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Original Research Article

Sunlight-Assisted Green Synthesis of Silver Nanoparticles using *Musa accuminata* Peel and their Antimicrobial Potential

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XRD,
SEM,
TEM.

ABSTRACT
Green nanotechnology has acquired high demand due to its cost-effective and eco-friendly approach for the synthesis of nanoparticles. Silver nanoparticles (AgNPs), currently, are among the most widely used artificial nanomaterials present in a range of consumer products. The silver nanoparticles were synthesized from the water extract of banana peels using a green technique that is eco friendly. The plant's secondary metabolites served as capping and reducing agents. The synthesized silver nanoparticles (MAP-AgNPs) were characterized using Fourier Transform Infrared (FTIR) Spectroscopy, Ultraviolet-visible Spectroscopy (UV-vis), X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM) and Energy-dispersive X-ray Spectroscopy (EDS). The plant extract contained bioactive components that were responsible for biogenic synthesis and the capping and stabilizing properties. These compounds could be the source of the vibration frequencies noticed in the spectra of the MAP AgNPs and that of the plant extract, such as those seen at 3272 cm^{-1}, 3280 cm^{-1}, 2918 cm^{-1}, 2851 cm^{-1}, 1736 cm^{-1}, 1636 cm^{-1} etc. The 400–500 nm absorption peak was visible in the UV–Vis spectra, showing the adsorption of silver nanoparticles. XRD studies confirmed the crystalline nature of the synthesized material showing five distinctive diffraction peaks at 2θ degrees of 38.37° (111), 44.54° (200), 64.75° (220), 77.89° (311) and 81.87° (222), which evidently indicated the formation of the face-centered cubic (fcc) crystalline structure of the AgNPs. The SEM image revealed the shape of the synthesized MAP AgNPs as being spherical. EDS result showed that the materials are primarily composed of silver, 65.20 wt%. Other minor visible elements like carbon, oxygen, silicon, iron, potassium, calcium, and aluminum may have come from the phytochemicals from the plant part used to bioreduce $AgNO_3$ solution. Thermogravimetric analysis shows that the material is stable, since no loss in mass was recorded until at a very high temperature of about 300 °C. The nanoparticles exhibited antibacterial activity against all tested organisms, indicating broad-spectrum efficacy.

CITATION
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INTRODUCTION

Nanotechnology, according to Mohammed *et al*. (2024), is the term used in describing any technology that functions at the nanoscale that has real-world applications. It is one of the most important advances in technology and science. Since last decade, the development of nanotechnology and Nano science have shown marked ability to address environmental pollution (Lee *et al*., 2010). Several physical and chemical features of nanomaterials make them particularly valuable for wastewater cleanup because of their distinct structure and particular surface properties (Aningo *et al*., 2025). Nanomaterials have shown high faster rates and efficiency in water treatment than traditional old materials. Nanoparticles commonly used include zero metals to uptake heavy metal ions from contaminated water (Xu *et al*., 2010). Nanotechnology is one of the most popular applications used in technical disciplines for developments and researches, which include medical. Among several metallic nanoparticles, silver nanoparticles (AgNPs) are among the most important and fascinating nanomaterials that are being used in biomedical and environmental applications. Green eco-friendly processes, in chemistry are becoming increasingly popular due to the worldwide problems that are associated with the environment (Larayetan *et al*., 2020). Synthesized nanoparticles by biological routes such as plants, micro-organisms, and viruses or their by products, such as lipids, proteins are seen to be better than those manufactured with physical and chemical methods (Khaydarov *et al* 2010). Green synthesis of silver nanoparticles makes use of secondary metabolites as capping and reducing agents (Abdulrazaq *et al.,* 2024). Silver nanoparticles have exceptional properties, and have drawn a lot of interest in a variety of applications (Aningo *et al*., 2025). As the size of the material approaches the nanometer, its properties change and the proportion of atoms on the surface of the material becomes larger. Different adsorbents have been used to remove heavy metals from water such as peels and wastes of different plants, activated carbons, biopolymers, clay and others. Operational challenges such as high cost, time consumption are some of the challenges associated with most of the available technologies for treatment of wastewater (Godwin *et al*., 2022). The sunlight-assisted synthesis of nanoparticles is a technique that utilizes diffused sunlight as the energy source to facilitate the chemical reaction, converting metal ions into nanoparticles. This process often employs a plant extract as a reducing agent, categorizing it as a green synthesis method.

MATERIALS AND METHODS

Apparatus and Equipment

Common laboratory glassware, an orbital shaker, a centrifuge, and a funnel were used during the synthesis.

Chemicals

All the chemicals used were of analytical grade and were purchased from Sigma-Aldrich Chemicals Limited. Silver nitrate ($AgNO_3$) was utilized as a reagent for the synthesis of the nanoparticles.

