absorptions, suggesting considerable oxygenated components resulting from thermochemical conversions. Neem oil exhibited stronger aliphatic C–H and ester-carbonyl absorptions, indicating its lipid-rich nature. Thus, the findings demonstrate that the composition of the feedstocks and the type of extraction significantly affect the physicochemical properties and potential uses of the extracted oil.

Future studies on these materials should employ statistical analysis and extensive chromatographic and mass-spectrometric characterizations, including GC–MS, to identify the major constituents associated with the observed differences in chemical properties. Bioassays targeted at the pests of interest as well as potential non-target effects, the storage stability, and formulation behaviors would be necessary to establish the materials' potential for use in pest management. This will aid in shifting the focus from simply characterizing biomass to

identifying sustainable and valuable use of such residues and promoting local production.

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REFERENCES

- Abatyough, M. T, Ajibola O. A, Agbaji E. B, & Yashim, Z. I. (2022a). Optimisation and Modelling of Process Conditions for the Yield of Improved Bio-Oil from Co-Pyrolysis of Corncobs and High-Density Polyethylene Wastes using Central Composite Design (CCD). *Chemistry Research Journal* 7(3). pp. 23 - 38.
- Agu, C. M., Orakwue, C. C., Ani, O. N., & Chinedu, M. P. (2025). Kinetics, Thermodynamics and Characterization of Neem Seeds (*Azadirachta indica*) Oil Extraction: Extensive Study of the Processes. *Green Technologies and Sustainability*, 3(1), pp 100-126.
- Bello, S. I., & Uthman, T. O. (2025). Urea Enhances the Yield and Quality of Bio-Oil Produced from Corncob through Pyrolysis. *Scientific Reports*, 15, Article 2990. <https://www.nature.com/articles/s41598-025-86800-7>
- Bisen, D., Lanjewar, R., Alawa, B., Chouhan, A. P. S., & Chakma, S. (2025). Kinetic Analysis and Fuel Characterization with Hydrocarbon Distribution in Pyro-Oil Produced from Co-Pyrolysis of Rice Husk and [J] Low-Density Polyethylene. *Journal of the Energy Institute*, 121, pp 102-175.
- Bruce, A., Wilson, A. N., Ranabhat, S., Montgomery, J., Nicholson, S., Harris, K., & Morrison III, W. R. (2022). A Biomass Pyrolysis Oil as a Novel Insect Growth Regulator

