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Comparative Study of Green Synthesis of Silver Nanoparticles Using Leaf Extracts of *Vitellaria Paradoxa* and Their Antioxidant Activities

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Abstract

The synthesis of nanoparticles from plant extracts has gained much attention in recent times. The objective of this work is to assess and contrast the antibacterial and antioxidant properties of silver nanoparticles mediated from Vitellaria paradoxa and its crude methanolic extracts against several enteric microbes. Silver nanoparticles synthesized with *Vitellaria paradoxa* (VPAgNP) and methanol extracts of *Vitellaria paradoxa* (MVP) were characterized using Ultraviolet-Visible Spectrometry, Fourier transform infrared spectroscopy, X-ray diffraction spectroscopy, energy-dispersive spectroscopy and scanning electron microscopy. Antioxidant assays were carried out on both samples. The assessment of the antibacterial activity of both synthesized and methanol extracts of *Vitellaria paradoxa* was determined using disc diffusion method varied at different concentration. The minimum inhibitory concentration and minimum bactericidal concentration was also determined. Data were analyzed by one-way analysis of variance and the difference ($\rho \leq 0.05$) separated by Duncan multiple range test.

The UV-visible spectrum of VPAgNP and MVP revealed peak at 450 nm and 420 nm respectively. The FTIR spectra of VPAgNP and MVP revealed the presence of 18 and 9 peaks values and their functional group respectively. The extracts and VPAgNPs produced

higher inhibition zones ranges between 8-45 mm against the isolated pathogenic organisms compared to the methanol extract while the MICs ranged from 0.1-5.0 µg/mL for extracts and VPAgNPs.
The study concluded that the silver nanoparticles synthesized using *V .paradoxa* has exhibited higher antibacterial activity against pathogenic organisms as compared to the methanol extract and could be used in future for therapeutic and pharmacological purposes in treating ailment or diseases caused by multidrug resistance.
Keywords: AgNPs, antioxidant, *Vitellaria paradoxa*, Methanol extract, Nanoparticles

INTRODUCTION

Many populations relied heavily on medicinal plants for their health care. According to the World Health Organization, a significant proportion of the global population, over 80%, predominantly utilizes traditional medicines as their primary means of addressing basic healthcare needs. (Prakash, 2015). Plants that possess therapeutic potential or exhibit pharmacological activities when used by humans are known as medicinal plants. They are also recognized as the backbone of phytomedicine, which focuses on treatment, prevention, and maintenance of health (Hasan et al., 2012) The practice of alternative medicine is globally spread and growing progressively, but is dominant in some areas located within Africa, China, India, Japan, Pakistan, Sri Lanka, Thailand, and Korea (Jima & Megersa, 2018). It has been reported that 60-80% of countries in the developing world depend on phytomedicine. However, in some of these areas, modern medicine is available but alternate medicines (phytomedicines) have always been preferred for ancient and cultural purposes. According to Singh (2015), over three million people in underdeveloped countries regularly make use of medicinal plants.

Despite the fact that we currently have a lot of novel drugs, it is still imperative to discover and advance model therapeutic agents. Studies show that tolerable therapy is only available for one third of human ailments. Due to this, the struggle against diseases must be carried on continuously. Phytomedicines still play an important role in the modern-day drug industries due to the synergistic characteristics of the combination of bioactive phytochemicals present in them (Ege et al., 2021).

Over the past few years, interest and application of using nanotechnology for medicine delivery has increased. (Pelaz et al., 2017). Numerous nanoparticles (NPs) with the appropriate physicochemical properties and biological functionalities have been created utilizing different polymers, lipids, inorganic substances, or their mixtures for the treatment of various diseases (Zhang et al., 2017) such as cancer (Shi et al., 2017), diabetes (Mo et al., 2014) and central nervous system (CNS) disorders (Srikanth & Kessle 2012).

Pharmaceutical firms exhibit reluctance in increasing their investments in natural product-based drug discovery and drug delivery systems, despite the presence of several potential (Beutler et al., 2009). and instead navigate through existing chemical compound databases to find new medications. Currently, there is ongoing research to investigate the potential therapeutic applications of natural substances in the treatment of various severe medical conditions, such as malignancy, cardiovascular conditions, diabetes, inflammatory disorders, and bacterial infections. The primary contributing factor to the prominence of natural medicines lies in their unique advantages, including less toxicity and side effects, affordability, and robust therapeutic efficacy. Nevertheless, a considerable number of natural chemicals are proving to be unsuccessful in progressing through the various stages of clinical testing. (Watkins et al., 2015). Significant challenges are encountered when employing materials on a large scale for drug delivery, encompassing issues such as in vivo instability, limited bioavailability and solubility, inadequate absorption inside the body, challenges in achieving target-specific distribution, compromised therapeutic efficacy, and potential adverse pharmacological effects. Hence, the use of novel drug delivery methods for targeted drug administration to specific anatomical regions presents a potential solution to mitigate these urgent challenges. (Jahangirian et al., 2017) However, nanotechnology is important in refined medicine and therapeutic formulations for fighting infections.