Plant Extract Preparation

The peels of *Musa acuminata* were air-dried at room temperature for 24 days before being pulverized into powder using an electric grinder. 100 g of the powdered sample was soaked in 1000 mL of distilled water and shaken on an orbital shaker for 24 hrs. The extract was filtered using Whatman No. 1 filter paper, and the resulting filtrate was labeled, and preserved in brown vial bottle in a refrigerator until the sample was needed for analysis (Larayetan *et al*., 2021; Abisoye, 2021).

Sunlight-driven biosynthesis of AgNPs

250 mL of 1mM of freshly prepared silver nitrate ($AgNO_3$) solution was mixed with 25 mL of *Musa acuminata* peel extract. After thoroughly mixing the $AgNO_3$ and the plant extract, it was promptly exposed to sunlight (at a temperature of 18–20°C). Within a few minutes of exposure, the color changed from pale grayish tint to dark brown, confirming the biogenic synthesis of AgNPs utilizing *Musa acuminata* peel extract. After that, the mixture was centrifuged for 25 minutes at 12,000 rpm. To get rid of the phyto-constituents that didn't participate in the reaction, the pellets were rinsed three times with distilled water after the supernatant was disposed of. After being dried at 37 °C, the pellets were put away for later use (Saha and Bandyopadhyay, 2019).

 + $AgNO_3$ + Sunlight - AgNPs

Characterization of Synthesized Silver Nanoparticles

The synthesized silver nanoparticles were characterized using analytical techniques. The biogenic reduction of Silver ions in the mixture was periodically measured using a Shimadzu Ultra Violet-visible (UV–Vis) spectrophotometer at a range of 200–800 nm. The UV-vis absorption spectrophotometer is the most effective and widely used technique to determine the synthesis of AgNPs at the initial stage of biosynthesis utilizing plants.

The vibration frequencies of AgNPs produced by Banana peel extract were determined using a Fourier Transformed Infrared Spectrophotometer (FTIR) (Perkin-Elmer Universal ATR 100). It helped to identify the functional groups that may be responsible for stabilization and capping using a scanning range of 4000-440 cm^{-1}. Scanning Electron Microscopy (SEM) (JEOL JSM-6490A), and Energy-dispersive X-ray Spectroscopy (EDS) studies were used to observe the surface shape and composition of the NPs respectively. X-ray diffraction (XRD) (Bruker D8 advanced x-ray diffractometer) was used to confirm the crystallinity phase of the biogenic AgNPs and was run at 45 k (Larayetan *et al*., 2019)

Minimum Inhibitory and Bactericidal Concentrations (MIC and MBC)

The minimum inhibitory concentration (MIC) of the extract was determined through the microdilution procedure illustrated by Collin et al. (2004). To achieve this, 750, 800, 850, 900, and 950 µL of Mueller-Hinton Broth (MHB) were distributed to each one of the Eppendorf tubes, and a stock solution of extract (20 mg/mL) was prepared in DMSO. Aliquots of 250, 200, 150, 100, and 50 µL of the extract were dispensed into each tube having the MHB to raise the final volume to 1000 µL, respectively. Precisely, 25 µL of the inoculum's suspension from each bacterial strain (0.5 McFarland, ~1 × 108 cfu/mL) was subsequently mixed and vortexed to permit for adequate mixing of the exract and broth. Each Eppendorf tube was labelled appropriately and incubated for a day at 37°C. Ciprofloxacin and DMSO were employed as both positive and negative controls. The MIC of the extract was described as the smallest concentration that depicts no observable growth when put side by side with the control containing only MHB, while the minimum bactericidal concentration (MBC) was determined by the pour plate method of all tube content devoid of any noticeable growth in the MIC method above onto fresh Mueller-Hinton agar plates, and the culture was then incubated for 24 h at 37°C. The smallest concentration of extracts that did not reveal any colony growth on the exterior of the solid medium after an incubation period of 24 h was considered as the MBC.

RESULTS AND DISCUSSION

Results

Characterization

The synthesized AgNPs obtained from the reduction of $AgNO_3$ by the plant extract of *Musa acuminata peels* was characterized by a number of techniques. When determining the contribution of plant extracts to the reduction of silver ions to silver nanoparticles, FTIR is a non-destructive, suitable, essential, and straightforward approach (Catalano, 2021). The plant extract contained bioactive components that were responsible for biogenic synthesis and their capping and stabilizing properties (Larayetan *et al*., 2018). These compounds could be the source of the vibrational frequencies noticed in the spectra of the synthesized AgNPs and that of the plant extract, such as those seen at 3272, 3280, 2918, 2851, 1736, 1636 cm^{-1}, etc.

This finding suggests that some moieties of the bioactive component residues in the utilized plant extract encapsulated the AgNPs serving as capping and stabilizing agents (Kusumaningsih *et al*., 2023). Additionally, it is possible to trace a broad peak at 3272 cm^{-1} for *Musa acuminata* extract to the N-H stretching vibration of group NH_2 in the extract; this stretching vibration was not conspicuous in the biosynthesized nanoparticles from the extract. The plant extract bands at 1736 cm^{-1} are attributed to C=O stretching vibrations of ketones in *Musa acuminata* extract. A similar stretching vibration of ketone at 1774 cm^{-1} was also observed in the AgNPs of the nanoparticles. The identified peaks may essentially be due to the flavonoids, tannins, and terpenoids present in the plant extract (Larayetan *et al.*, 2019).

