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BIOSYNTHESIS, CHARACTERIZATION, AND ANTIMICROBIAL ASSESSMENT OF METAL NANOPARTICLES FROM DRYOPTERIS MANNIANA (HOOK.) C. CHR LEAF EXTRACT

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Background: *An integral part of nature is medicinal plants containing natural constituents which are vital to health. Dryopteris manniana (Hook.) C. Chr. leaves contain phytochemicals such as polyphenols and flavonoids which serve as an effective reducing agent.* ***Methods:*** *Metallic nanoparticles were synthesized by reducing salts of silver, nickel, manganese, and copper using Dryopteris manniana leaf extracts to form metal nanoparticles represented as AgNPs, NiNPs, MnNPs, and CuNPs respectively. The obtained nanoparticles were then characterized using UV-Visible Spectroscopy, Fourier-transform infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and Energy-dispersive X-ray spectroscopy (EDX). The antimicrobial activities of the nanoparticles were investigated against six microbial strains using the disk diffusion method.* ***Results:*** *The EDX result identified the metal atoms present in the metal nanoparticles formed. The SEM revealed that AgNPs have a diamond-like crystalline, CuNPs have a triangular-like structure, NiNPs have a teardrop-like structure, and MnNPs have a spherical crystalline structure. The results of the antimicrobial experiments showed that the nanoparticles have activity against all the tested bacteria but are less active against some isolated fungi. AgNPs showed zone of inhibitions: S. aureus (10 mm), α-H. streptococcus (8 mm), and E. coli (12 mm), while CuNPs exhibited 9 mm, 11 mm, and 11 mm against S. aureus, E. coli, and α-H. streptococcus respectively.* ***Conclusion:*** *This method for green metal nanoparticle synthesis may useful in nanomedicine, environmental, and industrial applications as they possess greater effectiveness and reduced toxicity, however, further investigation will be implemented.*

Keywords: *Nanoparticles, Green synthesis, Dryopteris manniana, Antimicrobial, SEM, EDX*

INTRODUCTION

Nanoparticle (NP) is one of the most attractive materials across different fields of science due to its verse application, for example, in catalysis, electronics, medicine, biotechnology, chemistry, physics, and materials science[1&2]. Among several methods that are being adopted in synthesizing NP, the green synthetic method is gaining enormous attention due to its environmental friendliness, sustainability, cost-effectiveness, and less

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toxicity compared to physical and chemical systems[3&4]. Micro-organism and different extracts of plants are one of the most explored green methods for preparing NP, however, plants extracts are cheap, and they require a less scientific approach as compared to the microorganism that needs a systematic laboratory procedure of culturing and maintaining cells, nanoparticles from plants are more stable and faster to prepare compared to that from micro-organisms[5]. The plant extracts containing different concentrations and combinations of organic compounds such as alkaloids and flavonoids act both as reducing and stabilizing agents to reduce metallic salt to metallic nanoparticles[6&7]. Metal nanoparticles (MNPs) are NP obtained from the reduction of metal salts, they have a wide range of biomedical applications which include; their use as imaging-resource, multifunctional theranostic abilities, efficient antibacterial, antifungal, and antiviral agents, antitumor, and drug carrier properties[7-10]. Metal NPs exhibit unique physicochemical properties which are a result of their size and shape relationship[11&12]. Metal NPs have been produced from several plants in the literature; nickel nanoparticle was produced from *S. foetida* aqueous leaf extract among others[13-16]. *All the bio-reduced metallic nanoparticles showed significant biological properties which are very relevant in the field of medicine.*

Dryopteris manniana (Hook.) C. Chr. belonging to the family Dryopteridaceae is a specie of fern plant found mostly as undergrowth of moist and riverine forests, especially along streams. It is found in most regions of Africa and Madagascar, hence, it is referred to as the Flora of Tropical East Africa and Flora of West Tropical Africa, with great medicinal benefits such as secondary metabolites like phenolic compounds that have protective or disease preventive properties[17]. The plant possess fronds are tufted, arching, 4-7 per plant, to 1 m long, mostly unbranched, to 8 mm in diameter, herbaceous with proliferating buds on the rhachis near the apex of the frond. Studies have shown that *Dryopteris manniana* (Hook.) C. Chr. can be found in Lagos State, South West region of Nigeria[18]. In this work, *Dryopteris manniana* (Hook.) C. Chr. was used to produce nanoparticles of Ag, Ni, Mn, and Cu.

From the ancient past, Ag salt have be known to control the growth of bacteria in dental work, burns, wounds and catheters, they are found to be highly toxic to microorganisms[19]. Salts of Ni and Mn metals have been shown to have antimicrobial activities due to improving lipophilic properties[20-23]. The characteristic antimicrobial properties of nickel metal may be due to its potential to penetrate microbial cells and destroy the microorganism by inactivating their enzymes[24&25]. The redox cycling reactions between Cu(II) and Cu(I) oxidation states of copper which often result in the formation of reactive radical species (ROS) are responsible for its antimicrobial properties. Under a limited supply of oxygen, ROS produce free hydroxyl radicals that react within the cell resulting in the damage of bacterial DNA[26].

