https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 2 (2025); 660-671
e-ISSN:3092-8214 p-ISSN:3092-8206
doi.org/10.33003/chemclass-2025-0902/187

GC-MS Profile and Antibacterial Evaluation of the Ethanolic Extracts of Banana and Sweet Potato Peels

Samoh .F. Teghtegh[a]; Ikyenge .B. Aloo[b]; Agbidye G. Isaac[b]; Baker M. Temitope [a], Teghtegh V. Nguemo[c]

[a] *Chemistry Department, University of Ilorin, Ilorin, Kwara State, Nigeria*
[b] *Chemistry Department, Benue State University, Makurdi, Benue State, Nigeria*
[c] *Freshlife Foods and Beverages, Gboko, Benue State, Nigeria*

(*)Corresponding Author's: samoh.ft@unilorin.edu.ng

Abstract

*Banana (*Musa *spp.) and sweet potato (*Ipomoea batatas*) peels are often discarded during food processing, yet they contain a wealth of bioactive compounds with promising health and industrial benefits. This study set out to explore the chemical composition and biological potential of these underutilized byproducts. The peels were first subjected to ethanol extraction using a Soxhlet apparatus. To better understand the chemical profiles of the extracts, Gas Chromatography–Mass Spectrometry (GC-MS) and Fourier Transform Infrared Spectroscopy (FTIR) were employed. The GC-MS analysis showed that banana peel extract was particularly rich in cis-oleic acid (24.85%) and resorcinol (19.02%)***,*** *while sweet potato peel extract had a higher concentration of palmitic acid (39.66%) and pyrogallol (17.94%)***.*** *FTIR spectroscopy supported these findings, revealing prominent O–H stretching bands around 3300–3400 cm⁻¹, C=O stretching peaks near 1700 cm⁻¹, and C–O vibrations between 1000–1300 cm⁻¹, all indicative of phenolic and fatty acid structures. Antioxidant assays revealed that banana peel extract exhibited stronger free radical scavenging activity, particularly at lower concentrations. On the other hand, sweet potato peel extract demonstrated notable antibacterial effects, especially against* Pseudomonas aeruginosa*. These findings therefore point to the untapped potential of banana and sweet potato peels as valuable resources for developing natural antioxidant and antibacterial agents. Their utilization not only adds value to agricultural waste but also supports sustainable and eco-friendly approaches in food, pharmaceutical and cosmetic industries.*

Key words: Antibacteria, Antioxidant, Banana, GCMS, Peels, Potato

Introduction

Banana (*Musa* spp.) and sweet potato (*Ipomoea batatas*) are essential staple crops that play a crucial role in ensuring food security, particularly in tropical and subtropical regions [1]. However, large quantities of waste, primarily in the form of peels are generated during their processing and consumption. These peels which are traditionally regarded as agricultural by-products are now recognized as potential sources of high-value bioactive compounds including phenolics,

flavonoids and other phytochemicals with established pharmacological, nutritional and industrial significance [2, 3].

To explore and harness these bioactive constituents effectively, it is imperative to employ suitable extraction and analytical techniques. Ethanol is commonly utilized as an extraction solvent due to its broad polarity range, enabling efficient recovery of both polar and non-polar compounds from plant matrices [4, 5]. Its non-toxic and eco-friendly nature also makes it preferable for applications in food, pharmaceutical and cosmetic industries.

Following extraction, a robust and sensitive analytical method is required to identify and characterize the complex mixture of phytochemicals present in the extracts. Gas Chromatography–Mass Spectrometry (GC-MS) serves this purpose effectively, offering high-resolution separation and precise identification of volatile and semi-volatile constituents [7, 8]. The integration of ethanol extraction with GC-MS analysis thus provides a comprehensive and reliable approach for profiling the chemical composition of banana and sweet potato peels, thereby elucidating their potential value as raw materials for various industrial applications. Previous works reported the ethanolic extract of banana peel (*Musa paradisiaca* forma typica) to have a very strong antioxidant activity [26]. Sweet potato peel was also reported to have the highest antioxidant activity as compared to other parts [27]. Profiling the aqueous ethanolic extracts of banana and sweet potato peels with GC-MS could reveal a wide array of compounds with potential applications across multiple industries [7]. This research aims at investigating the chemical composition of ethanolic extracts from banana and sweet potato peels using GC-MS. By evaluating the spectral profiles and bioactive compounds present, the study seeks to promote the utilization of these agricultural byproducts, reducing waste and contributing to the development of value-added products.

