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Green Synthesis and Characterization of Bioinspired Metal Nanoparticles Mediated by Ipomoea Involucrata P. Beauv. as Potential Antimicrobial Agents

Ikechukwu P. Ejidike[1,2*], Doris O. Seyinde[1], Chidera F. Nwaeme[1], Mercy O. Bamigboye[3], Olajumoke Oluade[4], Racheal U. Ijimdiya[1], Temitope O. Fakoya[5], Dorcas A. Fadare[1], Oluwatoyin O. Ojo[1], Solomon A. Olaleru[6], Juliana B. Adetunji[7], Hadley S. Clayton[2]

[1]Biological and Analytical Application of Synthetic and Nanomaterials Research (BAASNMR) Group, Department of Chemical Sciences, Faculty of Science, Anchor University, Lagos 100278, Nigeria

[2]Department of Chemistry, College of Science, Engineering, and Technology, University of South Africa, Florida Park 1709, South Africa

[3]Department of Industrial Chemistry, Faculty of Physical Sciences, University of Ilorin, Ilorin 240003, Nigeria

[4]Department of Chemistry, Faculty of Science, Gombe State University, Gombe 760253, Nigeria

[5]Department of Industrial Chemistry, Faculty of Science, University of Ilesa, Ilesa 233252, Nigeria

[6]Department of Physical Science, School of Science, Yaba College of Technology, Lagos 100001, Nigeria

[7]Department of Biochemistry, Faculty of Basic and Applied Sciences, Osun State University, Oshogbo 210001, Nigeria

(*) Corresponding author: iejidike@aul.edu.ng; pejidike30@gmail.com
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Abstract

Chemical, physical, or biological routes have been beneficial to the synthesis of nanoparticles of varied shapes and sizes. Nevertheless, the synthesis of nanoparticles via the use of plants as precursors is a rapid, environmentally friendly, low-cost option and is safe for the human populace. Synthesis of metal nanoparticles with plant extracts is advantageous owing to their ease of scalability and capability as a capping, bio-reducing mediator, and/ or stabilizer. This study presents a simple and eco-friendly approach for the synthesis of AgNPs, MnNPs, NiNPs, and CuNPs from the leaf extract of Ipomoea involucrata. The synthesized nanoparticles were characterized by UV- visible spectroscopy, Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDX), and Fourier Transform Spectroscopy (FTIR). UV-vis spectra of the aqueous medium containing the metal nanoparticles showed a peak at 425 nm for AgNPs, CuNPs at 433 nm, and NiNPs around 416 nm, while MnNPs showed a peak at about 417 nm. The morphology of the metal nanoparticles (IP-MNPs) as documented by the SEM results reveals irregular but distinct morphologies for each nanoparticle type. The EDX analysis confirms the presence of each elemental metal in the synthesized nanoparticles. Furthermore, the nanoparticles showed better activities against microbial pathogens than the plant extract; it is therefore suggested that these green-synthesized metal nanoparticles tagged with Ipomoea Involucrata can address future health and medical concerns.

Keywords: *Green synthesis, Ipomoea involucrata, Nanoparticles, Antimicrobial, Spectroscopy*

1. INTRODUCTION

Large volumes of information are obtained from small quantities of data owing to the recent era of nanotechnology. The phenomenon of exploitation of materials at atomic, molecular, and macromolecular levels is where the world stands today, making life easier and less complex [1, 2, 3, 4, 5]. Nanoscience gives numerous focal points to the varied fields of science, including pharmaceuticals, cosmetics, dentistry, and bioengineering [6, 7, 8, 9]. Nanoparticles (NPs) with dimensions ranging from 1 nm to 100 nm function as a connector between bulk materials and atomic structures [8, 10, 11, 12]. The perspective of nanomaterials has received recognition through the "green chemistry" pathway. This area of nanoscience is culminating in the preparation of safe and eco-friendly NPs, which have gained acceptance in nanotechnology [1, 2, 13, 14, 15, 16]. Traditional methods have been used for many years; however, researchers have proved in recent eras that the green methods are effective to produce NPs with varied sizes and shapes at low cost and facilitate characterization [1, 16, 17, 18, 19, 20].

Plant extracts are made up of carbohydrates and protein biomolecules, which act as dipping and capping agents for nanoparticle synthesis, which is favourable over other methods owing to its simplicity and is safe for the environment [2, 21, 22]. The functional clusters like–C=O–, –C=C–, –NH, –C–O–C–, and –C–O– existing as phytochemicals like alkaloids, flavones, anthracenes, and phenols assist with the creation of metallic nanoparticles [14, 23, 24, 25]. To address the increasing need for environmentally responsive nanoparticles, scholars have used microorganisms for diverse metal nanoparticle synthesis [6, 7, 13, 19, 26]. Chemical, physical, or biological routes have been beneficial to the synthesis of nanoparticles of varied shapes and sizes.

However, the use of natural materials such as plants for nanoparticle synthesis is a fast, low-priced, environmentally-friendly route, and safe for human practice [6, 15, 16, 19, 21, 22, 27, 28]. Silver nanoparticles (AgNPs) facilitated by *Daucus carota* L. via green synthesis, with antimicrobial, antiradical possibilities, and cytotoxicity against brain glioblastoma (U87MG) cells have been reported [15]. Bioinspired ZnO nanoparticles from aqueous *Brassica oleracea* L. var. italic (broccoli extract) were utilized for the photo-boosted catalytic action against phenol red (PR) and methylene blue (MB), under UV light [29]. Biosynthesized copper nanoparticles (CuNPs) and iron nanoparticles (FeNPs) from extracts of *Eucalyptus* leaf were reported to possess an increased bacterial inhibition with an increased concentration range (100 mg/l – 800 mg/l) against selected strains [14].

AgNPs are being used progressively in catheters, wound dressings, and different household items due to their antimicrobial potential [8, 9, 22, 30, 31, 32, 33, 34]. The activity of nano molecules prepared from Allium species like garlic and ginger, with silver salt ($AgNO_3$), demonstrated antimicrobial potential against bacterial pathogens like *Proteus spp., Pseudomonas spp*, *Enterobacter spp., Klebsiella spp., E. coli, Staphylococcus spp., Bacillus spp.,* [35]. Dinga et al. [36] used *Melia azedarach* seed extract for the biosynthesis of zinc nanoparticles and appraised the cytotoxic against the human hepatoma (HepG2) cell line and antimicrobial potency against infectious pathogens [36]. Copper nanoparticles were synthesized from *Hagenia abyssinica* (Brace) JF. Gmel. leaf extract and evaluated its antibacterial activity against *P. aeruginosa*, *S. aureus*, *E. coli*, and *B. subtilis*. Its antibacterial activity exhibited a good inhibition zone 12.7, 14.7, 12.7, and 14.2 mm, respectively, demonstrating the potentiality of CuNPs as a therapy for infectious diseases triggered by tested pathogens [37]. Bioinspired metal nanoparticles mediated from Asteraceae species plant extracts were reported by Jaison and coworkers in 2023 to possess potential antioxidant, cytotoxic, antibacterial, antifungal, photocatalytic degradation, and antiparasitic activities [38].