Thus, it will be of medical advantage to explore the antimicrobial properties of green synthesis metal nanoparticles of Ag, Mn, Ni, and Cu using the plant extracts of *Dryopteris manniana* (Hook.) C. Chr. We assumed that the combination of the metal and plant extract should show significant microbial properties. The metal nanoparticles were characterized using different spectroscopic methods: UV-Visible, Fourier-transform infrared spectroscopy (FTIR), Energy-dispersive X-ray spectroscopy (EDX), and Scanning Electron Microscopy (SEM). The antimicrobial activity of the nanoparticles was investigated against six microbial strains using the disk diffusion method.

MATERIALS AND METHOD

Materials and Plant collection

$AgNO_3$, $NiCl_2.6H_2O$, $MnCl_2.4H_2O$, $CuSO_4.5H_2O$ of analytical grade. Leaves of *Dryopteris manniana* (Family: Dryopteridaceae) were collected around June/ July 2020 within the school premises of Anchor University (6.6040° N, 3.2419° E), Lagos Nigeria. The plant samples were taxonomically identified and authenticated by Dr. Olasupo Ilori (Assoc. Prof.) from the Department of Biological Sciences, Anchor University, Lagos. The leaves were washed under running water and dried at room temperature for 20 days. The dried leave material was pulverized using a Macasalab mill (model 200 Lab), to a fine powder and stored in an air-tight container until the time of extraction. Strains of *Escherichia coli, Staphylococcus aureus, α-hemolytic streptococcus, Aspergillus candideus, Aspergillus niger,* and *penicillium cephalosporin* were collected from the Department of Microbiology, Anchor University, Lagos, Nigeria.

Preparation of *Dryopteris Manniana* powder extract

50 g of cleaned *D. Manniana* (dried leaf powder) was introduced into a 1000 ml round bottom flask already containing 600 ml of distilled water. The mixture was placed on a heating mantle at 50 ℃ for 1 hr and allowed to stir. Thereafter, the plant extract was left to cool and then filtered three times using Whatman filter paper to achieve pure aqueous extract. The plant extract was kept in a refrigerator at 4 ℃ for future studies.

Synthesis of metal nanoparticles (AgNPs, CuNPs, MgNPs, NiNPs)

200 ml of *D. manniana* leaf extract was added to a clean 500 ml bottom flask and 50 ml of 0.1 M $NiCl_2.6H_20$ was added to synthesize NiNPs. Following this, the resulting solution was heated at 70 ℃ for 1 hr. The collected precipitate was allowed to cool and stirred overnight, followed by three-time washing and centrifugation at 4000 rpm for 25 min. After washing, the sample was dried at 100 ℃ in an oven. The NiNPs particle formed were characterized using different spectroscopic methods. The colour changed from greenish-brown to darkish-brown. A similar procedure was used for the synthesis of other metal nanoparticles.

Characterization of synthesized metal nanoparticles

The bio-reduced metal nanoparticles were subjected to various characterization techniques. The optical properties of the nanoparticles were analyzed by a UV-Vis spectrophotometer (Thermo Scientific GENESYS^{TM} UV-Vis Spectrophotometer). Agilent Cary 630 FTIR spectrometer was used to determine the functional groups in the plant extract and the synthesized metal nanoparticles. Scanning Electronic Microscope (SEM), JSM-7900F, JEOL USA was used for identifying the morphology and size of the nanoparticles. SEM was coupled with the EDX technique which identified the elemental composition of synthesized nanoparticles and also estimated their relative abundance.

Antibacterial activity

The antibacterial activity of the synthesized NPs was evaluated on different strains of bacteria: *Escherichia coli, Staphylococcus aureus,* and *α-hemolytic streptococcus* using the disk-diffusion agar method. 25 µg/mL of the synthesized nanoparticles were prepared in an aqueous solution and continuously stirred in a water bath to ensure uniform dispersion. 50 ml of molten nutrient agar was added in sterile Petri dishes, and each strain was swabbed uniformly using an inoculating loop, the prepared green-synthesized NPs were placed in the inoculated plates at six peripheral positions and incubated for 24 hrs at 37 ℃. After the incubation, a clear zone was formed around the disks. The diameter of the inhibition zones was measured using a meter rule.

Antifungal activity

Antifungal activity of the synthesized NPs was evaluated on fungi species *Aspergillus candideus*, *Aspergillus niger*, and *Penicillium cephalosporin* by using the disk-diffusion agar method. 25 µg/ml of the green-synthesized NPs were prepared in an aqueous solution and continuously stirred in a water bath for uniform dispersion. A total of 30 ml of molten Potato Dextrose agar (PDA) was added in sterile Petri dishes, and each inoculum was swabbed in a zigzag and thorough motion on the individual plates. The disks suspended in each green-synthesized NPs prepared were placed in the inoculated plates at six peripheral positions and incubated for 24 hrs at 25 ℃. Thereafter, a clear zone was formed around the disks. The diameter of the inhibition zones was measured using a meter rule.

RESULTS AND DISCUSSION

Phytochemical studies

The following phytochemical; terpenoids, phenolic, alkaloid, flavonoid, steroids, saponins, and tannins were detected in the crude extract of *D. manniana* as shown in Table 1. The result corroborates the results of Makanyane *et al.*[13] who showed that the leaf extract of *Sterculia foetida* contains several phytochemical constituents.

Table 1: Qualitative phytochemical contents of *D. manniana* leaf extract.