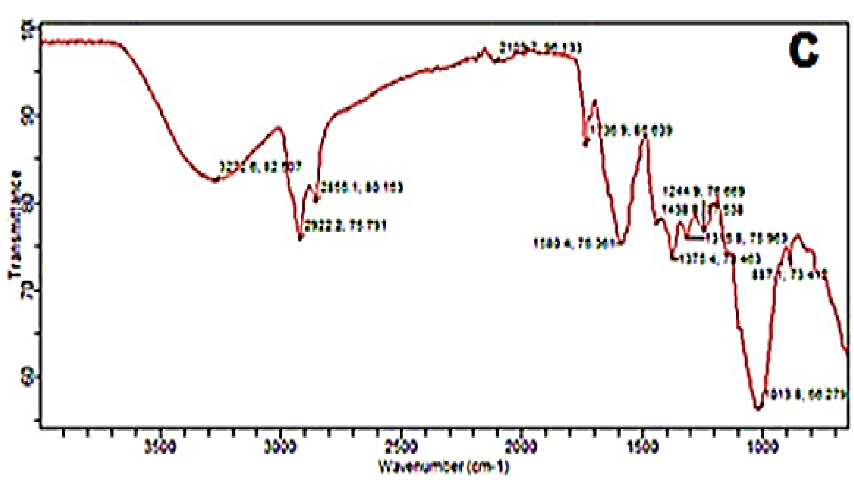

Figure 1: FTIR of the *Musa acuminata* peel extract

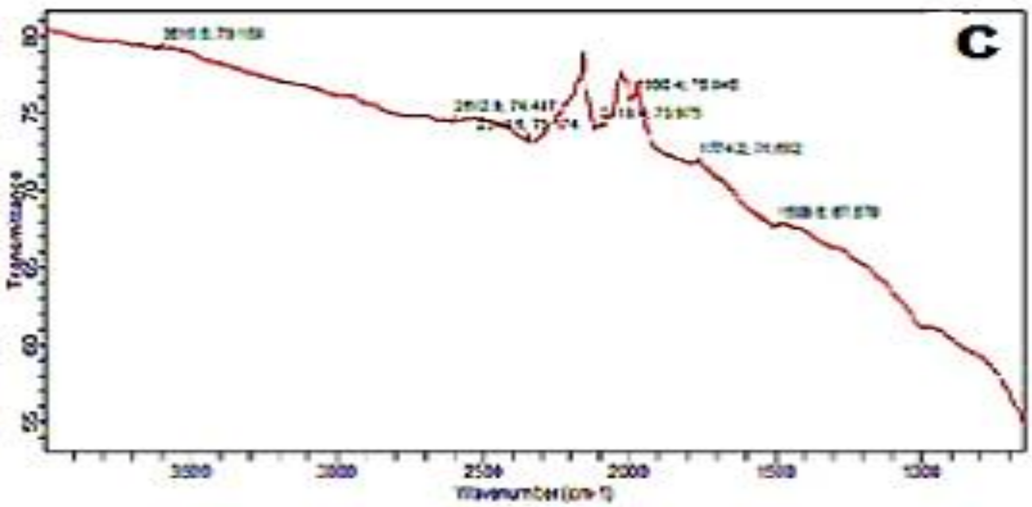

Figure 2: FTIR results of the MAP

The resulting colour combinations after the synthesis was deep brown, This might be due to the excitation of surface plasmon resonance (SPR) between 400 and 460 nm (Figure 3) which confirms the conversion of $AgNO_3$ to AgNPs. The results agreed with the absorbance value of biosynthesized silver nanoparticles reported from previous studies (Larayetan *et al*., 2021).