- Mimic for a Variety of Stored Product Beetles *Journal of Economic Entomology*, 115(3), pp 877-887.
- Cai, W., Kang, N., Jang, M. K., Sun, C., Liu, R., & Luo, Z. (2019). Long Term Storage Stability of Bio-Oil from Rice Husk Fast Pyrolysis. *Energy*, 186, 115882.
- Casoni, Andrés. I., Gutierrez, V., García, J. M., Cabada, S., Acevedo, A., & Volpe, M. A. (2022). Pyrolytic Coproduction of Bio-Char and Upgraded Bio-Oils from Abundant Agro-Industrial Wastes. *Brazilian Journal of Chemical Engineering*, 39(3), pp 561–570. <https://doi.org/10.1007/s43153-021-00167-6>
- Domazetovska, S., Strezov, V., Filkoski, R. V., & Kan, T. (2023). Exploring the Potential of Biomass Pyrolysis for Renewable and Sustainable Energy Production: A Comparative Study of Corn Cob, Vine Rod, and Sunflower. *Sustainability*, 15(18), 13552. <https://doi.org/10.3390/su151813552>
- Kumar, R., Chandra, S., Kumar, K., Kumar, T., & Kumar, V. (2018). Analysis of the Physical and Chemical Characteristics of Edible Vegetable Blended Oil. *International Journal of Chemical Studies*. 6(6)
- Mabasa, X. E., Mathomu, L. M., Madala, N. E., Musie, E. M., & Sigidi, M. T. (2021). Molecular Spectroscopic (FTIR and UV-Vis) and Hyphenated Chromatographic (UHPLC-qTOF-MS) Analysis and In Vitro Bioactivities of the *Momordica balsamina* Leaf Extract. *Biochemistry Research International*, 2021(1), 2854217.
- Martins-Vieira, J. C., Lachos-Perez, D., Draszewski, C. P., Celante, D., & Castilhos, F. (2023). Sugar, Hydrochar and Bio-Oil Production by Sequential Hydrothermal Processing of Corn Cob. *The Journal of Supercritical Fluids*, 194, 105838.
- Mishra, J., Dutta, V., and Arora, N. K. (2020). Biopesticides in India: Technology and Sustainability Linkages. *3 Biotech* 10, 1–12. <https://doi.org/10.1007/s13205-020-02192-7>
- Novita, S. A., Putera, P., Djinis, M. E., & Ernita, Y. (2025). Analysis of Bio-Oil of Pyrolysis Production Process from Corn Cobs. *Journal of Applied Agricultural Science and Technology*, 9(3), pp 436–448. <https://doi.org/10.55043/jaast.v9i3.463>
- Nura, I., Jamo, H. U., Getso, I. Y., Tolufase, E., Belo, O. M., Ismail, U. I. & Yusuf, A., 2023. The Effect of Addition of Fly Ash on Physical Properties of Transesterified Calabash Oil as Source of Biodiesel. *Science World Journal*, 18(1), pp.55-59.
- Ojo, A. A., Awogbemi, O., & Oni, T. (2024). Physicochemical Assessment of Vegetable Oil used to Fry some Nigerian Food Items. *Science and Technology for Energy Transition*, 79, 87. <https://doi.org/10.2516/stet/2024086>
- Okidhika, C. U., & Ekpete, O. A. (2023). Comparative Evaluation of some Physicochemical Characteristics of Selected Brands of Refined Edible Vegetable Oils Marketed in Rivers State, Nigeria. *Faculty of Natural and Applied Sciences Journal of Scientific Innovations*, 4(1), pp 37-48.
- Olaleye, G. O., Odetoeye, T. E., Zubairu, A. A., & Olufowora, F. O. (2024). Upgrading and Optimization of Pyrolysis Oil from Corncob (*Euphorbia mammillaris*) and Peanut (*Arachis hypogaea*) Shells by Liquid-Liquid Extraction Process. *ABUAD Journal of Engineering and Applied Sciences*, 2(2), pp 66–76. <https://doi.org/10.53982/ajeas.2024.0202.10-j>
- Padilla, E. R. D., Nakashima, G. T., Hansted, A. L. S., Santos, L. R. O., Barros, J. L. D., De Conti, A. C., & Yamaji, F. M. (2019). Thermogravimetric and FTIR Analyzes of Corn Cob Pyrolysis. *Química Nova*, 42(5), pp 566-569.
- Shayan A & Iqra Z. (2023). Biopesticides: A Green Substitute to Chemical Pesticide. *International Journal of Chemical and Biochemical Sciences, IJCBS*, 24 (4) (2023): pp 141-156.
- Zing, B. Z., Guemfo, W. V. N., Nana, C. T., Halimatou, S., & Ehabe, E. E. (2026). Use of Essential and Vegetable Oil-Impregnated Rice Husk Silica to Control *Sitophilus zeamais* (Motschulsky) on Stored Maize (*Zea Mays* L.) Seeds. *Bulletin of the National Research Centre*, 50(1), 2.
- Zuhane, M.K.A., Rahman, M.M., Hassan, M.M., Hossain, M.I., Ghos, B.C., Rana, G.M., Hossain, M.S., Ahmed, N., Rahman, M.N. & Yeasmin, M.S., 2025. Production, characterization and yield optimization of biodiesel from waste neem *Melia azadirachta* seeds available in Bangladesh. *Scientific Reports*, 15(1), p.33913.