Materials and Methods

Samples Collection and Preparation

Fresh Potatoes and Banana were bought at Wurukum market in Makurdi and taken to the Department of Chemistry, Benue State University, Makurdi, Nigeria. Healthy potato tubers and Banana were selected and washed with distilled water to remove any adhering dirt or residues, peeled carefully and peels blanched for 3 minutes. After blanching, the peels were dried in an oven at 40°C until they maintained consistent weight. They were then pulverized using a mortar, sieved with a 40 micron mesh and kept for further use.

Extraction

Exactly 1000 g of each peels powder was subsequently extracted using70 % absolute ethanol in a Soxhlet apparatus at the ethanol boiling point for 48 h. The crude extract obtained from the peels was concentrated using a rotary evaporator, coded as sample A and B and stored for further analyses.

Characterization of Extracts

GC-MS analyses

GC-MS analyses were carried out using the GCMS-QP2010 PLUS SHIMADZU, Kyoto Japan. The column used was Perkin Elmer Elite - 5 capillary column measuring 30 m × 0.25 mm with a film thickness of 0.25 mm composed of 95 % Dimethyl polysiloxane. The carrier gas used was Helium at a flow rate of 0.5 mL/min. Exactly 1 µL sample injection volume was utilized. The inlet temperature was maintained as 250 °C. The oven temperature was programmed initially at 80 °C for 4 min, then an increase to 200 °C, and then programmed to increase to 280 °C at a rate of 20 °C ending at 5 min. Total run time was 25 min. The MS transfer line was maintained at a temperature of 200 °C. The source temperature was maintained at 180 °C. GC-MS was analyzed using electron impact ionization at 70 eV and data was evaluated using total ion count (TIC) for compound identification and quantification. The spectrums of the components were compared with the database of spectrum of known components stored in the GC-MS library [8].

Fourier transform infrared spectroscopy (FT-IR) analyses

Fourier transform infrared spectroscopy (FT-IR) analyses were performed on isolated samples to have a prompt result regarding the biomineral. A few crystals were mixed with KBr (Merck for spectroscopy) and pulverized in an agate mortar to form a homogenous powder from which, under a pressure of 7 tons, the appropriate pellets were prepared. All spectra were recorded from 4000 -400 cm^{-1} using a Pelkin Elmer 3000 MX spectrometer, United States of America. Scans were 32 per spectrum with a resolution of 4 cm^{-1}. The IR spectra were analyzed using the spectroscopic software Win-IR Pro Version 3.0 with a peak sensitivity of 2 cm^{-1}.

Antioxidant Assay

With hydrogen peroxide (H_2O_2)

The reaction mixture composed of 500 µL of 1,10 phenanthroline, 1000 µL of Sodium phosphate buffer, 500 µL of ferrous sulfate, 500 µL of hydrogen peroxide and 500 µL of different concentration of the sample 200-1000 µg/mL. The content was incubated for 30 min at room temperature after which the absorbance was recorded at 536 nm against the reagent blank. Distilled water was used in place of sample as blank while ascorbic acid was used as positive control having the same concentration as the sample [9].

$$\text{Scavenging activity (\%)} = \frac{A-B}{C-B} \text{x } 100 \quad \text{---------} \quad \text{Eqn. 1}$$

Where A is the absorbance of sample, B is the absorbance of control and C is the absorbance of distilled water in place of H_2O_2 and sample.

Anti-bacterial Test Analyses

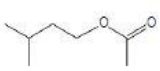
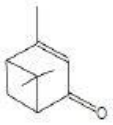
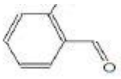
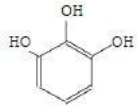
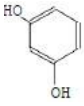
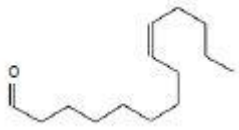
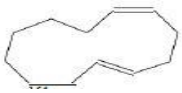
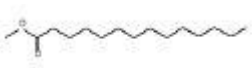
Agar well technique was employed in the assay of the sample against bacterial pathogens. Bacterial pathogen was standardized using 0.5 MacFarland standards which is expected to give an approximate cell number of 1.0 x 10^8 CFU/mL. Standardized