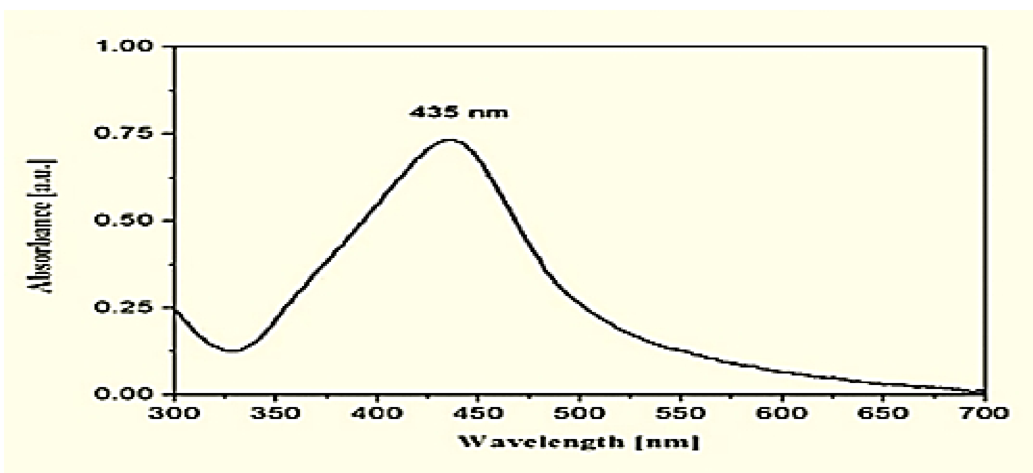

Figure 3: UV-vis result of MAP

XRD is commonly employed to reveal the crystalline nature of AgNPs. It enumerates the firmness of various chemical compounds, thus indicating an idea of the estimated different chemical groups and particle sizes. In this investigation, a monochromatic beam of X-rays was focused towards the AgNPs sample, which consequently generated a pattern that was analyzed using Bragg's equation in order to reveal the unique features of the crystallinity of the studied AgNPs (Ajayi, *et al*., 2022). The X-ray diffraction spectra of silver nanoparticles obtained from the reduction of $AgNO_3$ by an aqueous extract of *Musa acuminata* AgNPs, is presented in Figure 4. It can be observed that the synthesized material is crystalline in nature upon reduction of $AgNO_3$. The XRD pattern revealed five distinctive diffraction peaks at 2θ degrees of 38.37° (111), 44.54° (200), 64.75° (220), 77.89° (311) and 81.87° (222), which evidently indicated the formation of the face-centered cubic (fcc) crystalline structure of the AgNPs, mediated by the aqueous peel extracts of *Musa acuminata*. Ojemaye *et al*. (2017a) opined that diffraction peaks at (111), (200), (220), and (311) are characteristic peaks of metal nanoparticles, and these peaks are also observed in the diffractogram in Figure 4 confirming the successful synthesis of AgNPs. The crystallite size of all synthesized materials with the (111) diffraction peak using the Scherrer formular ($D=K\lambda/B\cos\theta$) showed that the synthesized material is in the size range of 22-32 nm.

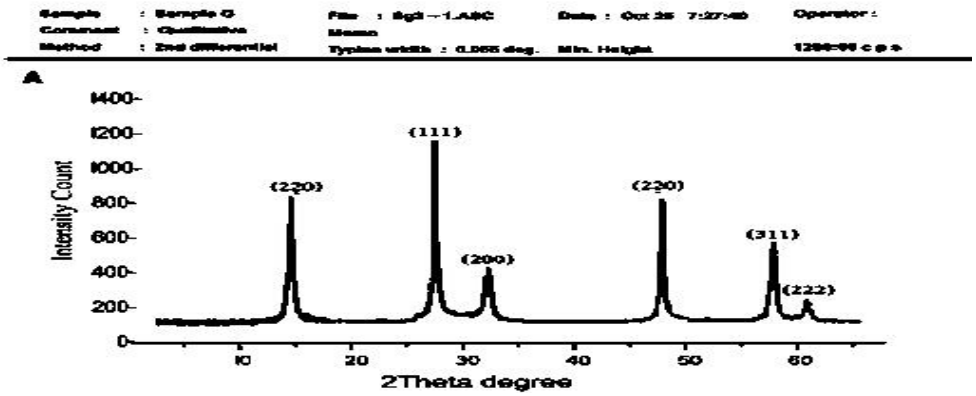

Figure 4: X-ray Diffractogram of MAP

Scanning Electron Microscopy (SEM) provides insights into the morphology, size, and distribution of synthesized silver nanoparticles (AgNPs). Based on the provided SEM image, the following observations were made: The nanoparticles appear spherical and well-dispersed, which is a desirable characteristic for AgNPs in biomedical and catalytic applications. Minimal aggregation was also observed, suggesting effective capping and stabilization by the phytochemicals in the Musa acuminata peel extract. (Figure 6). The absence of excessive aggregation suggests that the synthesis method ensures good colloidal stability, which is crucial for real-world applications. Selected Area Electron Diffraction (SAED) is used to determine the crystalline nature of nanoparticles. The provided SAED pattern offers crucial insights into the structural properties of the green-synthesized silver nanoparticles (AgNPs).

The SAED pattern shows distinct concentric rings with indexed planes corresponding to the (111), (200), (220), and (311) reflections. These are characteristic of face-centered cubic (FCC) silver (Ag), confirming the crystalline nature of the nanoparticles. The bright, well-defined diffraction spots along the rings indicate that the synthesized AgNPs are highly crystalline. The observed diffraction planes (111, 200, 220, and 311) match the standard JCPDS card (No. 04-0783) for silver, confirming that the nanoparticles are composed of pure silver. The sharp diffraction rings confirm that the green synthesis method using *Musa acuminata* peel leads to well-ordered crystalline nanoparticles.