Phytochemicals	*D. manniana* leaf extract
Phenolic	+
Alkaloids	+
Steroids	+
Anthraquinones	-
Saponins	+
Anthocyanosides	-
Tannins	+
Terpenoids	+
Flavonoids	+
Glycosides	-

Key of distribution: + = present - = Absent

UV-Vis analysis

UV-vis spectroscopy is an important technique for the initial characterization of nanoparticles. The absorption spectra of metal nanoparticles showed various bands as shown in Figure 1. The absorption maxima peak at about 300 nm demonstrated that the plant leaf extracts contain biological Phyto-molecules such as alkaloids, flavonoids, steroids, and saponins which have been shown to absorb UV light in this region due to the presence of carbonyl group[27]. The spectrum of AgNPs showed bands at 422 and 670 nm, NiNPs showed bands at 433 and 654 nm, CuNPs at 427 and 537 nm, and MnNPs exhibited bands at 781 nm. These bands were 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. Chandrasekhar and Vinay[28] reported a UV-vis band at 428 nm for silver nanoparticle synthesized from *C. tomentosum*, characteristic surface plasmon band at 565 nm due to Cu colloids formation of non‐ oxidized CuNPs was observed by Chung *et al.*[16].

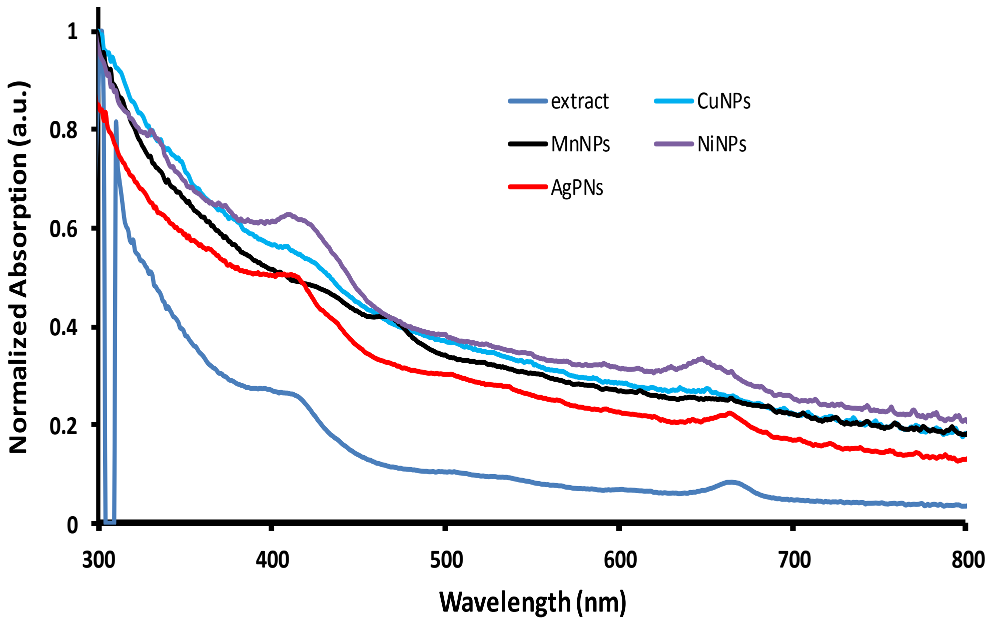

Fig. 1: UV-Vis spectra of DM-MNPs synthesized from D. *manniana* (Hook.) C. Chr leaf extract.

Fourier-transform infrared spectroscopy (FTIR)

The FTIR was used to obtain significant information on the functional groups present in the extract of *D. manniana* and their corresponding nanoparticles. The spectrum of the *D. manniana* extract (Figure 2) showed a very strong broad peak around 3355 cm^{-1} which can be attributed to O-H vibration from polyphenols, alkaloids, and flavonoid[29], weak peaks around 2985 cm^{-1} to 2993 cm^{-1} were due to CH_2/CH_3 symmetric and asymmetric vibrations, C=C stretch was observed at 1559 and 1533 cm^{-1}, C-C stretch was observed at 1251 cm^{-1} and the peaks around 1038 to 1016 cm^{-1} were identified as C-O aliphatic alkanes. In the spectrum of AgNPs (Figure 2), O-H vibrations were observed at 3305 cm^{-1}, the decrease in O-H wave number concerning that of the plant extract confirms the interaction between the Ag ion and bioactive component of *D. manniana* leaf extract. CH_2/CH_3 symmetric and asymmetric vibrations at 2913 and 2847 cm^{-1} were very strong, and a peak signifying C=O was observed at 1729 cm^{-1} which described the donation of electrons from the carbonyl group of the plant extract to the metal center. Peaks reflecting C=C related functional group at 1530 cm^{-1} were observed, C-C stretch was observed at 1237 cm^{-1} and a peak was observed at 541 cm^{-1} showing that AgNPs were successfully formed.