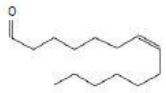
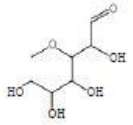
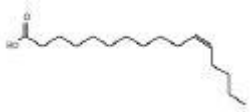
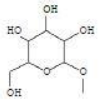
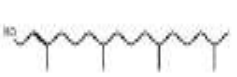
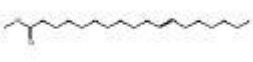
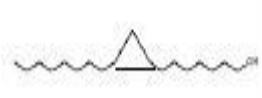
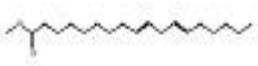
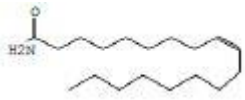
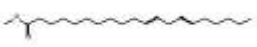
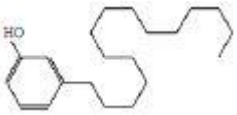
isolates (*Klebsiella pneumoniae, Proteus mirabilis* and *Pseudomonas aeruginosa*) were spread on sterile Mueller Hinton agar plates for growth of bacteria. Wells were made into the agar plates using sterile cork borer (5 mm diameter). The different concentrations were introduced into the wells for bacterial isolates and left for about 1 h for diffusion to occur before incubating at 37 ^{o}C for 24 h. Diameter of clear zones obtained were measured and recorded accordingly. The appearance of zone of clearance indicates susceptibility of isolate to the antimicrobial agents (samples) [10].

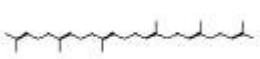
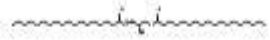
Results and Discussion

In this research, potato and banana peels were collected, extracted using ethanol, characterized and investigated for antioxidant and antibacterial activities and the results are presented in Table 1-3 and Figure 1-2.

Table 1: Qualitative and Quantitative Phytochemical Analyses of Banana and Potato Peels Ethanolic Extracts by GC-MS

S/N	Banana Peel Extract		Potato Peel Extract	
	Compound	% Composition	Compound	% Composition
1	 Isoamyl acetate (Banana oil)	2.61	 l-Verbenone	0.69
2	 Benzaldehyde	1.61	 Pyrogallol	17.94
3	 Resorcinol	19.02	 Tridecanol	0.10
4	 Cis-3-Undecene	0.91	 (Z)-9-Tetradecenal	4.02
5	 1,5-Cyclododecadiene	3.12	 Methyl tetradecanoate	0.77

6	 7-Tetradecenal	8.12	 Methyl 14-methylpentadecanoate	0.45
7	 3-O-Methyl-d-glucose	14.50	 Palmitic acid	39.66
8	 Methyl alpha-D-glucopyranoside	7.55	 (Z,Z)-9,12-Octadecadien-1-ol	2.34
9	 Palmitic acid	6.44	 Methyl n-octadecanoate	0.28
10	 Phytol	4.28	 Methyl 11-octadecenoate	0.94
11	 2-Octylcyclopropene-1-heptanol	0.29	 Methyl linolelaidate	0.86
12	 Cis-11-Octadecenoic acid methyl ester	1.09	 Oleic acid amide	4.22
13	 Cis-Oleic Acid	24.85	 Arachidic acid	5.31
14	 Cis-11,14-eicosadienoic acid methyl ester	1.41	 Cyclogallipharaol	10.63

15	 2-Monopalmitin	2.10	 2-mono-Palmitin	4.18
16	 Squalene	0.78	 1,3-di-Stearin	5.73

The GC-MS results for banana and potato peel extracts showed great differences in their chemical makeup and compositions (Table 1). Banana peels contained Cis-Oleic acid (24.85 %) which is the most abundant compound, a monounsaturated fatty acid widely present in plant-based oils, Resorcinol (19.02 %), known for its antioxidant properties and often used in chemical formulations and skincare products, 3-O-Methyl-d-glucose (14.50 %), sugar derivative that reflects the carbohydrate content in banana peel, 7-Tetradecenal (8.12 %), a fatty aldehyde that might contribute to bioactivity or flavor, Palmitic acid (6.44 %), saturated fatty acid commonly found in fats and waxes, Phytol (4.28 %), used in the synthesis of chlorophyll and vitamins and Isoamyl acetate (2.61 %), widely used as a flavoring agent. Potato peels on the other hand predominantly contained Palmitic acid (39.66 %), indicating a higher concentration of saturated fatty acids in the peels, Pyrogallol (17.94 %), a phenolic compound known for its antioxidant properties and widely used in various chemical processes, Cyclogallipharaol (10.63 %), have specific industrial or biological applications, Arachidic acid (5.31 %), saturated fatty acid, and Oleic acid amide (4.22 %), a derivative of oleic acid that is used in surface-active agents and lubricants.