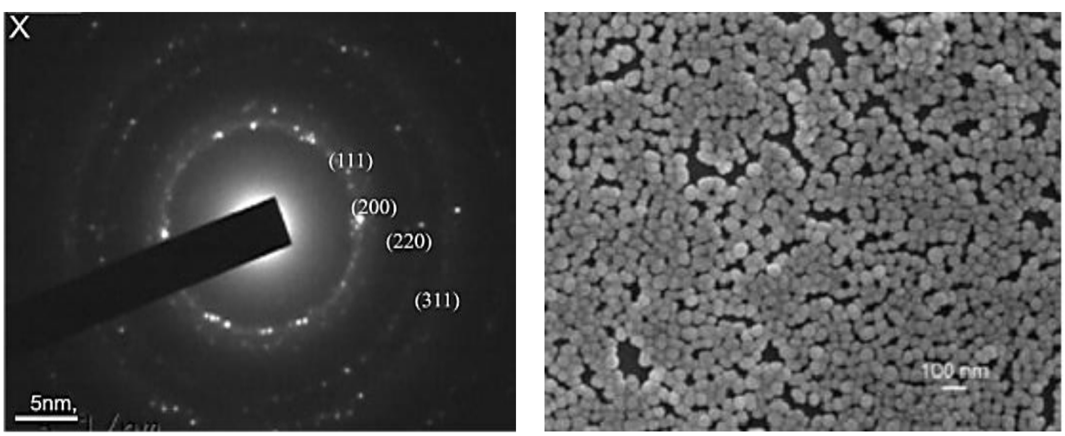

Figure 5: SEM and SAED Image of MAP

The provided TEM image offers valuable insights into the structural characteristics of the green-synthesized AgNPs. The nanoparticles appear predominantly spherical, with some slight variations in shape. This confirms that the green synthesis method using *Musa acuminata* peel leads to the formation of well-defined nanoparticles. The scale bar indicates 100 nm, and the observed nanoparticles are generally within the 10–50 nm range. The variation in particle size suggests some degree of polydispersity, which is common in green synthesis methods due to natural variations in reducing agents. Some nanoparticles are well-separated, while others show minor aggregation. This indicates that the plant extract components provide effective capping and stabilization, but some nanoparticles may still cluster together due to *Van der Waals* forces. The dark regions in the nanoparticles indicate their high electron density, confirming the presence of metallic silver. The well-defined edges suggest crystallinity, which aligns with the SAED results showing an FCC structure.

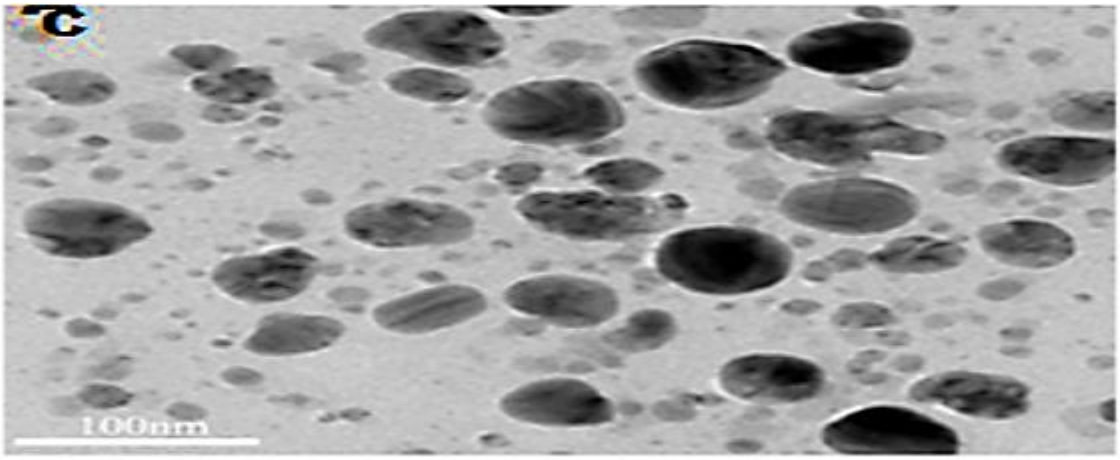

Figure 6: TEM image of MAP

Energy-dispersive X-ray Spectroscopy (EDS) was used to assess the composition of the materials obtained from the reduction of $AgNO_3$ by plants. EDS result (Figure 7) shows that the material is primarily composed of silver, at 65.20 wt %. Other minor, visible, elements like carbon, oxygen, silicon, iron, potassium, calcium, and aluminum may have come from the phytochemicals from the plant part used to bioreduce $AgNO_3$ solution (Larayetan *et al.,* 2020).