CuNPs exhibited O-H vibration at 3292 cm^{-1} (Figure 2), and CH_2/CH_3 symmetric and asymmetric vibrations were observed at 2914 and 2846 cm^{-1}, at 1726 cm^{-1} C=O peak was visible. C=C str. were observed at 1563 cm^{-1}, C-C stretch was observed at 1373 cm^{-1} and a peak was observed at 565 cm^{-1} showing that CuNPs were formed. In the MnNPs spectrum (Figure 2), O-H vibration was seen at 3276 cm^{-1}, at 2915 and 2847 cm^{-1}, CH_2/CH_3 symmetric and asymmetric vibrations were observed, C=O peak at 1730 cm^{-1} denotes the donation of an electron from the carbonyl group to the metal. C=C str. were seen at 1583 cm^{-1}, C-C stretch was observed at 1238 cm^{-1} and a peak was visible at 529 cm^{-1} showing that MnNPs were formed. NiNPs exhibited O-H vibration at 3317 cm^{-1} (Figure 2), and CH_2/CH_3 symmetric and asymmetric vibrations were observed at 2914 and 2847 cm^{-1}, and at 1730 cm^{-1} C=O peak was visible. C=C str. were observed at 1538 cm^{-1}, C-C stretch was observed at 1400 cm^{-1} and a peak was observed at 522 cm^{-1} showing that NiNPs were formed. The presence of different functional groups such as; carbonyl, OH, and C=C in the green synthesized metal nanoparticles (AgNPs, NiNPs, CuNPs, and MnNPs) corroborate other reports who also identify similar functional groups in their biosynthesized metal complexes[10&11&16].

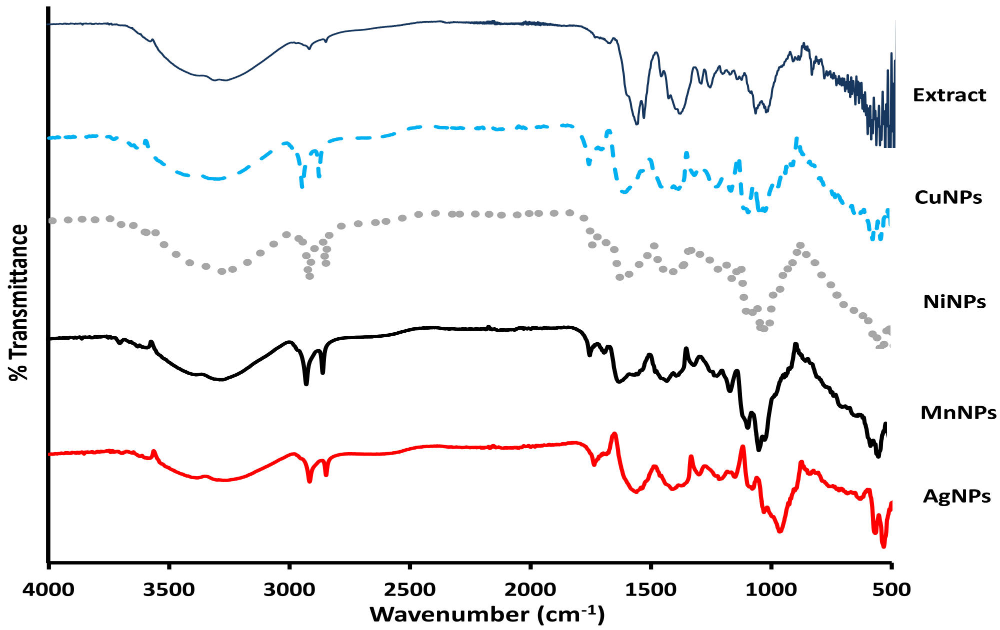

Fig. 2: FTIR spectra of the green-synthesized DM-MNPs and *D. manniana* (Hook.) C. Chr leaf extract.

Scanning Electron Microscopy (SEM) studies

SEM was used for identifying the morphology of the nanoparticles. Figure 3 shows the SEM image of the green-synthesized *D. Manniana* metal nanoparticles (DM-MNPs). The SEM image in Figure 3a revealed that AgNPs have diamond-like crystalline morphology, CuNPs (Figure3b) are triangular-like, NiNPs (Figure 3c) have a teardrop-like structure, and MnNPs (Figure 3d) have a spherical crystalline structure. The SEM image further showed that the synthesized AgNPs were uniformly distributed, CuNPs were packed, NiNPs were closely packed and MnNPs were uniformly dispersed. The size and shape of a green synthesized metal nanoparticle depend on the concentration of precursor metal salts and the reducing agent from the biomolecule. The optimum concentrations of both precursors are essential to forming the desired size and shape of nanoparticles.