Both extracts contain significant amounts of fatty acids. However, banana peel is richer in unsaturated fatty acids, particularly cis-oleic acid, while potato peel contains more saturated fatty acids, mainly palmitic acid. Zou *et al*. (2022) reported similar compounds [11]. Potato peel has higher levels of phenolic compounds such as pyrogallol, which suggests stronger antioxidant properties. The compounds identified in this research have also been reported [12, 13]. In contrast, banana peel contains resorcinol, but in lower concentrations. Banana peel has a greater presence of carbohydrate-related compounds, such as 3-O-Methyl-d-glucose and methyl alpha-D-glucopyranoside, suggesting a higher sugar content [14]. Alaa (2024) also reported similar results [15].

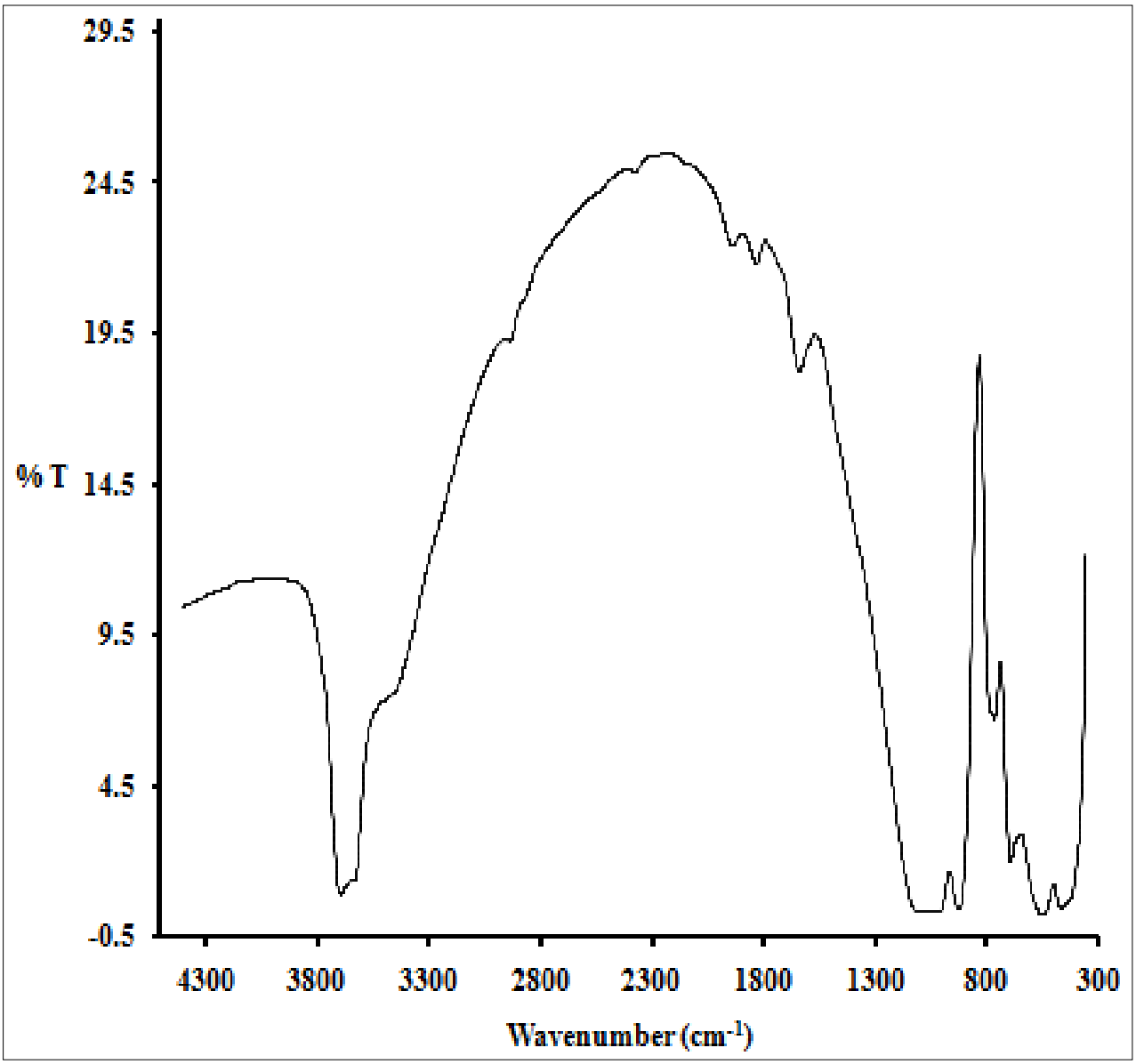


Figure 1: Fourier Transform Infrared Spectral of Banana Peels Ethanolic Extract

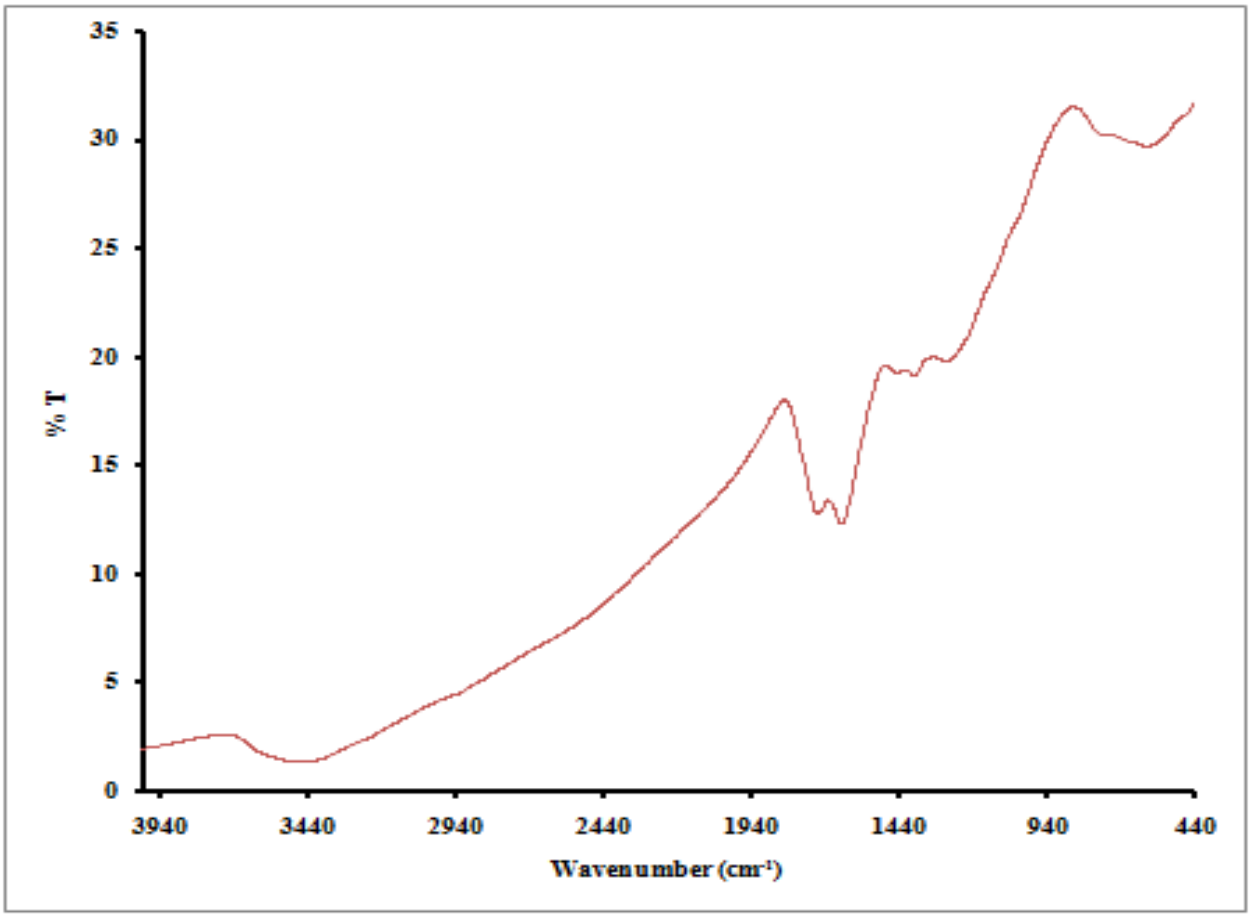


Figure 2: Fourier Transform Infrared Spectral of Potato Peels Ethanolic Extract.