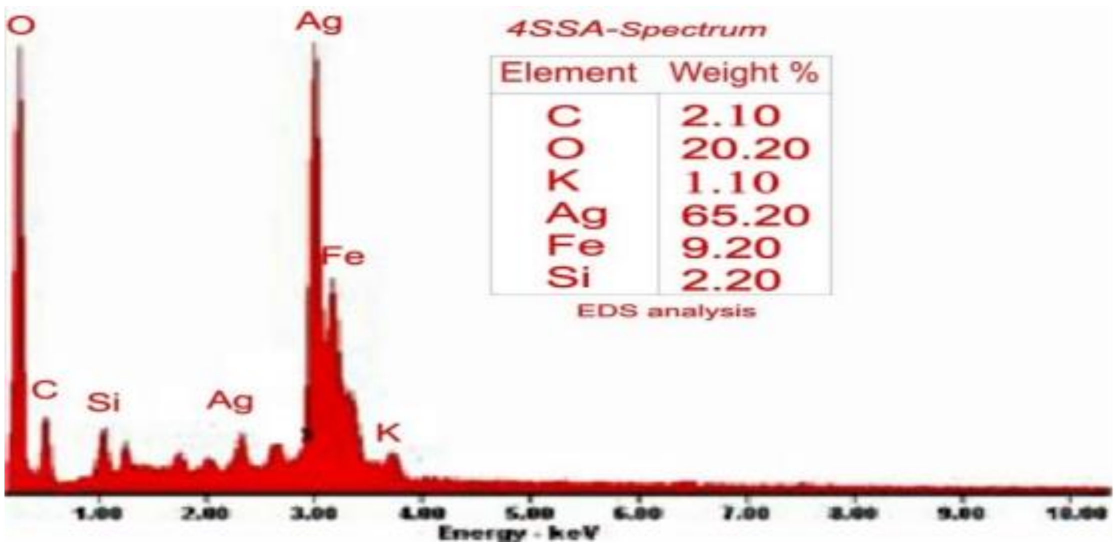

Figure 7: EDS result of MAP

Thermogravimetric Analysis (TGA) is used to study the thermal stability and composition of materials. In the context of this study, the TGA curve provides insights into the decomposition behavior of the banana peel-derived silver nanoparticles (AgNPs) and their organic content. The weight remains nearly constant, indicating minimal moisture loss or decomposition of volatile compounds. This suggests that the synthesized AgNPs are relatively stable at low temperatures. A significant weight drop is observed in this region (~200°C to ~400°C). This corresponds to the decomposition of organic biomolecules (e.g., polysaccharides, flavonoids, and phenolics) present in the banana peel extract, which acted as capping and reducing agents during AgNPs synthesis. The loss confirms the presence of plant-derived stabilizing agents. Further degradation was evident at this region (~400°C to ~600°C), this may likely due to the breakdown of residual organic matter or carbonaceous content. At this stage, most organic components were eliminated, leaving behind the metallic silver core. There was weight stabilization at (above ~600°C), indicating that only the inorganic silver nanoparticles remain, confirming successful AgNPs formation. The thermal degradation of the organic components confirms the role of banana peel extract in AgNPs synthesis. The residual weight at high temperatures supports the presence of silver nanoparticles, as silver is thermally stable at these temperatures. The decomposition profile provides insight into the thermal stability of the AgNPs, which is essential for biomedical and industrial applications.