Ipomoea involucrata is a species of plant that is widely accepted with a native range of tropical and South Africa, a sprawling, slender, or twisting annual or perennial herb, of grassland, secondary scrub, and forest. It is of the family *Convolvulaceae* [39]. It is also considered to be a good talisman in Gabon, so pregnant women sometimes wear it around the waist. In Congo, the length of the stem is sometimes tied around a baby's waist to promote early walking, and the leaf sap is applied and rubbed into areas of birth; a compress of pounded-up stems is used for headaches. In Ghana, the stems and leaves are used for treating anemia [40]. In Sierra Leone, a decoction of the fresh sap is taken as a remedy for gonorrhea. In Ivory Coast, a plant formulation is added to baths or fabricated into a lotion for treating jaundice. The leaves are used in Nigeria for the treatment of asthma and convulsions [40, 41].

Due to the uniqueness of these *Ipomoea* species, investigators have narrated the biosynthesis of metal nanoparticles from extracts of several species such as *Ipomoea laxiflora* [42], *Ipomoea aquatica* [43], *Ipomoea hederifolia* [44], *Ipomoea indica* [45], *Ipomoea digitata* [46], *Ipomoea batatas* [47, 48, 49], *Ipomoea mauritiana* [50], however, no report exist for the green synthesis of metal nanoparticles like copper, silver, nickel, and manganese with Nigeria indigenous *Ipomoea involucrata* P. Beauv plant extract as precursors (IP-MNPs) and its antimicrobial potentials to the best of our knowledge. The metal nanoparticles were characterized by different spectroscopic techniques like Fourier-transform infrared spectroscopy (FTIR), UV-visible, Energy-dispersive X-ray spectroscopy (EDX), and Scanning electron microscopy (SEM). The antimicrobial potentials of the as-synthesized nanoparticles were explored against six microbial pathogens via the disk diffusion technique.

2. MATERIALS AND METHODS

2.1. Materials and Plant Collection

Leaves of *Ipomoea involucrata* P. Beauv. (Family: *Convolvulaceae*) were collected around July 2020 around Anchor University (6.6040° N, 3.2419° E), Lagos, Nigeria. The plant samples were taxonomically identified and authenticated by Prof. Olasupo Ilori from the Department of Biological Sciences, Anchor University, Lagos. The leaves were cleansed under steady water flow and dried at room temperature for about 15 - 20 days. The Macasalab mill (model 200 Lab) was used to pulverize the dried leaf material into a fine powder and store it in an air-tight container until the time of extraction. $AgNO_3$, $CuSO_4.5H_2O$, $NiCl_2.6H_2O$, and $MnCl_2.4H_2O$ were of analytical grade (BDH Chemicals). Strains of *Staphylococcus aureus, Escherichia coli, α-haemolytic streptococcus, Aspergillus candidus, Penicillium cephalosporin,* and *Aspergillus niger* were collected from the Biological Sciences Department, Anchor University, Lagos, Nigeria.

2.2. Ipomoea Involucrata Powder Extract Preparation

60 g of cleaned *I. involucrata* (dried leaf powder) was introduced into a 1000 mL flask, and 600 mL of distilled water was carefully added. The mixture was gently positioned on a heating mantle at 70 °C for 1 hr and allowed to stir. Thereafter, the plant extract was permitted to cool and then filtered three times with Whatman filter paper to obtain a clean aqueous extract. The plant extract was kept in a refrigerator at 4 °C for further investigations.

2.3. Synthesis of Metal Nanoparticles

200 mL of *I. involucrata* leaf extract was added to a pre-cleaned 500 mL bottom flask, and the addition of 50 mL of 0.1 M solution was added to each hydrated metal salt ($AgNO_3$, $NiCl_2.6H_2O$, $CuSO_4.5H_2O$, and $MnCl_2.4H_2O$). The resulting solution was heated at 70 °C for 1 hr. The change of colour from pale brown to darkish-brown/grey signifies the complete bio-reduction of the metal ions. The precipitate obtained was permitted to cool, followed by sample washing trice and centrifugation at 4000 rpm for 25 min. After purification, the sample was dried at 105 °C in an oven. The IP-MNPs formed were characterized using spectroscopic methods [15, 21, 22].

2.4. Characterization of Synthesized Metal Nanoparticles

The bio-reduced metal nanoparticles (AgNPs, CuNPs, NiNPs, MnNPs) were subjected to different characterization techniques. An Agilent Cary 630 FTIR spectrometer was utilized for the functional group determination in the plant extract and the synthesized metal nanoparticles. UV-Vis spectrophotometer (Thermo Scientific GENESYS^{TM} UV-Vis Spectrophotometer) for the optical properties of the nanoparticles. Scanning Electron Microscope (SEM), JSM-7900F, JEOL USA, was utilized for the morphology and size identification of the nanoparticles. SEM was coupled with the EDX technique for sample elemental composition identification and to estimate their relative abundance.

2.5. Antibacterial Analysis

The antibacterial activity of the as-synthesized NPs was assessed on strains of bacteria: *Staphylococcus aureus, Escherichia coli,* and *α-hemolytic streptococcus* using the disk-diffusion agar method. 50 mL of molten nutrient agar was added to sterile Petri dishes, and each strain was swabbed uniformly using an inoculating loop. The prepared, green-synthesized NPs in an aqueous solution (25 μg/mL) were placed in the inoculated plates at six peripheral positions and incubated for 24 hr at a temperature of 37 °C. After the gestation, an inhibition zone was observed around the disks. The inhibition zone diameter was calculated using a meter rule [8, 15, 22].

2.6. Antifungal Activity

Disk-diffusion agar method was utilized for the assessment of the NPs' antifungal activity on fungi species: *Aspergillus candidus, Penicillium cephalosporin*, and *Aspergillus niger*. 30 ml of molten Potato Dextrose agar (PDA) was added to sterile Petri dishes, with each inoculum swabbed in a zigzag and thorough motion on the individual plates. The disks suspended in each aqueous solution of synthesized NPs (25 μg/ml) were placed in the inoculated plates at six peripheral positions and incubated for 24 hr at 25 °C. Afterward, the clear zone observed around the disks was measured using a meter rule and recorded as the diameter of the inhibition zones [15, 22, 23].

3. RESULTS AND DISCUSSION

3.1. Phytochemical Studies

The phytochemical testing of *I. involucrata* leaf extract revealed the existence of quinones, terpenoids, steroids, saponins, phenolic, flavonoids, alkaloids, and tannins; however, cardiac glycosides and anthocynosides were not uncovered in the crude extract of *I. involucrata* as illustrated in Table 1. The data from this study agree with the report of Essiet and Ukpong [39], who showed that leaf extract of *I. involucrata, I. triloba, and I. batatas* contains various phytochemical constituents exhibiting a wide range of biological activities such as antibacterial, antitumor, antiviral, antiradical, antifungal, antiparasitic, and anti-inflammatory activities [39].

3.2. UV-Vis Analysis

A significant technique for the initial characterization of nanoparticles is UV-vis spectroscopy. The absorption spectra of the metal nanoparticles showed various bands as shown in Figure 1 The absorption maxima peak at about 398 nm demonstrated that the plant leaf extracts contain biological Phyto-molecules such as terpenoids, steroids, saponins, phenolic, flavonoid, alkaloid, and tannins, signifying UV light absorption within this region due to the presence of carbonyl group [15, 32]. The spectrum of AgNPs showed a band at 425 nm, CuNPs at 433 nm, NiNPs showed a band at 416 nm, and MnNPs demonstrated a band at about 417 nm. These bands have been attributed to Surface Plasmon Excitation due to the collective excitation of conducting electrons in the metals. Similar bands due to Plasmon excitation have been reported for different green synthesized metal nanoparticles [3, 8, 14, 21, 22, 32, 34].