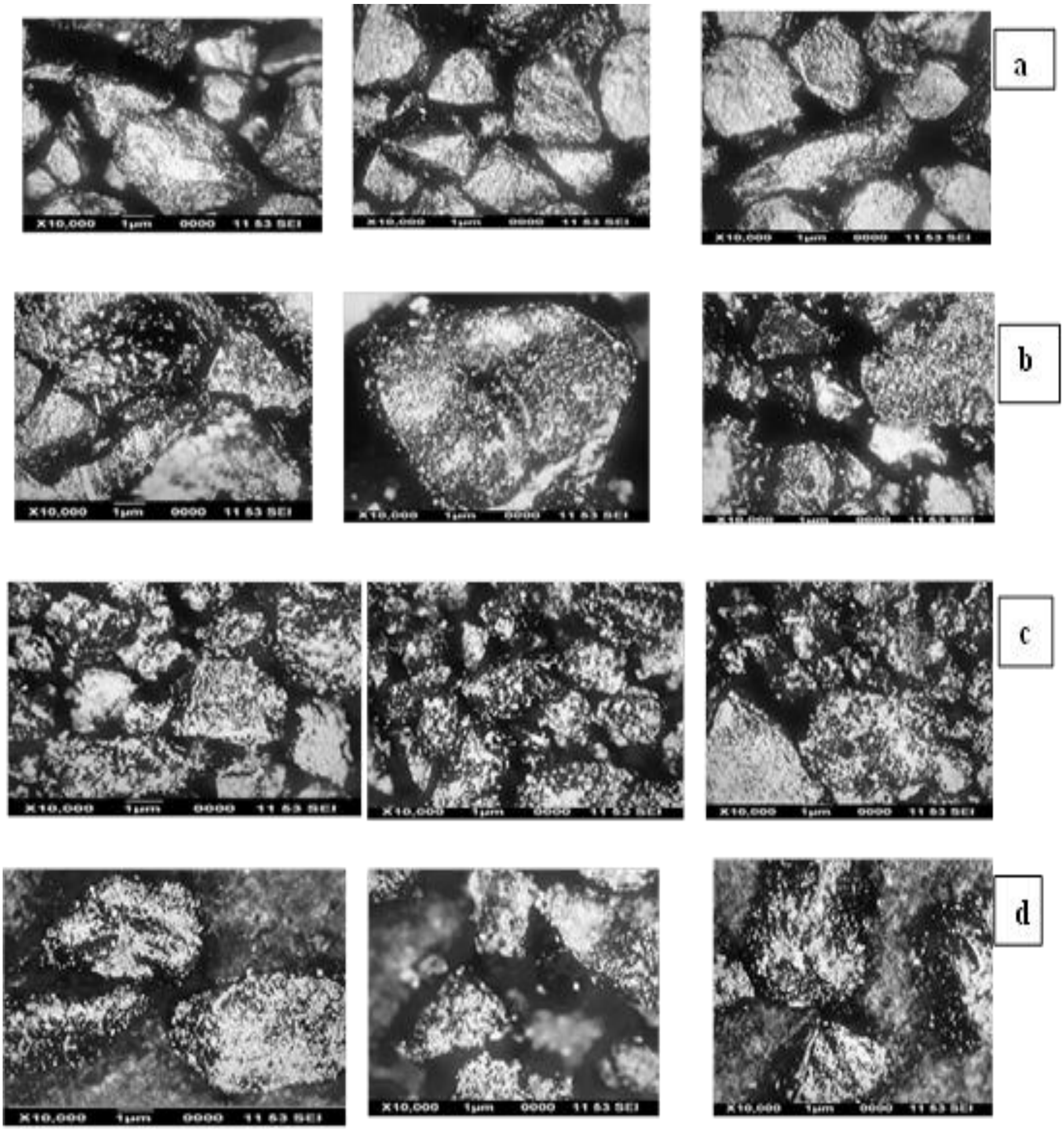

Fig. 3: Scanning Electronic Microscope (SEM) of (a) AgNPs (b) CuNPs (c) MnNPs (d) NiNPs.

The size of the synthesized nanoparticles (AgNPs, NiNPs, CuNPs, and MnNPs) was large, this may be due to too varying concentrations of different reducing agents (flavonoid and alkaloid) present in the bulk leaf extract that bound to the surface of the formed nuclei, this increases the secondary reduction of the respective metal salt on the surface of the nuclei which will consequently lead to the increased growth rate of the NPs, thus forming a large size NPs[7&30]. In addition, many reducing agents may affect the formed NPs, leading to the aggregation of NPs this might be a result of too many metal ions absorbed on the surface of preformed nuclei, where the secondary reduction process occurred[31]. Similarly, the shapes of the formed metal NPs are also affected by the concentrations of metal salt and extract concentration. Several reports have shown that the same metal nanoparticle formed from different plant extracts with varying concentrations shows different shapes. Rani *et al*.[13] reported nickel nanoparticles formed from *Sterculia foetida* leaf extract showed a spherical shape, and the leaf extract of *Euphorbia hirta* generated spherical silver nanoparticles[32]. Vijayaraghavan *et al*.[33] showed that various triangular silver nanoparticles were obtained from *Trachyspermum ammi* extract.

Energy-dispersive X-ray spectroscopy (EDX) analysis

The EDX analysis was performed to verify the chemical composition of the green-synthesized MNPs. Figure 4 displays the EDX pattern and EDX mapping, respectively, and these results validated the successful green synthesis of the NPs using biological molecules of leaf extract of *D. manniana*. The presence of Ag atoms in the synthesized AgNPs was validated by its EDX peaks at 20.45 keV and 22.95 keV. The element Cu in CuNPs was seen by its peaks at 20.52 keV and 22.95 keV. The peaks at 20.17 keV and 22.73 keV indicated the presence of Ni in NiNPs and also the peaks at 20.44 keV and 22.68 keV identified Mn present in MnNPs. In addition to the metal peaks of the green synthesized DM-MNPs EDX peaks, the peaks corresponding to carbon (C) and oxygen (O) also clearly appeared in the spectrum, which corroborated the adsorption of biological molecules on the NPs surface from the plant extract. Hence, it is apparent from the EDX results that the green syntheses of the respective nanoparticles from the plant leaf extracts were successful.