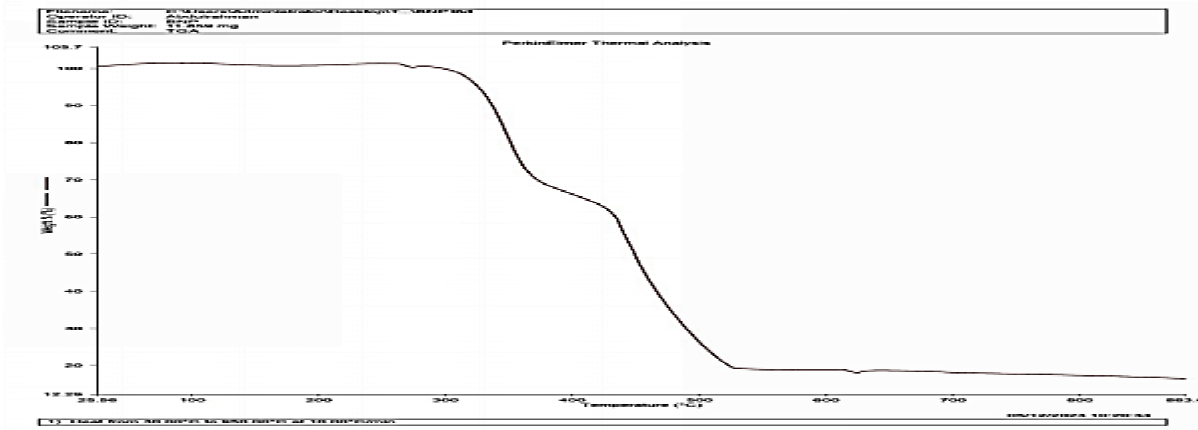

Figure 8: Thermogravimetric graph for MAP

The study evaluates the antimicrobial activity of silver nanoparticles (AgNPs) synthesized using *Musa acuminata* (banana peel) extract under sunlight-assisted conditions. The findings provide insights into the efficacy of these green-synthesized AgNPs against different bacterial strains. The nanoparticles exhibited antibacterial activity against all tested organisms, indicating broad-spectrum efficacy. S*taphylococcus aureus* and *Klebsiella pneumoniae* were the most susceptible, with MIC values of 0.94 mg/mL and MBC values of 1.88 mg/mL (Table 1). This suggests that these bacteria require the lowest concentration of AgNPs for inhibition and eradication. *Bacillus cereus* exhibited moderate susceptibility, with MIC and MBC both at **1.88 mg/mL**. *Bacillus subtilis* showed a high MBC (>30 mg/mL), indicating that while growth inhibition occurs at 1.88 mg/mL (Table 1), complete bactericidal action requires much higher concentrations. *Serratia marcescens* and *Proteus vulgaris* had MIC and MBC values of 3.75 mg/mL and 7.5 mg/mL, indicating reduced sensitivity compared to other tested organisms. The low MIC and MBC values against *S. aureus* and *K. pneumoniae* highlight the potential application of these green-synthesized AgNPs in treating infections caused by these bacteria. The higher MBC values for *B. subtilis*, *S. marcescens*, and *P. vulgaris* suggest that higher doses or extended exposure times might be needed for effective treatment. The broad-spectrum activity aligns with existing research on silver nanoparticles, emphasizing their role as an alternative to conventional antibiotics (Larayetan *et al*., 2019).

Table 1: Sensitivity of selected bacteria to antibacterial agents and determination of Minimum Inhibitory and Minimum Bactericidal concentration using broth dilution method.

Organism	Sensitivity 30 mg/mL	MIC (mg/mL)	MBC (mg/m)
***Serratia marcescens* (NCIB 1377)**	S	3.75	7.5
***Bacillus subtilis* (NCIB3610)**	S	1.88	>30
***Staphyloccocus aureus* (NCIB 8588)**	S	0.94	1.88
***Bacillus cereus* (NCIB 6349)**	S	1.88	1.88
***Klebsiella pneumoniae* (NCIB 418)**	S	0.94	1.88
***Proteus vulgaris* (NCIB67)**	S	3.75	7.5

CONCLUSION

MAP nanomaterial was synthesized by the green synthesis method, sunlight assisted. The method is simple, mild, low-cost and ecofriendly. Functional group determination by FTIR spectral analysis showed that MAP, contains C-O, C=O, O-H, etc. functional groups, which were believed to be from the metabolites of the used plant sample. The UV-vis absorption spectrophotometer technique was used to determine the synthesis of AgNPs at the initial stage of biosynthesis since it is the most effective and widely utilized technique. UV–Vis spectrophotometer displayed SPR absorption bands ranging from 350nm to 550 nm, characteristic of Ag NPs. Instrumental characterization by XRD revealed that the nanoparticles are crystalline in nature. Morphological examination by SEM showed that MAPs were inconsistent in shape but majorly spherical with Ag, Si, O, S, Fe, Ca, and Na K elements, as revealed by EDS analysis, with Ag having the highest peak and others very small and coming from the metabolites of the plant extracts. The antimicrobial broad-spectrum activity aligns with existing research on silver nanoparticles, emphasizing their role as an alternative to conventional antibiotics.

REFERENCES

Abdulrazaq, Y., Larayetan, R. A., Ayeni, G., Omatola, K. M., Deborah, O. K., & Atoga, A. E. E. (2024). Application of Inorganic and Green Nanocomposite for the Cleaning of Toxic Metals Ions from Industrial Effluent Contaminated Water.

Abisoye, L. R. (2021). Antimalarial, antitrypanosomal, antimicrobial activities and volatile oil profile of xylopia aethiopica (dunal) rich (annonaceae). *Lett Appl NanoBioScience*, *11*(3), 3897-3908. https://doi.org/10.33263/LIANBS113.38973908

Ajayi, A., Larayetan, R., Yahaya, A., Falola, O. O., Ude, N. A., Adamu, H., ... & Ukanu, P. I. (2021). Biogenic synthesis of silver nanoparticles with bitter leaf (Vernonia amygdalina) aqueous extract and its effects on testosterone-induced benign prostatic hyperplasia (BPH) in Wistar rat. *Chemistry Africa*, *4*(4), 791-807.

Aningo G.N., Abdulrazaq Y, Larayetan R. A., Ayeni G, Aliyu A.O.C. John G., Okpanachi C.B. (2025). Isotherms, Kinetics and Thermodynamics of Removal of Pb (II), Cd (II) and Cr (III) Ions in Wastewater onto Green Silver Nanoparticle. Adsorbent. Journal *of Applied Chemical Science International 16(1), 11-25.*

Catalano, P. N., Chaudhary, R. G., Desimone, M. F., & Santo-Orihuela, P. L. (2021). A survey on analytical methods for the characterization of green synthesized nanomaterials. *Current Pharmaceutical Biotechnology*, *22*(6), 823-847. . https://doi.org/10.2174/1389201022666210104122349.