From the spectral, both banana (Figure 1) and potato (Figure 2) peels contain similar functional groups, but their compositions differ in terms of the specific compounds and their relative abundance. These differences reflect the unique biochemical composition of each plant material. Both extracts display broad O-H stretching bands at ~3300-3400 cm^{-1}, with banana peels showing a more intense peak, suggesting a higher content of hydroxyl groups, possibly from phenolics, alcohols, or water [16].

The potato peel extract exhibits a stronger C=O stretching peak around 1700 cm^{-1}, indicating a higher presence of carbonyl-containing compounds such as starch degradation products or organic acids. Both extracts showed absorption in the range 1000-1300 cm^{-1}, indicative of C-O stretching, though the peak is slightly sharper in the potato peel extract, indicating a greater presence of ester or ether groups [17]. Dahiru *et al.* (2018) also reported these absorption bands from banana peels [18]. The spectra suggest that potato peels have a higher concentration of carbonyl compounds and phenolics, while banana peels likely contain more hydroxyl-rich

compounds such as polysaccharides and water as depicted by GC-MS analysis.

Table 2: Antioxidant Properties of Potato and Banana Peels Ethanolic Extracts

Samples	200 µg/mL	400 µg/mL	600 µg/mL	800 µg/mL	1000 µg/mL
Banana Peel	89.86±1.23	87.89±0.65	89.04±0.19	89.22±0.32	88.12±0.58
Potato Peel	87.75±0.06	84.82±0.06	84.86±0.13	84.45±0.19	83.89±0.06
Control	86.63±0.23	87.75±0.23	90.79±0.23	91.91±0.45	93.92±0.57

Control = Ascorbic acid; n= 2.

The result of the comparative analysis of the antioxidant activities of potato and banana peel extracts at varying concentrations (200–1000 µg/mL) using hydrogen peroxide as a reactive oxygen species (Table 2). Banana peel extract demonstrated the highest antioxidant activity than both potato peel extract and ascorbic acid at concentration of 200 µg/mL. This suggests that banana peel extract contains potent antioxidants effective at lower concentrations [19, 20]. At the concentrations of 400-600 µg/mL, the antioxidant activity of Ascorbic acid supersedes both extracts. However, the banana peel extract remains effective and relatively stable, whereas the potato peel extract seemed to have reached its optimal antioxidant activity. These findings are consistent with report of [21] and [22] who stated similar results. At higher concentrations (800-1000 µg/mL), Ascorbic acid becomes the most efficient antioxidant. However, banana peel extract still shows stronger antioxidant activity than potato peel extract, which experienced a small reduction in activity.

Table 3: Antibacterial Activities of Potato and Banana Peels Ethanolic Extracts

Sample	**Concentration of Extract (mg/mL)**	**Zone of Inhibition (mm)**		
		Klebsiella pneumoniae	***Proteus mirabilis***	***Pseudomonas aeruginosa***
B. peel	250	0±0.00	0±0.00	12.67±2.08
	125	0±0.00	0±0.00	0±0.00
	62.5	0±0.00	0±0.00	0±0.00
P. peel	250	15.67±0.58	17.00±1.00	22.33±1.53
	125	13.67±0.58	14.33±0.58	17.33±0.58
	62.5	11.33±0.58	10.67±0.58	12.33±0.58
Control		0±0.00	0±0.00	0±0.00

Control = Water without extract; n = 3.

The antibacterial effects of the extracts against *Klebsiella pneumoniae, Proteus mirabilis,* and *Pseudomonas aeruginosa* was also assessed (Table 3). The zones of inhibition were measured at various extract concentrations (250 mg/mL, 125 mg/mL and 62.5 mg/mL), with the control showing no antibacterial activity. The potato peel extract demonstrated significant antibacterial activity against the three bacterial strains tested. The most prominent effect was against *Pseudomonas aeruginosa*, with substantial inhibition even at lower concentrations. *Klebsiella pneumoniae* and *Proteus mirabilis* were also inhibited, though less effectively and a concentration-dependent reduction in activity was observed.

In contrast, the ethanolic extract of banana peel did not show any antibacterial activity against the tested strains except in *Pseudomonas aeruginosa* at high concentrations. The result of this research is contrary to the report of Ehiowemwenguan *et al*. [22] and Shaukat *et al*. [23] who stated high antimicrobial activities of the peels. This suggests that it may lack effective bioactive compounds when extracted with ethanol or that the concentration of active compounds is insufficient to inhibit bacterial growth [24, 25].