Antibacterial activity

The antibacterial potential of green-synthesized DM-MNPs was assessed following the disk-diffusion method against three bacteria species in comparison to plant extract as shown in Table 2 and Figure 5. The metal nanoparticles (NiNPs, MnNPs, CuNPs, and AgNPs) had activities a bit higher than the plant extract. AgNPs from the leaf extract of *D. manniana* showed a zone of inhibitions: *S. aureus* (10 mm), *α-H. streptococcus* (8 mm), *E. coli* (12 mm), and of CuNPs exhibited 9 mm, 11 mm, and 11 mm against *S. aureus*, *E. coli*, and *α-H. streptococcus* respectively. *S. aureus* (8 mm), *α-H. streptococcus* (7 mm), *and E. coli* (9 mm) were observed for the MnMPs and NiNPs exhibited 9 mm, 11 mm, and 7 mm against *S. aureus*, *E. coli*, and *α-H. streptococcus* respectively. The higher antibacterial activities usually recorded for Schiff base metal complexes are due to chelating behaviour upon complexation of the metal as a result of partially shared positive charges and electron delocalization over the metal complex into the ligand, this trend was not observed in the biosynthesized metal nanoparticles reduced by plant extract[21-23]. The moderate antibacterial activities of the green synthesized metal nanoparticle when compared to the crude plant extract may be due to aggregation of the nanoparticle. This result corroborates the report of Norouzi *et al*.[34] who showed that aggregation of nanodiamond nanoparticles played an important role in its antibacterial properties. The green synthesized metal nanoparticles from crude plant extract is a preliminary research work that gives evidence that there could be higher and better antibacterial activities of metal nanoparticles supposed the plant extract has been isolated and the reduction was done using a specific phytomolecule[7&10].

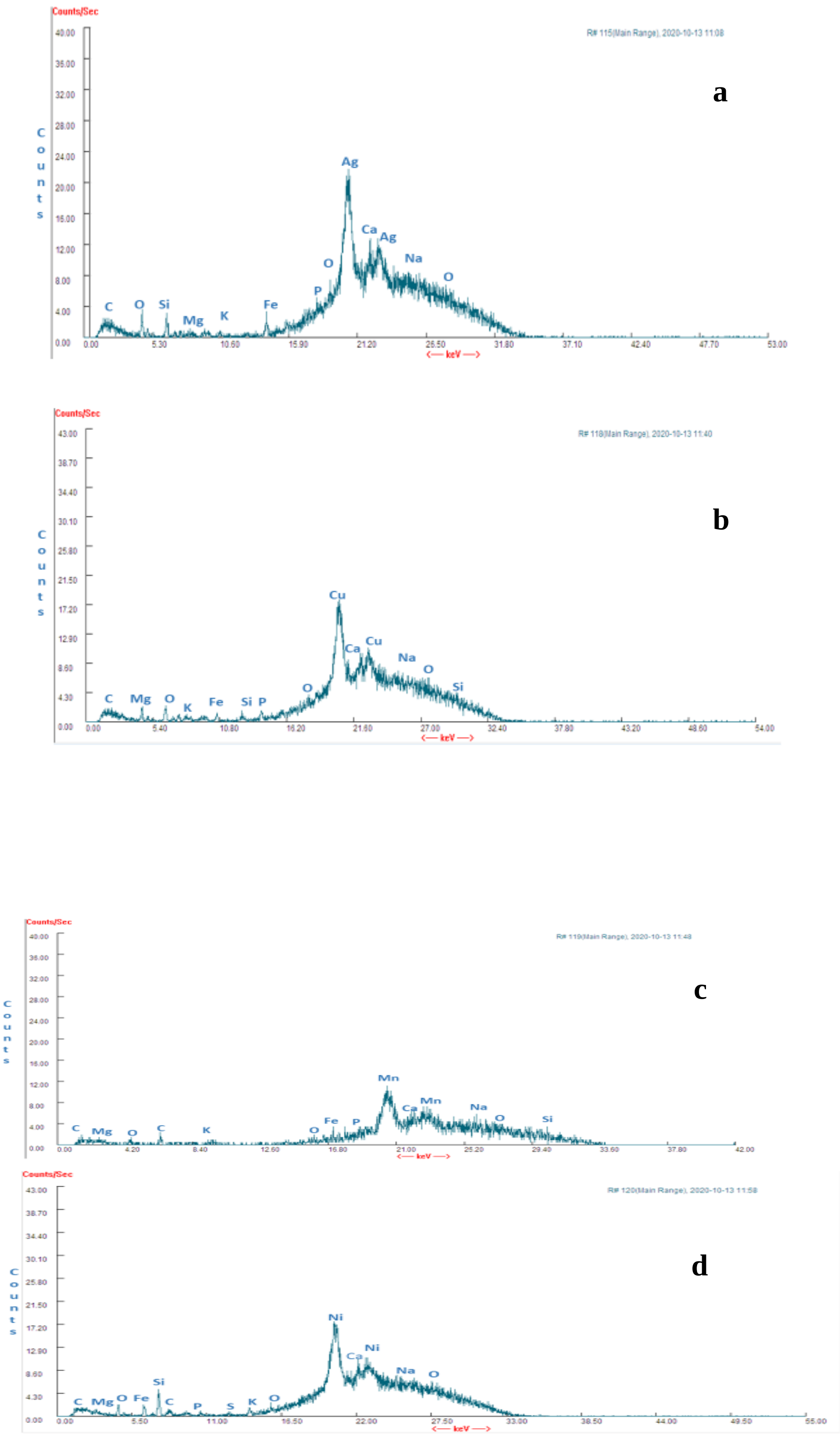

Fig. 4: EDX spectrum of (a) AgNPs (b) CuNPs (c) MnNPs (d) NiNPs.