Table 1. *Qualitative phytochemical constituents of I. involucrata leaf extract.*

Test	***I. involucrata*** **leaf extract**
Cardiac glycosides	-
Phenolic	+
Alkaloids	+
Steroids	+
Quinones	+
Saponins	+
Anthocynosides	-
Tannins	+
Terpenoids	+
Flavonoids	+

Key of distribution: + = present - = Absent

According to Dudhane et al., the UV-visible spectrum of gold nanoparticles using the plant extract of *Terminalia arjuna* showed a peak of 530 nm [51]. Chandrasekhar and Vinay [52] reported a UV-vis band at 428 nm for silver nanoparticles synthesized from *C. tomentosum*, while silver nanoparticles mediated by *Diospyros kaki* L. (Persimmon) via green synthesis displayed the highest absorbance at 453.34 nm wavelengths [13].

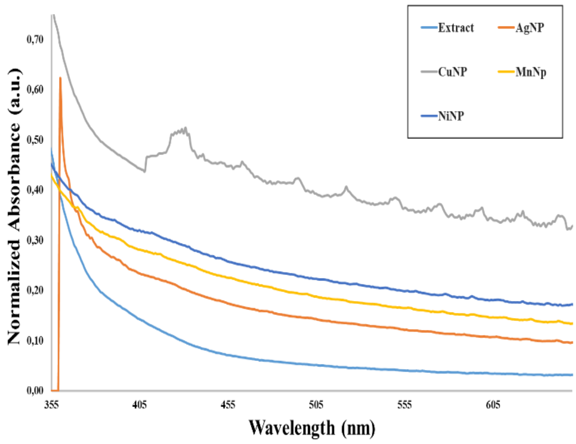

Figure 1. *UV-Vis spectra of metal NPs synthesized from I. involucrata leaf extract.*

3.3. Fourier-Transform Infrared Spectroscopy (FT-IR)

Important information on the functional groups existing in the extract of *I. involucrata* and its corresponding metal nanoparticles (IP-MNPs) was investigated using the FT-IR. The spectrum of the *I. involucrata* extract (Figure 2) showed a very strong broad peak around 3334 cm^{-1}, which can be attributed to O-H vibration from polyphenols, alkaloids, and flavonoids [12, 15, 17, 32, 34]. Weak peaks around 2849 cm^{-1} to 2916 cm^{-1} were attributed to CH_2/CH_3 symmetric and asymmetric vibrations, C=C stretch was detected at 1648 and 1594 cm^{-1}, C-C stretch was observed at 1273 cm^{-1}, and the peaks around 1049 to 1015 cm^{-1} were identified as C-O aliphatic alkanes.

In the spectrum of AgNPs (Figure 2), O-H vibrations were observed at 3357 cm^{-1}; the increase in O-H wavenumber concerning that of the plant extract confirms the interaction between the Ag ion and bioactive component of *I. involucrata* leaf extract. CH_2/CH_3 symmetric and asymmetric vibrations at 2917 and 2840 cm^{-1} were very strong, and a peak signifying C=O was observed at 1784 cm^{-1}, which described the donation of electrons from the carbonyl group of *I. involucrata* extract to the metal center [3, 10, 14, 21, 22, 23].

Peaks replicating the C=C functional group at 1559 cm^{-1} were detected, a shift in peaks from 1351 to 1335 cm^{-1} depicts C–N stretching for the aromatic amines, C-C stretch was observed at 1280 cm^{-1}, and a peak around 536 cm^{-1} shows that AgNPs were effectively synthesized [3, 8, 13, 15]. MnNPs exhibited O-H vibration at 3378 cm^{-1} (Figure 2), and CH_2/CH_3 symmetric and asymmetric vibrations were observed at 2917 and 2852 cm^{-1}, and at 1706 cm^{-1} C=O peak was visible. C=C str. was observed at 1515 cm^{-1}, C-N stretch was observed at 1331 cm^{-1}, C-C stretch was observed around 1251 cm^{-1}, and peaks around 1052 and 1021 cm^{-1} were identified as C-O aliphatic alkanes, while the peak around 532 cm^{-1} signifies the formation of MnNPs.

For nickel nanoparticles, the spectrum revealed O-H vibration around 3398 cm^{-1}, peaks at 2921 and 2849 cm^{-1} signify CH_2/CH_3 symmetric and asymmetric vibrations, C=O peak at 1707 cm^{-1} denotes the donation of an electron from the carbonyl group to the metal. C=C str. was perceived at 1600 cm^{-1}, C-N stretch was observed at 1365 cm^{-1}, C-C stretch was observed at 1232 cm^{-1}, and the formation of NiNPs was confirmed by a peak around 547 cm^{-1} [14, 22, 29, 37, 35]. In the spectrum of CuNPs, O-H vibration showed around 3409 cm^{-1} (Figure 2), and CH_2/CH_3 symmetric and asymmetric vibrations were noted around 2918 and 2852 cm^{-1}, and at 1717 cm^{-1} C=O peak was visible. C=C str. was detected at 1525 cm^{-1}, C-N stretch was observed at 1363 cm^{-1}, C-C stretch was observed around 1244 cm^{-1}, peaks around 1087 and 1030 cm^{-1} were identified as C-O aliphatic alkanes, and the peak observed around 564 cm^{-1} supported the formation of CuNPs.

The existence of diverse functional groups such as; carbonyl, proteins, carboxylic acid, ether, and flavonoids (O–H, C–H, CO_2NH_3, C=O, C=C, N–H, C–O) in the green synthesized metal nanoparticles (AgNPs, CuNPs, NiNPs, and MnNPs) substantiate other reports who also identify similar functional groups in their biosynthesized metal complexes as the contributing factor accountable for the bio-reduction and capping of metal ions into metal nanoparticles in the current study [13, 14, 15, 35, 36, 37].

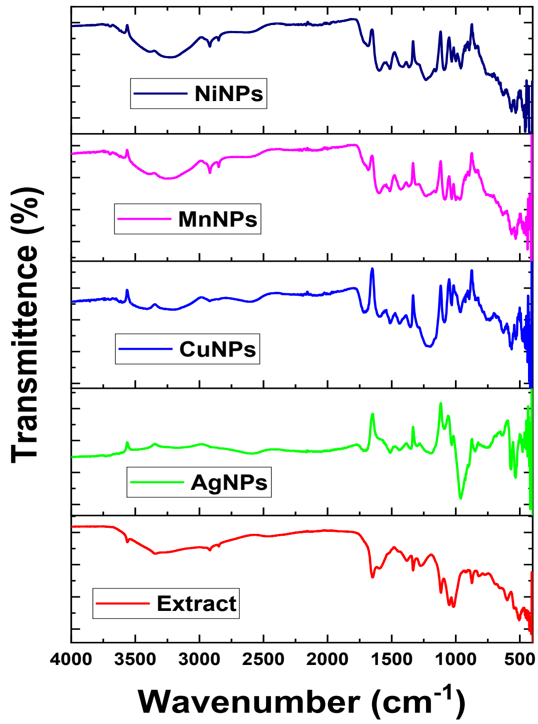

Figure 2. *FT-IR spectra of the green-synthesized metal NPs and I. involucrata leaf extract.*

3.4. Scanning Electron Microscopy Studies

The green-synthesized metal nanoparticle morphologies were identified via SEM. Figure 3 displays the SEM image of the biosynthesized *I. involucrata* metal nanoparticles (IP-MNPs). Figure 3a micrographs revealed that IP-AgNPs have teardrop-like rhombic crystalline morphology, IP-CuNPs (Figure 3b) are coral-like, IP-NiNPs (Figure 3c) have a branched tree-like structure, and IP-MnNPs (Figure 3d) have a rough-edged rectangular structure.