Conclusion

In this research, the bioactive components in banana and potato peels were extracted with ethanol using Soxhlet method, characterized and tested for antibacterial activities. Result of GC-MS showed that potato peel extract has higher content of saturated fatty acids and phenolics than banana peels. Spectra data of these peels suggest that potato peels have a higher concentration of carbonyl compounds and phenolics, while banana peels likely contain more hydroxyl-rich compounds, such as polysaccharides and water. However, banana peel extract showed stronger antioxidant activity than potato peel extract. Potato peel extract showed promising antibacterial properties, particularly against *Pseudomonas aeruginosa*, while banana peels did not show any antibacterial effect except at higher concentration of 250 mg/mL for *Pseudomonas aeruginosa*.

Acknowledgement

The authors hereby appreciate the Researcher Collaboration Grant (Grant ID: C23-4224772216) under the Royal Society of Chemistry UK and UNILORIN Tetfund for funding this research.

References

[1] Vastolo, A., Calabrò, S. & Cutrignelli, M. I. (2022). A review on the use of agro-industrial CO-products inanimals' diets. *Italian Journal of Animal Science*, 21: 577-594. https://doi.org/10.1080/1828051X.2022.2039562

[2] Sogi, D. S. (2020). Value-added processing and utilization of banana by-products. Handbook of Banana Production, Postharvest Science, Processing Technology, and Nutrition, 191–206. https://doi.org/10.1002/9781119528265.ch10

[3] Sree, S. S., Bharathi, R. & Rajani, N. (2022). Banana center corecoconut cookies: Value added healthy product from Bio-Waste.*Journal of Pharmaceutical Negative*, 13(7): 1335–1341.

https://doi.org/10.47750/pnr.2022.13.S07.196

[4] Naik, M. & Rawson, A. (2022). Tender coconut water: A review on recent advances in processing and preservation. *Food Reviews International,* 1-22. https://doi.org/10.1080/87559129.2020.1785489

[5] Susanah R. I., Made D. S., Ida A.R., Astiti A. & Ni M. P. (2020). Antibacterial activity and antioxidant capacity of selected local banana peel (musa sp.) Methanol extracts cultivated in Bali. *Wiwik*, **5**(3): 114-158. https://doi.org/10.35410/IJAEB.2020.5519

[6] Yang, J., Martinson, T. E. & Liu, R. H. (2016). Phytochemical profiles and antioxidant activities of wine grapes. *Food Chemistry*, 211: 187–194. https://doi.org/10.1016/j.foodchem.2016.05.018

[7] Yee, W. (2015). Feasibility of various carbon sources and plant materials in enhancing the growth and biomass productivity of the freshwater microalgae Monoraphidium griffithii NS16. *Bioresource Technology*, 196: 1-8. https://doi.org/10.1016/j.biortech.2015.07.033

[8] Ezhilan B. P. & Neelamegam R. (2012). GC-MS analysis of phytocomponents in the ethanol extract of Polygonumchinense L. *Pharmacogn Res.*, 4(1): 11–14. doi: 10.4103/0974-8490.91028

[9] Gulcin, I., Zubeyr, H., Mahfuz, E., Hassan, Y. & Aboul E. (2010). The reducing power of tannic acid. *Arabian Journal of Chemistry*, 3: 43–53.

[10] Banerjee, A., Sharma, N., & Nayan, R. (2019). Antifungal potential of plant extracts: A review. *Journal of Applied Pharmaceutical Science*, 9(1): 57–65. https://doi.org/10.7324/JAPS.2019.90110

[11] Zou, F., Tan, C., Zhang, B., Wu, W., & Shang, N. (2022). The valorization of banana by-products: Nutritional composition, bioactivities, applications, and future development. *Foods*, 11(20): 3170. https://doi.org/10.3390/foods11203170

[12] Toledo, T. T., Nogueira, S. B., Cordenunsi, B. R., Gozzo, F. C.,Pilau, E. J., Lajolo, F. M., & do Nascimento, J. R. O. (2012). Proteomic analysis of banana. *Postharvest Biologyand Technology,* 70: 51–58. https://doi.org/10.1016/j.postharvbio.2012.04.005

[13] Wani, K. M. & Dhanya, M. (2025). *Unlocking the potential of banana peel bioactives: extraction methods, benefits, and industrial applications. Discover Food*, 5: 8. https://doi.org/10.1007/s44187-025-00276-y

[14] Rodríguez-Martínez, B., Gullón, B. & Yáñez, R. (2021). Identification and Recovery of Valuable Bioactive Compounds from Potato Peels: A Comprehensive Review. *Antioxidants*, 10: 1630. https://doi.org/10.3390/antiox10101630.