The advantages of employing plants for nanoparticle synthesis are that they are readily available and safe to handle, and they contain a wide range of active compounds that can enhance the reduction of silver ions. The majority of plant parts, such as the leaves, the roots, the latex substances, the bark, stem, and seeds, are used in the production of nanoparticles (Mustapha et al., 2022).

The most significant aspect is the active agent present in these components, which allows for reduction and stability. Ecofriendly plant extracts are composed of biomolecules that provide dual functionality as both reducing and capping agents, enabling the formation of stable nanoparticles with regulated shape. The reduction and capping of nanoparticles are primarily influenced by many biomolecules, including phenolics, terpenoids, complex sugars, flavones, alkaloid substances, enzymes, protein molecules, amino acids, and alcoholic substances. (Mustapha et al., 2022)

The African plant *Vitellaria paradoxa* is highly regarded as a source of medicine and is becoming increasingly popular among rural residents who use it to treat illnesses and infections. It has been proven that various *V. paradoxa* components can be used to cure various illnesses. For instance, the decoction of seed oil is used in Nigeria to treat cough and tuberculosis (Ariyo et al., 2020), while the bark decoction is used for the treatment of diarrhoea and hypertension in Benin (Lagnika et al., 2016). *Vitellaria paradoxa* have been known to possess bioactive compounds that have attracted attention in medicinal plant research, this compounds are reported to possess several pharmacological potentials such as antimicrobial, anti-inflammatory, anticancer, antioxidant, anti-proliferative, antimalarial and antifungal potentials. Phytochemically, different parts of *V. paradoxa* have been reported as source of flavonoids and phenolic compounds, highly rich in triterpenoids and many more (Mbiantcha et al. 2011). However this study is to determine the antibacterial and antioxidant activities of silver nanoparticles mediated from the leaves of *Vitellaria paradoxa*, extracts on some enteric organisms isolated from patients' stool samples in Babcock University Teaching Hospital.

MATERIAL AND METHOD

Preparation of Plant Sample

Fresh leaves of *V. paradoxa* were collected from Ijagbo, Kwara State, Nigeria, in the month of May 2021. The leaves were subjected to an air-drying process at room temperature for a duration of three weeks until a stable weight was achieved. Following this, the leaves were ground into a coarse form using a sterile mortar and pestle. The plant leaves, which had previously undergone the drying process, were subsequently pulverized and refined into a fine powder utilizing a Waring blender (Aina et al., 2019). Subsequently, the blended sample of the dried leaves was placed in an airtight container for future utilization.

Extract Preparation

Hundred grams of blended leaves of *V .paradoxa* were weighed into 500 ml of methanol. The samples were then placed in shaker incubator for 72hrs. The macerated samples were sieved with Whatman filter paper No.1, and was allowed to evaporate to a concentrate using an oven under reduced pressure at 40°C. The concentrated samples were carefully weighed and subsequently transferred into sterile sample bottles. These bottles were then maintained in a refrigerated environment to facilitate additional investigations (Jesumirhewe et al., 2021).

Synthesis of Silver Nanoparticle

Analytical grade silver nitrate ($AgNO_3$) was collected from the Microbiological Laboratory, Babcock University, Ilishan Remo, and Ogun State, Nigeria. Five milliliters (5ml) of freshly prepared methanol extract of *V .paradoxa* were added to 45ml of 10mM of silver nitrate solution separately and it was left till a color changed was observed. The reduction of $AgNO_3$ to Ag^+ ions was confirmed by the changed in colour from light brown to dark brown. In order to ascertain that the biosynthesized nanoparticles were mediated by the presence of the bioactive compounds in the leaf extract, a control experiment was set up containing silver nitrate and sterile distilled water. When the color changed from yellow to dark brown and finally to black, this is an indication that nanoparticles have been synthesized. The solution was centrifuged at 10,000 rpm in a centrifuge machine (JEOL, JEM-200EX; Tokyo, Japan) and the supernatant was washed with distilled water, filtered, dried at 40^0C and stored for further analysis (Silambarasan et al., 2021).