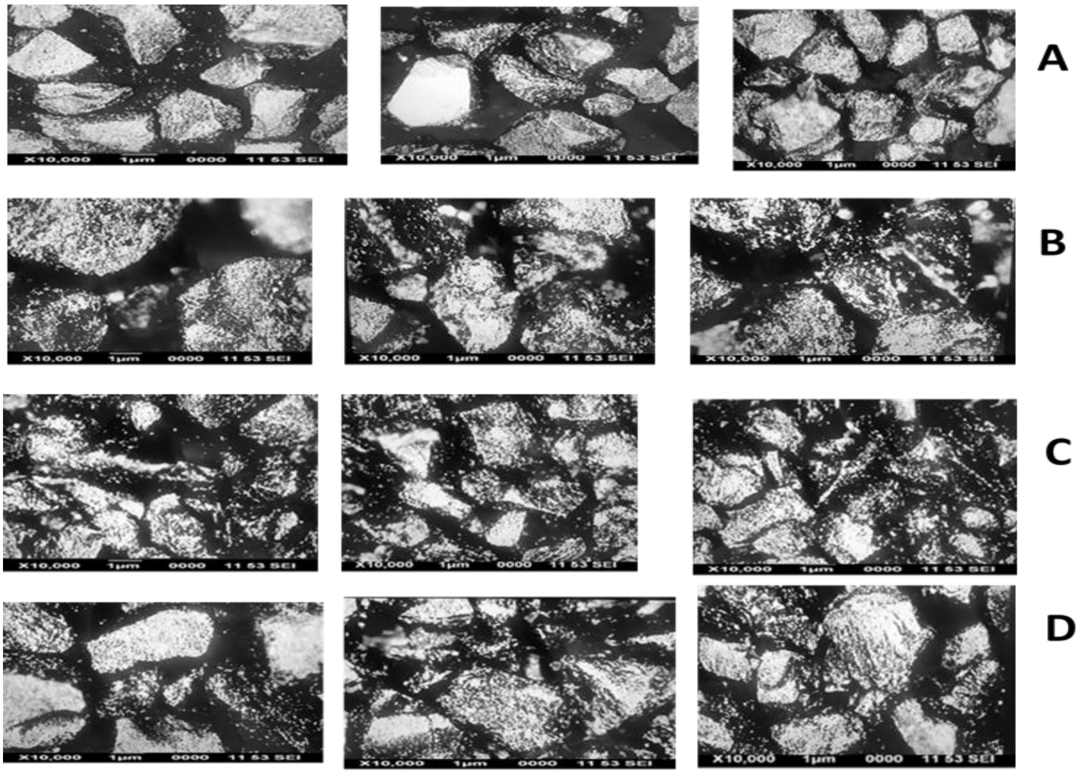

***Figure 3.** Scanning electron microscope (SEM) of (a) AgNPs, (b) CuNPs, (c) NiNPs, (d) MnNPs.*

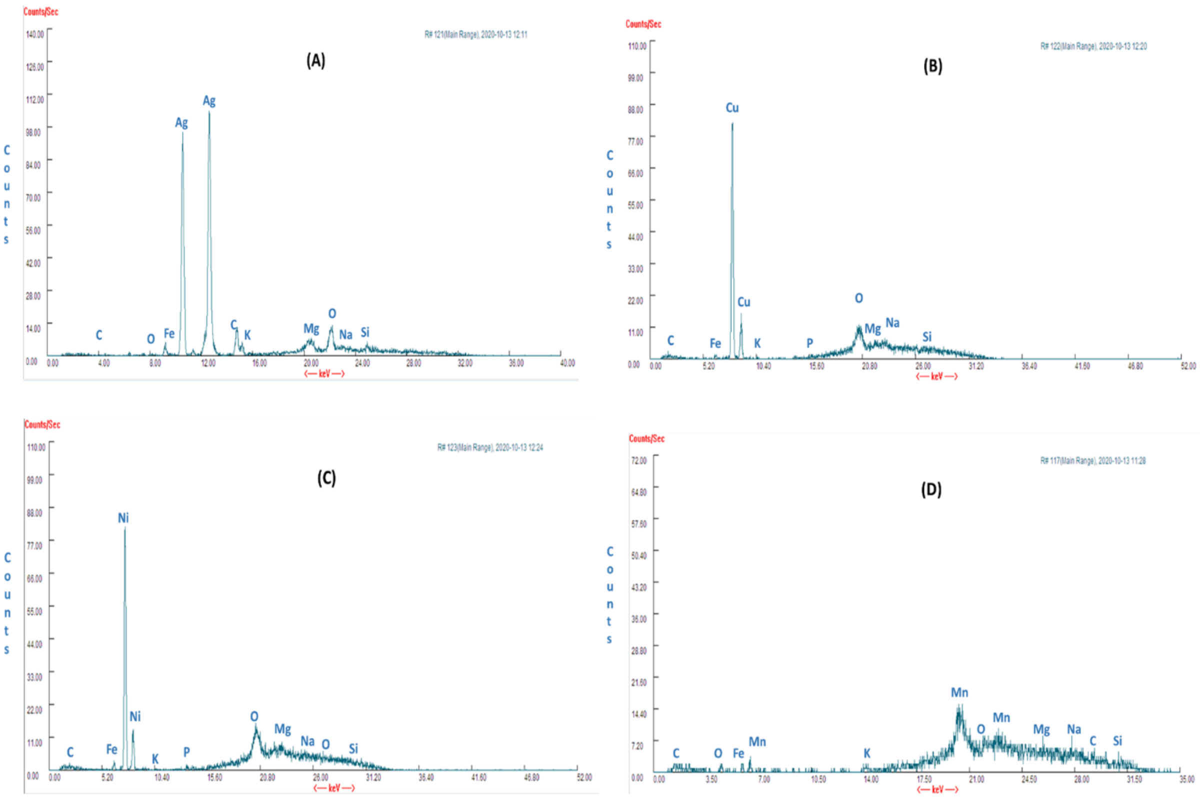

***Figure 4.** EDX spectrum of (a) AgNPs (b) CuNPs (c) NiNPs (d) MnNPs.*

The SEM image further established that the prepared AgNPs were distributed uniformly, CuNPs were fairly packed, NiNPs were close and roughly packed, and

MnNPs were uniformly dispersed. The optimum concentrations of both precursors are essential to forming the shape and desired size of nanoparticles [8, 14, 29]. The size of the green-synthesized metal nanoparticles (AgNPs, CuNPs, NiNPs, and MnNPs) was relatively large, this feature may be due to varying concentrations of diverse reducing agents (flavonoid, carboxylic acid, ether, and alkaloid) present in the bulk *I. involucrata* leaf extract that bounded to the surface of the already formed cores, this increases the secondary bio-reduction of the respective metal salt on the surface of the nuclei which subsequently lead to the increased growth rate of the NPs, thereby establishing a large size NPs [8, 13, 15, 19, 20, 52].