[15] Alaa K. N. (2024). Determination, Identification of Bioactive Compounds Extracted from Yellow Banana peels and used in vitro as Antimicrobial. *International Journal of Phytomedicine,* 6(4): 625-632. http://arjournals.org/index.php/ijpm/index

[16] Qudsia M., Uzair I., Nicolas J. & Patrick M. (2024). Investigation and characterization of changes in potato peels by thermochemical acidic pre-treatment for extraction of various compounds. *Sci Rep.* 14: 12655. doi: 10.1038/s41598-024-63364-6

[17] Ee, L. Y., Ng, B. H., Ng, B. Y. (2024). *Phytochemical fingerprint revealing antibacterial and antioxidant activities of endemic banana cultivars in Southeast Asia.* Heliyon, 10(15): e35139. https://doi.org/10.1016/j.heliyon.2024.e35139

[18] Dahiru M., Zango Z. & Haruna M. (2018). Cationic Dyes Removal Using Low-Cost Banana Peel Biosorbent. *American Journal of Materials Science*, 8(2): 32-38. 10.5923/j.materials.20180802.02.

[19] Helal M. M., El-Adawy, T. A., El-Beltagy, A. E., El-Bedawey, A. A. & Youssef. S. M. (2020). Evaluation of potato peel extract as a source of antioxidant and antimicrobial substances. *Menoufia J. Food & Dairy Sci.*, 5: 79 – 90. Doi:10.21608/mjfds.2020.171473.

[20] Truong, Q. T., & Nguyen, D. K. (2024). *Optimization of extraction parameters of phenolic compounds from Cau banana (Musa paradisiaca) peel and evaluation for antioxidant and antibacterial potential. European Journal of Biology*, 83(2): 131–143. https://doi.org/10.26650/EurJBiol.2024.1459106

[21] Hikal W., Kacaniova M. & Said-Al A. H. (2021). Banana Peels as Possible Antioxidant and Antimicrobial Agents. *Asian Journal of Research and Review in Agriculture*, 3(3): 35-45.

[22] Ehiowemwenguan G., Emoghene A. & Inetianbor J. Antibacterial and phytochemical analysis of Banana fruit peel. *IOSR Journal of Pharmacy (IOSRPHR).*2014, 4. 18-25. 10.9790/3013-0408018025.

[23] Shaukat N., Farooq U., Akram K., Shafi A., Hayat Z., Naz A., Hakim A., Hayat K., Naseem S. & Khan M. Z. (2023). Antimicrobial potential of banana peel: A natural preservative to improve food safety. *Asian J. Agric. Biol.*, 3(1): 202003188 DOI: https://doi.org/10.35495/ajab.2020.03.188

[24] Sulaiman, S. F., Sajak, A. A., Ooi, B., Supriatno, K. L. & Seow, E. M. (2011). Effect of solvents in extracting polyphenols and antioxidants of selected raw vegetables. *Journal of Food Composition and Analysis*, 24(4–5): 506–515. https://doi.org/10.1016/j.jfca.2011.01.020

[25] Ahmad, W., Ahmed, S., Shameem, M. (2025). *Nanophotocatalytic degradation of phenolic contaminants by ZnS nanoparticles synthesized from banana peel extract: a greener approach.* Environmental Monitoring and Assessment, 197: 401. https://doi.org/10.1007/s10661-025-13899-6

[26] Novia A. and Laela H. N. (2018). The Antioxidant Activity Analysis of the Ethanolic Extract of Banana Peel (*Musa paradisiaca* forma typica) with DPPH Method. In Proceedings of the 1st Muhammadiyah International Conference on Health and Pharmaceutical Development (MICH-PhD 2018), pages 44-47. DOI: 10.5220/0008239100440047

[27] Sami A. A., Hassan M. M., Hassan M. M., Khaled E., et al. (2019). Protective Effect of Sweet Potato Peel against Oxidative Stress in Hyperlipidemic Albino Rats. *Food and Nutrition Sciences* 10(05):503-516, DOI: 10.4236/fns.2019.105037.