Table 2: Antimicrobial potential of *D. manniana* leaf extract and green-synthesized DM-MNPs against bacteria and fungi pathogens.

	Test Compounds (Zones of Inhibition, mm)						
Strains	**Extract**	**AgNPs**	**CuNPs**	**MnNPs**	**NiNPs**	**Ciprofloxacin**	**Fluconazole**
			Bacteria				
S. aureus	**7**	**10**	**9**	**8**	**9**	**22**	**-**
E. coli	**6**	**12**	**11**	**9**	**11**	**25**	**-**
α-H. streptococcus	**5**	**8**	**11**	**7**	**7**	**20**	**-**
			Fungi				
A. niger	**5**	**7**	**-**	**7**	**7**	**-**	**22**
A. candideus	**-**	**-**	**-**	**-**	**-**	**-**	**15**
P. cephalosporin	**-**	**-**	**-**	**-**	**-**	**-**	**21**

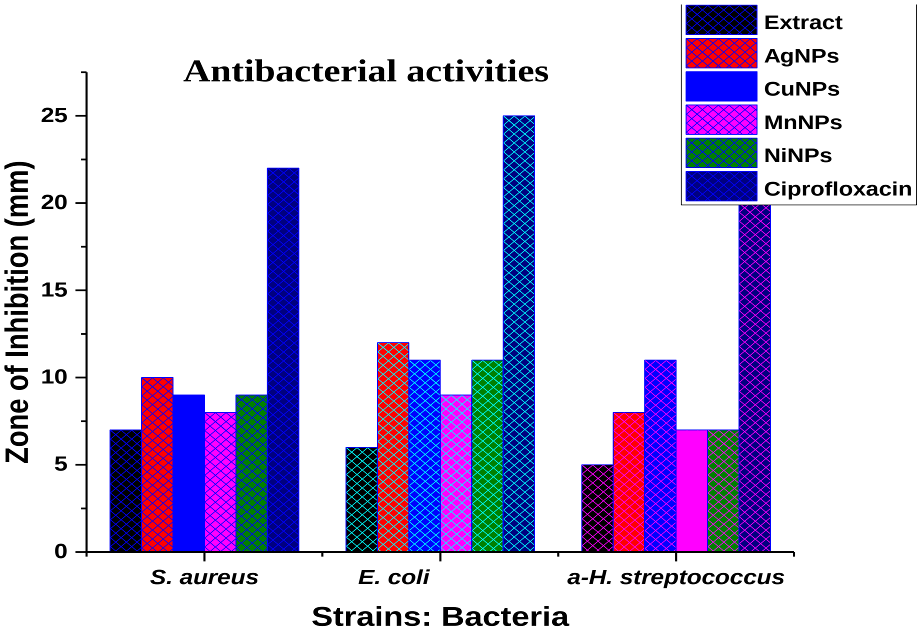

Fig. 5: Antimicrobial activity of extract and green-synthesized DM-MNPs against various pathogenic bacteria strains.

Antifungal activity

The antifungal activity was observed against three microorganisms; *P. cephalosporin, A. niger,* and *A. candideus* as shown in Table 2 and Figure 6. AgNPs, MnNPs, and NiNPs all showed a zone of inhibition of 7 mm against *A. niger*, while 5 mm was observed for the *D. manniana* extract. However, an inhibition zone was not observed for *P. corypholium* and *A. candideus* indicating that both *Dryopteris manniana* leaf extract and the metal nanoparticles synthesized did not show antifungal activity against these microorganisms at the tested dosage. AgNPs, MnNPs, and NiNPs made an impact on *A. niger* same as the plant extract but CuNPs showed no effect. The green-synthesized DM-MNPs showed greater antimicrobial potential toward bacteria pathogens as compared to fungi pathogens under this study, this was also corroborated by Ogunsile *et al.*[10], and Ejidike and Clayton[7].