Consequently, metal NPs are also affected by the metal salt and precursor (extract) concentrations. Literature has shown that the same metal nanoparticles formed from different plant species extracts with varying concentrations display different shapes. Green synthesis of biogenic AgNPs mediated by *Diospyros kaki* L. (Persimmon) was spherical in SEM images [13]. Dudhane et al. [51] reported that gold nanoparticles (AuNPs) using plant extract of *Terminalia arjuna* are mostly spherical, while the green copper nanoparticles (CuNPs) using medicinal plant *Hagenia abyssinica* (Brace) JF. Gmel. leaf extract exhibited a mixture of spherical, triangular, cylindrical, hexagonal, and irregularly shaped CuNPs [37].

Nickel oxide nanoparticles (NiO) synthesized utilizing the leaf extract of *Ocimum sanctum* for cytotoxicity application against HeLa (human cervical cancer cells) and MM2 (human breast cancer cells) showed rod-like structures [1]. Souri et al. showed that the manganese dioxide nanoparticles (MnO_2 NPs) via green synthesis with *Yucca gloriosa* leaf extract have spherical shapes [53].

3. Energy Dispersive X-ray Spectroscopy (EDX) Analysis

The EDX analysis was performed to verify the occurrence and chemical components of the biosynthesized metal NPs. Figure 4 displays the EDX pattern, respectively, and these outcomes validate the effective green synthesis of the metal NPs using the biological moieties of *I. involucrata* leaf extract. The presence of Ag atoms in the synthesized AgNPs was justified by their EDX peaks at 10.00–12.50 keV. Sharp peaks at 6.10–7.10 keV indicated a higher concentration of nickel in the synthesized nickel nanoparticles (NiNPs).

The element Cu in CuNPs was observed by its peaks at 6.80–7.10 KeV, and the peaks at 19.50–21.00 KeV identified the presence of elemental Mn in MnNPs. In addition to the metal peaks of the green synthesized IP-MNPs EDX peaks, the other peaks corresponding to carbon (C) and oxygen (O) materialized in the spectrum, which validated the presence of biological molecules on the NP's surface owing to the plant extract. Hence, it is noticeable from the EDX results that the green syntheses of the respective nanoparticles were successfully prepared from the plant leaf extracts as precursors [8, 13, 15, 29, 32, 37].

3.6. Biological Potentials

3.6.1. Antibacterial Activity

The antibacterial potential of the biosynthesized IP-MNPs against three bacteria species: *S. aureus*, *E. coli*, and *α-H. streptococcus* in comparison to *I. involucrata* leaf extract as presented in Table 2 and Figure 5 was evaluated via the disk-diffusion method. The metal nanoparticles (AgNPs, MnNPs, NiNPs, and CuNPs) demonstrated activities higher than the plant extract. AgNPs from the leaf extract of *I. involucrata* displayed a zone of inhibition: *S. aureus* (11 mm), *E. coli* (14 mm), *α-H. streptococcus* (9 mm), while *α-H. streptococcus* (7 mm), *E. coli* (11 mm), and *S. aureus* (9 mm) were displayed by the MnNPs. NiNPs demonstrated 9 mm, 10 mm, and 8 mm against *E. coli*, *S. aureus*, and *α-H. streptococcus* respectively, while

9 mm, 9 mm, and 11 mm against *S. aureus*, *α-H. streptococcus*, and *E. coli,* respectively, were exhibited by CuNPs. The moderate to higher antibacterial activities of the green-synthesized IP-MNPs may be due to partially shared positive charges and electron delocalization over the biosynthesized metal nanoparticles reduced by plant extract, aggregation of the nanoparticles, and lipophilic character as demonstrated by Tweedy's chelation and Overtone's cell penetrability theories [8, 13, 15, 22, 23, 24, 32].

The improved antimicrobial properties of metal nanoparticles (IP-NPs) could also be associated with the fact that the nanoparticles enter inside the cell of the pathogens, thus, causing damage to the cell wall, and permeability, and eventually resulting in necrobiosis and obstructing the growth signaling of the bacterial [15, 30, 31, 34, 37, 54, 55]. This result validates the report of Keskin et al. [13] that the spherical-shaped nanoparticles played an important role in their antibacterial properties. The antimicrobial activity of the bioinspired silver nanoparticle at different *Chromolaena Odorata* leaf extract to Ag ion ratios, against five (5) microorganisms, showed better AgNP activities [8].

The green synthesis of CuNPs using *Hagenia abyssinica* (Brace) JF. Gmel. leaf extract demonstrated antibacterial activities against *B. subtilis, E. coli, S. aureus*, and *P. aeruginosa* with excellent inhibition zones of 14.2, 12.7, 14.7, and 12.7 mm, respectively, thus verifying the capability of g-Cu NPs as a remedy for infectious diseases [37]. The antimicrobial activities of green synthesized iron nanoparticles (FeNPs) and copper nanoparticles (CuNPs) from extracts of *Eucalyptus* leaf showed moderate to good potentials on the selected bacterial strains like *E. coli*, *P. aeruginosa*, *K. pneumoniae*, and *S. aureus* with an increase in concentration [14]. The antibacterial activities of metal nanoparticles from *I. involucrata* leaf extract show similar and comparable results to other Ipomoea species, such as *Ipomoea batatas* (48), *Ipomoea digitata* [46], *Ipomoea laxiflora* [42], and *Ipomoea hederifolia* [44].

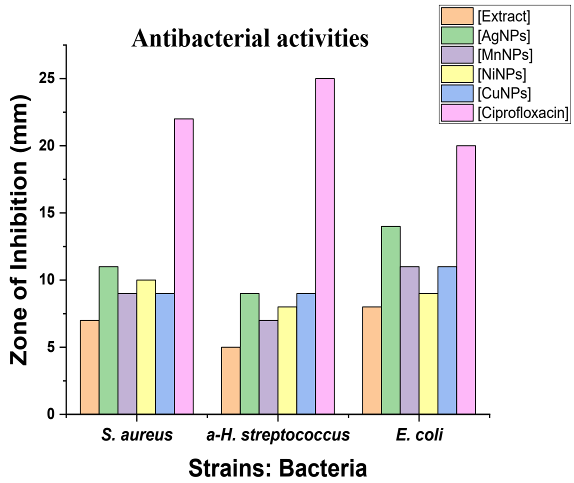

Figure 5. *Antibacterial potential of I. involucrata leaf extract and green-synthesized IP-MNPs against bacterial strains.*

3.6.2. Antifungal Activity

The antifungal activity of the bioinspired IP-MNPs was evaluated against three microorganisms: *P. cephalosporin, A. niger,* and *A. candidus,* as presented in Table 2 and Figure 6. AgNPs, NiNPs, and CuNPs all exhibited a zone of inhibition of 8 mm, 6 mm, and 7 mm against *A. niger,* respectively, while 5 mm was observed for *I. involucrata* leaf extract. Nevertheless, no inhibition zone was observed for *A. candidus,* indicating that both *I. involucrata* leaf extract and the metal nanoparticles (IP-MNPs) synthesized did not show any antifungal activity against this microorganism at the evaluated dosage. But an inhibition zone of 5 mm was communicated for AgNPs and CuNPs against *P. cephalosporin*. The green-synthesized IP-MNPs showed better antimicrobial potential toward bacterial pathogens as compared to fungal pathogens in this study; this was also corroborated by Ejidike and Clayton [15], Bamigboye et al. [23], Ejidike et al. [22], Silina et al. [55], and Ogunsile et al. [8].