Collins, C. H., Lyne, P. M., Grange, J. M., & Falkinham III, J. O. (2004). Microbiological Methods Eight Edition. *By Arnold*, *466*.

Godwin, J., Abdus-Salam, N., Haleemat, A. I., Bello, M. O., Inyang, E. D., Alkali, M. I., & Tripathy, B. C. (2022). High performance nanohybrid ZnO-α-FeOOH nanocomposite prepared for toxic metal ions removal from wastewater: combined sorption and desorption studies. *Inorganic Chemistry Communications*, *145*, 109900. https://doi.org/10.1016/j.inoche.2022.109900

Khaydarov, R., Khaydarov, R., Gapurova, O., & Estrin, Y. (2010). A novel method of continuous fabrication of aqueous dispersions of silver nanoparticles. *International Journal of Nanoparticles*, *3*(1), 77-91. https://doi.org/10.1504/IJNP.2010.033223

Kusumaningsih, T., Prasetyo, W. E., Istiqomah, A., Firdaus, M., & Wibowo, F. R. (2023). Sustainable synthesis of silver nanoparticles with enhanced anticancer, antibacterial, and antioxidant properties mediated by dimeric 2, 4-diacetyl phloroglucinol: Experimental and computational insights. *Surfaces and Interfaces*, *36*, 102545. https://doi.org/10.1016/j.surfin.2022.102545

Larayetan, R., Osanekwu, S., & Sokwo, M. (2018). Phytochemical components of methanolic fruit extract of Dennettia tripetala. *Journal of Functional Materials and Biomolecules*, *2*(2), 48-52.

Larayetan, R., Ojemaye, M. O., Okoh, O. O., & Okoh, A. I. (2019). Silver nanoparticles mediated by Callistemon citrinus extracts and their antimalaria, antitrypanosoma and antibacterial efficacy. *Journal of Molecular Liquids*, *273*, 615-625. https://doi.org/10.1016/j.molliq.2018.10.020

Larayetan, R. A., Ayeni, G., Yahaya, A., Ajayi, A., Omale, S., Ishaq, U... & Enyioma-Alozie, S. (2021). Chemical composition of Gossypium herbaceum linn and its antioxidant, antibacterial, cytotoxic and antimalarial activities. *Clinical Complementary Medicine and Pharmacology*, *1*(1), 100008. https://doi.org/10.1016/j.ccmp.2021.100008

Larayetan, R., Olisah, C., & Idris, O. A. (2020). Research progression on studies related to green synthesis nanoparticles: a bibliometric review. *Green synthesis of nanoparticles: applications and prospects*, 1-22. https://doi.org/10.1007/978-981-15-5179-6_1

Larayetan, R., Yahaya, A., Ayeni, G., & Moronkola, B. (2020). Biogenic Synthesis, Characterization, Toxicity Assessment, Antiparasitic and Antibacterial Activities of Silver Nanoparticles from Lippia multiflora. *Green Synthesis of Nanoparticles: Applications and Prospects*, 273-287. https://doi.org/10.1007/978-981-15-5179-6_12

Lee, J., Mahendra, S., & Alvarez, P. J. (2010). Nanomaterials in the construction industry: a review of their applications and environmental health and safety considerations. *ACS nano*, *4*(7), 3580-3590. https://doi.org/10.1021/nn100866w

Mohammed, N., Nawar, S. H., Etawy, M. S., Nassar, G. E., & Hassabo, A. G. (2024). Nanotechnology and its applications in industry and product design. *Journal of Textiles, Coloration and Polymer Science*, *21*(2), 273-284. 10.21608/JTCPS.2024.258215.1251.

Ojemaye, M. O., Okoh, O. O., & Okoh, A. I. (2017). Surface modified magnetic nanoparticles as efficient adsorbents for heavy metal removal from wastewater: Progress and prospects. *Materials Express*, *7*(6), 439-456. https://doi.org/10.1166/mex.2017.1401

Saha, M., & Bandyopadhyay, P. K. (2019). Green biosynthesis of silver nanoparticle using garlic, allium sativum with reference to its antimicrobial activity against the pathogenic strain of bacillus sp. and pseudomonas sp. infecting Goldfish, Carassius auratus. In *Proceedings of the Zoological Society* (Vol. 72, pp. 180-186). Springer India.

Xu, X., Wang, Q., Choi, H. C., & Kim, Y. H. (2010). Encapsulation of iron nanoparticles with PVP nanofibrous membranes to maintain their catalytic activity. *Journal of Membrane Science*, *348*(1-2), 231-237. https://doi.org/10.1016/j.memsci.2009.11.006