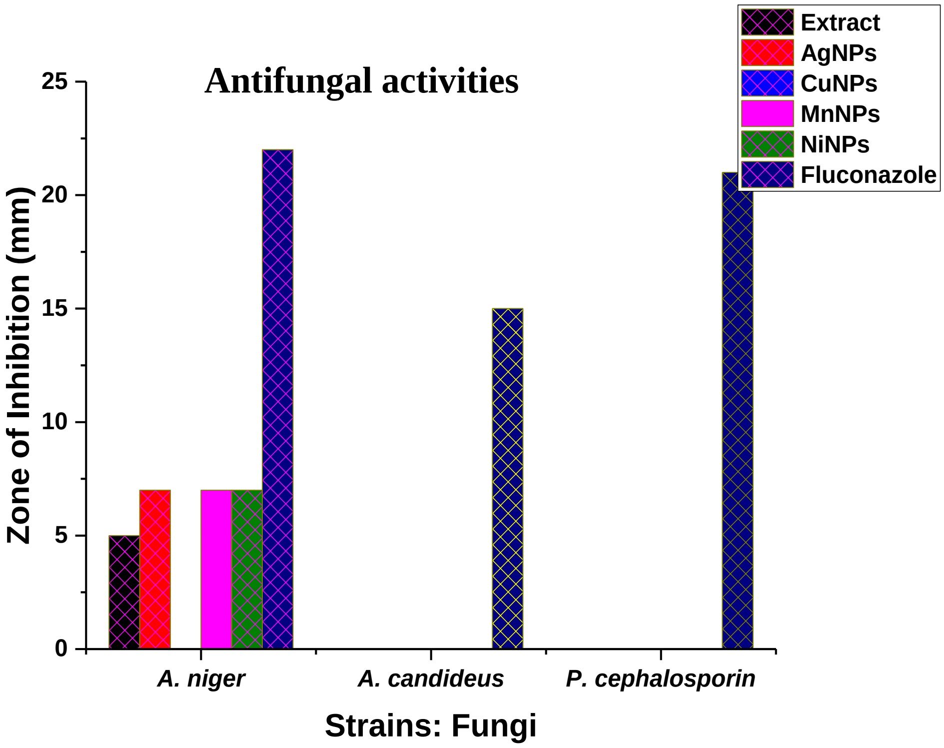

Fig. 6: Antifungal activity of extract and green-synthesized DM-MNPs against various pathogenic fungi strains.

Conclusion

The study demonstrated a simple approach to the synthesis of metal nanoparticles such as AgNPs, CuNPs, MnNPs, and NiNPs using *Dryopteris manniana* leaf extracts. The approach is green, eco-friendly, and economical. The green synthesized MNPs were confirmed by the rapid colour change of plant extracts and characterized using, UV-Vis, FT-IR, SEM, and EDX techniques. terpenoid, phenolic, alkaloid, flavonoid, steroids, saponins, and tannins present in the *D. manniana* leaf extracts serve as an effective reducing agents. FTIR confirmed the respective functional groups, the EDX result identified the metal atoms present in the metal nanoparticles formed while their morphology was confirmed by SEM. AgNP, CuNP, and NiNP exhibited moderate antimicrobial activities against the strain of bacteria cultures which indicated that the green synthesized metal nanoparticles can be used potentially for different medical applications.

Acknowledgments

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Conflict of Interest

The authors declare no potential conflict of interest in this study.

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التخليق الحيوى و التعرف و التقييم كمضاد للميكروبات لجسيمات نانوية معدنية من مستخلص أوراق نبات دريوبتريس مانيانا (هوك) س. كر

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خلفية مرجعية: تعتبر النباتات الطبية التي تحتوي على مكونات طبيعية حيوية للصحة جزء لا يتجــزأ من الطبيعة. تحتوى أوراق نبات دريوبتريس مانيانا (هوك) س. كر.على مواد كيميائية نباتيــة مثــل البوليفينول والفلافونويدات التي تعمل كعامل اختزال فعال.

طرق العمل: تم تصنيع الجسيمات النانوية المعدنية عن طريق اختزال أملاح الفضة والنيكل والمنغنيــز والنحاس باستخدام مستخلصات أوراق دريوبتريس مانيانا لتشكيل جزيئات نانوية معدنية ممثلــة فــي AgNPsو NiNPs و MnNPs و CuNPs على التوالي. بعد ذلك تم التعرف و توصيف الجسيمات النانوية التي تم الحصول عليها باستخدام التحليل الطيفي للأشعة فوق البنفسجية و المرئية، والتحليـل الطيفــي للأشعة تحت الحمراء (FTIR) ، والفحص المجهري الإلكتروني (SEM) ، والتحليـل الطيفــي للأشــعة السينية المشتت للطاقة .(EDX) تم فحص الأنشطة المضادة للميكروبات للجسيمات النانوية ضــد ســتة سلالات ميكروبية باستخدام طريقة الانتشار القرصي.

النتائج: حددت نتيجة EDX ذرات المعدن الموجودة في الجسيمات النانوية المعدنية المتكونــة. كشــف الفحص المجهري الإلكتروني SEM أن AgNPs لها هيكل بلوري شبيه بالماس ، وأن CuNPs لها هيكــل يشبه المثلث ، و NiNPs لها هيكل يشبه الدمعة ، وأن MnNPs لها هيكل بلوري كروي. أظهرت نتــائج تجارب مضادات الميكروبات أن للجسيمات النانوية نشاطًا ضد جميع البكتيريا المختبرة ولكنهــا أقــل نشاطًا ضد بعض الفطريات المعزولة. و أظهرت AgNPs تثبيط لنمو البكتيريا S. aureus بقدر ١٠ مم ، α-H. العقدية (٨ مم) ، والإشريكية القولونية (١٢ مم) ، بينما أظهرت CuNPs 9 مم و ١١ مم و ١١ مم ضد بكتريا S. aureus و E. coli و α-H. العقدية على التوالي.

الخلاصة: قد تكون هذه الطريقة لتخليق الجسيمات النانوية المعدنية الخضراء مفيدة في الطب النـــانوي والتطبيقات البيئية والصناعية لأنها تمتلك فعالية أكبرو سمية أقل ومع ذلك تحتاج هذه الدراسة لمزيد من البحث و التحقيق.