Table 2. *Antimicrobial potential of I. involucrata leaf extract and green-synthesized IP-MNPs against bacteria and fungi pathogens.*

	Test Compounds (Zones of Inhibition, mm)						
Strains	**Extract**	**AgNPs**	**MnNPs**	**NiNPs**	**CuNPs**	**Ciprofloxacin**	**Fluconazole**
Bacteria							
S. aureus	7	11	9	10	9	22	-
E. coli	8	14	11	9	11	25	-
α-H. streptococcus	5	9	7	8	9	20	-
Fungi							
A. niger	5	8	-	6	7	-	22
A. candidus	-	-	-	-	-	-	15
P. cephalosporin	-	5	-	-	5	-	21

Footnotes: AgNPs = MnNPs NiNPs CuNPs

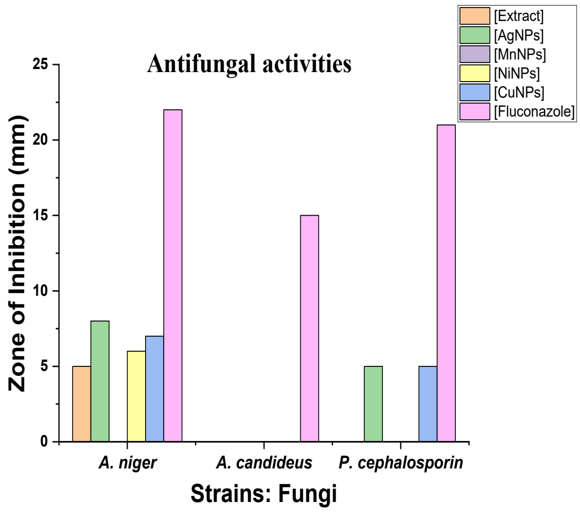

Figure 6. *Antifungal potential of I. involucrata leaf extract and green-synthesized IP-MNPs against fungal strains.*

4. CONCLUSION

A green, environmentally friendly technology and economical process were utilized in this study to demonstrate a simple approach to synthesizing metal nanoparticles such as AgNPs, MnNPs, NiNPs, and CuNPs using *Ipomoea involucrata* leaf extract as precursors.

The green synthesized IP-MNPs were confirmed by the rapid colour change and absorption in UV-vis spectra at 425 nm for AgNPs, CuNPs at 433 nm, NiNPs showed a band around 416 nm, while MnNPs showed a band at about 417 nm. The green synthesized IP-MNPs nanoparticles were characterized using UV-Vis, FT-IR, SEM, and EDX techniques. Essential biological components like terpenoids, carbonyl, proteins, carboxylic acid, saponins, ether, flavonoids, phenolic, alkaloids, steroids, and tannins present serve as effective bio-reduction and capping proxies for the metal ions. The occurrence of functional clusters was identified by FT-IR, the EDX data ascertained the presence of metal atoms in the nanoparticles, and morphology was confirmed by SEM. AgNPs, NiNPs, and CuNPs exhibited moderate antimicrobial activities against the pathogenic strains, thus indicating that the green-synthesized metal nanoparticles can be used as a potential for diverse medical and industrial applications.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. Gobinath, E., Dhatchinamoorthy, M., Saran, P., Vishnu, D., Indumathy, R., Kalaiarasi, G., “Synthesis and characterization of NiO nanoparticles using *Sesbania grandiflora* flower to evaluate cytotoxicity”, *Results Chem.*, 6 (2023) 101043.
2. Ettadili, F. E., Aghris, S., Laghrib, F., Farahi, A., Saqrane, S., Bakasse, M., Lahrich, S., El Mhammedi, M.A., “Recent advances in the nanoparticles synthesis using plant extract: Applications and future recommendations”, *J. Mol. Struct.*, 1248 (2021) 131538.
3. Montazersaheb, S., Eftekhari, A., Shafaroodi, A., Tavakoli, S., Jafari, S., Baran, A., Baran, M. F., Jafari, S., Ahmadian, E., “Green-synthesized silver nanoparticles from peel extract of pumpkin as a potent radiosensitizer against triple-negative breast cancer (TNBC)”, *Cancer Nano* 15 (2024) 47.
4. Mathur, P., Jha, S., Ramteke, S., Jain, N. K., “Pharmaceutical aspects of silver nanoparticles”, *Artif Cells Nanomed. Biotechnol.*, 46 (2018) 115–126
5. Ejidike, I. P., Ogunleye, O., Bamigboye, M. O., Ejidike, O. M., Ata, A., Eze, M. O., Clayton, H. S., Nwankwo, V. U., Fatokun, J. O., “Role of nanotechnology in medicine: Opportunities and challenges”, In: Shah, M.P., Bharadvaja, N., Kumar L. (eds). *Biogenic Nanomaterials for Environmental Sustainability: Principles, Practices, and Opportunities*. Environmental Science and Engineering. Springer, *Cham Pg.*, (2024) 353-375.
6. Shah, S., Shah, S. A., Faisal, S., Khan, A. A., Ullah, R., Ali, N., Bilal, M., “Engineering novel gold nanoparticles using *Sageretia thea* leaf extract and evaluation of their biological activities”, *J. Nanostructure Chem.*, 12 (2021) 129-140.

7. Ullah, R., Shah, S., Muhammad, Z., Shah, S., Faisal, S., Khattak, U., Haq, T., Taj-Akbar, M., "*In vitro* and *in vivo* applications of *Euphorbia wallichii* shoot extract mediated gold nanospheres", *Green Process. Synth*., 10 (2021) 101-111.
8. Ogunsile, B. O., Okoh, O. S., Ejidike, I. P., Omolaja, O. R. "Biosynthesis and optimization of AgNPs yield from *Chromolaena Odorata* leaf extract using response surface methodology (RSM)", *Phys. Chem. Res.*, 12 (2024) 21-31.
9. Do, H. T. T., Nguyen, N. P. U., Saeed, S. I., Dang, N. T., Nguyen, T. T. H., "Advances in silver nanoparticles: unraveling biological activities, mechanisms of action, and toxicity". *Appl. Nanosci*., 15 (2025) 1.
10. Ejidike, I. P., Bamigboye, O. M., Ijimdiya, R. U., Seyinde, D. O., Ojo, O. O., "Synthesis, characterization and biological evaluation of hexagonal wurtzite structured ZnO nanoparticle from Zn(II)-Schiff base complex", *Proceed. Niger. Acad. Sci.*, 13 (2020) 136-147.
11. Haleem, A., Javaid, M., Singh, R. P., Rab, S., Suman, R., "Applications of nanotechnology in medical field: a brief review", *Glob. Health J*., 7 (2023) 70-77.
12. Ejidike, I. P., Direm, A., Parlak, C., Bamigboye, M. O., Oluade, O., Adetunji, J. B., Ata, A., Eze, M. O., Hollett, J. W., Clayton, H. S., "Cadmium oxide nanoparticles from new organometallic Cd(II)-Schiff base complex and *in vitro* biological potentials: Dual *S. aureus* and *E. coli* DNA gyrase inhibition by the precursors via *in-silico* binding modes' study", *Res. on Chem. Intermed*., 50 (2024) 2763–2791.
13. Keskin, C., Ölçekçi, A., Baran, A., Baran, M. F., Eftekhari, A., Omarova, S., Khalilov, R., Aliyev, E., Sufianov, A., Beilerli, A., Gareev, I., "Green synthesis of silver nanoparticles mediated Diospyros kaki L. (Persimmon): determination of chemical composition and evaluation of their antimicrobials and anticancer activities", *Front. Chem*., 11 (2023) 1187808.
14. Adamu, S., Pindiga, N. Y., Nuhu, A. H., Ibrahim, A., Yakubu, M. S., "Green synthesis of copper and iron nanoparticles from extracts of *Eucalyptus* with their antimicrobial activities", *Science World Journal*, 19 (2024) 279-283.
15. Ejidike, I. P., Clayton, H. S., "Green synthesis of silver nanoparticles mediated by *Daucus carota* L.: antiradical, antimicrobial potentials, *in vitro* cytotoxicity against brain glioblastoma cells", *Green Chem. Lett. Rev*., 15 (2022) 297-310.
16. Olaleru, S. A., Molokwu, M. I., Mathew, S., Ejidike, I. P., Oyebamiji, O. O., "Enhanced photocatalytic degradation of methylene blue dye using TiO_2 nanoparticles obtained via chemical and green synthesis: a comparative analysis", *Pure Appl. Chem*., 97 (5) (2025). https://doi.org/10.1515/pac-2024-0326
17. Emeribe, J., Nkwoada, A., Bilar, A., Alisa, C., "Green synthesis of silver nanoparticle using *Okoubaka aubrevillei* for antimicrobial treatment", *Int. J. Nanosci. Nanotechnol*., 20 (3) (2024) 219-229.
18. Abdelghany, T. M, Al-Rajhi, A. M. H., Al Abboud, M. A., Alawlaqi, M. M., Magdah, A. G., Helmy, E. A. M., Mabrouk, A. S., "Recent advances in green synthesis of silver nanoparticles and their applications: About future directions, A review", *BioNanoSci.*, 8 (2018) 5–16.
19. Nishanthi, R., Malathi, S., Paul-S., J., Palani, P., "Green synthesis and characterization of bioinspired silver, gold and platinum nanoparticles and evaluation of their synergistic antibacterial activity after combining with different classes of antibiotics", *Mater. Sci. Eng.: C Mater. for Biol. Appl*., 96 (2019) 693-707.
20. Namburi, K. R., Kora, A. J., Chetukuri, A., Kota, V. S. M. K., "Biogenic silver nanoparticles as an antibacterial agent against bacterial leaf blight causing rice phytopathogen *Xanthomonas oryzae* pv. Oryzae", *Bioprocess Biosys. Eng*., 44 (2021) 1975–1988.
21. Al-Rajhi, A. M. H., Salem, S. S., Alharbi, A. A., Abdelghany, T. M., "Ecofriendly synthesis of silver nanoparticles using Kei-apple (*Dovyalis caffra*) fruit and their efficacy against cancer cells and clinical pathogenic microorganisms", *Arab. J. Chem*., 15 (2022) 103927.
22. Ejidike, I. P., Ijimdiya, R. U., Emmanuel-Akerele, H. A., Emmanuel, G. C., Ejidike, O. M., Bamigboye, M. O., Seyinde D. O., Olaleru, A., Tanimowo, W. O., Awolope, R. O., "Biosynthesis, characterization, and antimicrobial assessment of metal nanoparticles from *Dryopteris manniana* (HOOK.) C. Chr leaf extract", *Bull. Pharm. Sci. Assiut Univ*., 46 (2023) 225-238.
23. Bamigboye, O. M., Ejidike, I. P., Lawal, M., "Synthesis, characterization, and antimicrobial potentials of some flavonoid-metal complexes from *Chromolaena Odorata*", *Iraqi J. Sci*., 61 (2020) 2440-2447.
24. Ejidike, I. P., Fadare, D. A., Bamigboye, O. M., Ijimdiya, R. U., Lasore, I. C., Oladokun, M. S., Olajumoke, O., "Phytochemical constituents of biological prominence from medicinal plants as therapeutic agents in disease treatment", *Anchor University Journal of Science and Technology*, 2 (2022) 89-114.
25. Hamilton-Amachree, A., Fadare, D. A., Uzoekwe, N. M., Ejidike, I. P., "Phytochemicals, nutritional and antibacterial evaluation of a domestic plant - *Tetradenia riparia*", *Al-Qadisiyah Journal of Pure Science*, 29 (2024) 94-98.
26. Dimo, S. N., Obidi, O. F., Nejo, A. O., Olaleru, S. A., Ejidike, I. P., Adetona, A. J., "Biofabrication, spectroscopic, and photocatalytic studies of titania nanoparticles mediated by *Proteus mirabilis* strain NG-ABK-32 for smart applications", *Smart Sci*., 12 (2024) 373–386.

27. Vorobyova, V., Vasyliev, G., Uschapovskiy, D., Lyudmyla, K., Skiba, M., "Green synthesis, characterization of silver nanoparticals for biomedical application and environmental remediation", *J. Microbio. Methods*, 193 (2022) 106384.
28. Dimo, S. N., Obidi, O. F., Nejo, A. O., Olaleru, S. A., Ejidike, I. P., Adetona, A. J., "Preparation of nanosized TiO_2 in the presence of bacteria *Bacillus paralicheniformis* and its photocatalytic properties in the process of decolorization of dyes", *Theor. Exp. Chem*., 60 (2024) 194-201.
29. Osuntokun, J., Onwudiwe, D. C., Ebenso, E. E., "Green synthesis of ZnO nanoparticles using aqueous *Brassica oleracea* L. var. *italica* and the photocatalytic activity". *Green Chem. Lett. Rev*., 12 (2019) 444–457.
30. Beegum, S. A., David, S. B., "Investigation of antimicrobial activity of plant-mediated green synthesis of silver nanoparticles", *Int. J. Nanosci. Nanotechnol.*, 18 (4) (2022) 265-274.
31. Mosaviniya, M., Kikhavani, T., Tanzifi, M., Yaraki, M. T., Tajbakhsh, P., Lajevardi, A., "Facile green synthesis of silver nanoparticles using *Crocus Haussknechtii* bois bulb extract: Catalytic activity and antibacterial properties", *Colloids Interface Sci. Commun*., 33 (2019) 100211.
32. Andleeb, A., Andleeb, A., Asghar, S., Zaman, G., Tariq, M., Mehmood, A., Nadeem, M., Hano, C., Lorenzo, J. M., Abbasi, B. H., "A systematic review of biosynthesized metallic nanoparticles as a promising anti-cancer-strategy", *Cancers (Basel)*, 13 (2021) 2818.
33. Bruna, T., Maldonado-Bravo, F., Jara, P., Caro, N., "Silver nanoparticles and their antibacterial applications", *Int. J. Mol. Sci*., 22 (2021) 7202.
34. Lail, N. U., Sattar, A., Omer, M. O., Hafeez, M. A., Khalid, A.R., Mahmood, S., Shabbir, M. A., Ahmed, W., Aleem, M. T., Alouffi, A., Almutairi, M. M., "Biosynthesis and characterization of zinc oxide nanoparticles using *Nigella sativa* against coccidiosis in commercial poultry", *Sci. Rep*., 13 (2023) 6568.
35. Lekshmi, N. C., Sumi, S. B., Viveka, S., Jeeva, S., Brindha, J. R., "Antibacterial activity of nanoparticles from *Allium* sp", *J. Microbio. Biotech. Res*., 2 (2012) 115-119.
36. Dinga, E., Mthiyane, D. M. N., Upenyu Marume, U., Botha, T. L., Horn, S., Pieters, R., Wepener, V., Ekennia, A., Onwudiwe, D. C., "Biosynthesis of ZnO nanoparticles using *Melia azedarach* seed extract: Evaluation of the cytotoxic and antimicrobial potency", *OpenNano*, 8 (2022) 100068.
37. Murthy, H. C., Desalegn, T., Kassa, M., Abebe, B., Assefa, T., "Synthesis of green copper nanoparticles using medicinal plant *Hagenia abyssinica* (Brace) JF. Gmel. leaf extract: Antimicrobial properties", *J. Nanomater*., 2020 (2020) 3924081.
38. Jaison, J. P., Balasubramanian, B., Gangwar, J., James, N., Pappuswamy, M., Anand, A. V., Al-Dhabi, N. A., Valan Arasu, M., Liu, W. -C., Sebastian, J. K., "Green synthesis of bioinspired nanoparticles mediated from plant extracts of Asteraceae family for potential biological applications", *Antibiotics*, 12 (2023) 543.
39. Essiet, U. A., Ukpong, U. J., "Comparative phytochemical, nutrient and anti-nutrient of stems of *Ipomoea Involucrata* Beauv, *Ipomoea. Triloba* L. and *Ipomoea Batatas* Lam", Am. J. Food Nutr., 2: 71-76.
40. Okudaira, R., Kyanba, H., Ichiba, T., Toyokawa, T., "*I. Ipomoea* extracts with disaccharidase-inhibiting activities", *Jpn. J. Sanit Zool*., 17 (2005) 213–221.
41. Ogunka-Nnoka, C. U., Okolo, L. U., Uwakwe, A. A., "Ameliorative potentials of aqueous extracts of leaf and stem of *Ipomoea involucrata* on selected bio-chemicals in experimental diabetic rats", *Int. J. Basic Clin. Pharmacol*., 9 (2020) 8–15.
42. Prabhakar, Y., Kamalakar, P., "Green synthesis and characterization of silver nanoparticles from *Ipomoea laxiflora*: A comprehensive evaluation of antimicrobial efficacy", *Int. J. Herb. Med*., 12 (2024) 91-106.
43. Handayani, W., Yasman, Umar, A., Yudasari, N., "Phytotoxicity study of silver nanoparticles on the germination of water spinach (*Ipomoea aquatica* Forsk.) and mustard green (*Brassica rapa* L.) seeds", *IOP Conf. Ser.: Earth Environ. Sci*., 1201 (2023) 012080.
44. Nataraj, K., Vanishree, S., Murali, M., Amruthesh, K. N., "Bio-fabrication, characterization and biological properties of zinc oxide nanoparticles (ZnO-NPs) from scarlet morning glory- *Ipomoea hederifolia*", *Mater. Chem. Phys*., 314 (2024) 128873.
45. Pavani, K. V., K, G., Banerjee, A., Suresh, S., "Phyto-synthesis of silver nanoparticles using extracts of *Ipomoea indica* flowers", *American Journal of Nanomaterials*, 1 (2013) 5-8.
46. Varadavenkatesan, T., Selvaraj, R., Vinayagam, R., "Dye degradation and antibacterial activity of green synthesized silver nanoparticles using *Ipomoea digitata* Linn. flower extract", *Int. J. Environ. Sci. Technol*., 16 (2019) 2395-2404.
47. Bharathi, P. V., Ragavendran, C, Murugan, N, Natarajan, D., "*Ipomoea batatas* (Convolvulaceae)-mediated synthesis of silver nanoparticles for controlling mosquito vectors of *Aedes albopictus*, *Anopheles stephensi*, and *Culex quinquefasciatus* (Diptera: Culicidae)", *Artif. Cells Nanomed. Biotechnol*., 45 (2017) 1568-1580.
48. Rohaeti, E., Rakhmawati, A., "Application of silver nanoparticles synthesized by using *Ipomoea batatas* L. waste to improve antibacterial properties and hydrophobicity of polyester cloths", *Chiang Mai J. Sci*., 45 (2018) 2715-2729.

49. Wibowo, A., Tajalla, G. U. N., Marsudi, M. A., Cooper, G., Asri, L. A. T. W., Liu, F., Ardy, H., Bartolo, P. J. D. S. “Green synthesis of silver nanoparticles using extract of Cilembu sweet potatoes (*Ipomoea batatas* L var. Rancing) as potential filler for 3D printed electroactive and anti-infection scaffolds”, *Molecules*, 26 (2021) 2042.
50. Nataraj, K., Murali, M., Satish, A., Amruthesh, K. N., “Structural characterization and biological properties of novel biosynthesized zinc oxide nanoparticles from the giant potato plant *Ipomoea mauritiana* Jacq.”, *Biomass Conv. Bioref*., 15 (2025) 399-408.
51. Dudhane, A. A., Waghmode, S. R., Dama, L. B., Mhaindarkar, V. P., Sonawane, A., Katariya, S., “Synthesis and characterization of gold nanoparticles using plant extract of *Terminalia arjuna* with antibacterial activity”, *Int. J. Nanosci. Nanotechnol.*, 15 (2) (2019) 75-82.
52. Chandrasekhar, N., Vinay, S. P., “Yellow colored blooms of *Argemone mexicana* and *Turnera ulmifolia* mediated synthesis of silver nanoparticles and study of their antibacterial and antioxidant activity”, *Appl. Nanosci.*, 7 (2017) 851–861.
53. Souri, M., Hoseinpour, V., Ghaemi, N., Shakeri, A., “Procedure optimization for green synthesis of manganese dioxide nanoparticles by *Yucca gloriosa* leaf extract”, *Int. Nano. Lett*., 9 (2019) 73–81.
54. Tesfaye, M., Gonfa, Y., Tadesse, G., Temesgen, T., Periyasamy S., Green synthesis of silver nanoparticles using *Vernonia amygdalina* plant extract and its antimicrobial activities. *Heliyon*, 9 (2023) e17356.
55. Silina, E. V., Ivanova, O. S., Manturova, N. E., Medvedeva, O. A., Shevchenko, A. V., Vorsina, E. S, Achar, R. R., Parfenov, V. A., Stupin, V. A., “Antimicrobial activity of citrate-coated Cerium Oxide nanoparticles”, *Nanomaterials (Basel)*, 14 (2024) 354