Characterization of biosynthesized AgNPs using *Vitellaria paradoxa*

Several methods such as UV-VIS spectroscopy, scanning electron microscopy (SEM), energy-dispersive X-ray (EDX) analysis, X-ray powder diffraction (XRD) analysis, and Fourier transform infrared spectroscopy (FT-IR) were used to characterize the physical, chemical, and morphological properties of the produced silver nanoparticles (AgNPs) according to the method of Varadavenkatesan et al, (2021).

SEM and EDX analyses of the biosynthesized sliver nanoparticles (AgNPs)

SEM analysis was performed on a JEOL-JSM-5400, Japan, SEM running at 30 kV to assess the surface morphology and structure of the leaf extract and the nanoparticle mediated by it. A very small volume of each sample was applied to a carbon-coated copper grid in order to spread uniform films of each sample. Two drops of the sample was placed on the grip and excess liquid was removed with the aid of blotting paper and subsequently, the films that had been formed on the SEM machine grid were subjected to a drying process by exposure to a mercury lamp for duration of 5 minutes. Following the capture of SEM pictures, photomicrographs were obtained at various magnifications, and the AgNPs were passed through an EDX detector to evaluate the elemental composition of silver nanoparticles attached to the SEM machine, as described by Patra et al., (2018).

Antioxidant Assay of the nanoparticles and *V. paradoxa* methanol extract

DPPH radical Scavenging activity assay

The DPPH free radical scavenging activity was assessed using the methodology outlined by Liyana et al. (2005). Briefly, 1 ml of 0.135mM 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH) in methanol was combined with 1.0 ml of silver nanoparticles and V. paradoxa methanol extract, BHT and ascorbic acid were used at doses ranging from 0.025 to 0.5 mg/ml. The reaction mixture was vigorously mixed using a vortex mixer and thereafter incubated in a dark environment at ambient temperature for a duration of 30 minutes. The measurement of absorbance for the mixture was conducted using a spectrophotometer at a wavelength of 517 nm. The observed reduction in absorbance was compared to that of the reference. The experiments and analyses were conducted in triplicate. The calculation of the scavenging potential of *V. paradoxa* was performed using the following equation:

DPPH scavenging activity of Abs control - Abs sample = Abs control x 100

Ferric reducing antioxidant power (FRAP)

The Ferric reducing antioxidant power assay was determined using the method of Benzie & Devaki (2018) with little modification. The FRAP reagent was prepared by mixing 100 mL of acetate buffer at 30 mM, 10 mL of 10 mM TPTZ [2,4,6-tripyridyl-s-triazine] in 40 mM HCL, and 10 mL of $FeCl_3.6H_2O$ at 20 mM. Next, a volume of 3 ml of the recently prepared FRAP solution was properly added to 100 ml of the crude extract. After 30 min at 37°C, the ferric tripyridyl triazine (Fe3+ TPTZ) complex reduced to ferrous (Fe2+) and formed a blue complex. The absorbance at 593 nm was recorded. For calibration, freshly prepared stock solutions of $FeSO_4$ were used. All determinations were done in triplicates and are expressed as Gallic acid equivalents (GAE) in mg per gram dry weight

Total antioxidant capacity (TAC)
The total antioxidant capacity (TAC) of the extracts and nanoparticles was determined by the method described by Aliyu et al., (2021) with slight modification. In brief, 3 ml of reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate) was mixed with 0.3 ml each of the methanol extract and the synthesized nanoparticles. The test tubes containing the already prepared solution were incubated for 90 min at 95^{o}C. Then, the absorbance of the solution was determined at 695 nm with the aid of a UV-VIS spectrophotometer. Ethanol was used as a blank. Total antioxidant capacity was expressed as Gallic acid equivalents (GAE) in milligrams per gram dry weight**.** All determinants were carried out in triplicates.

Determination of Total Phenolic Content
The Folin-Ciocalteu method, as described by Zhang et al. (2023), was employed to assess the total phenolic content (TPC) of the sample. In test tubes, 1 mL of the methanol extract and the produced nanoparticle was dispensed and evenly mixed with 1 mL of FC reagent (first diluted 6-fold with water), then mixed with 2 mL of 20% (w/v) sodium carbonate. The absorbance of the mixture was measured at 765nm utilizing a spectrophotometer UV-VIS (jascov-530) after 30 minutes in the dark. The standard used was gallic acid. The assay was performed in triplicate and the results were expressed as milligrams of Gallic acid per gram of the dried extract.

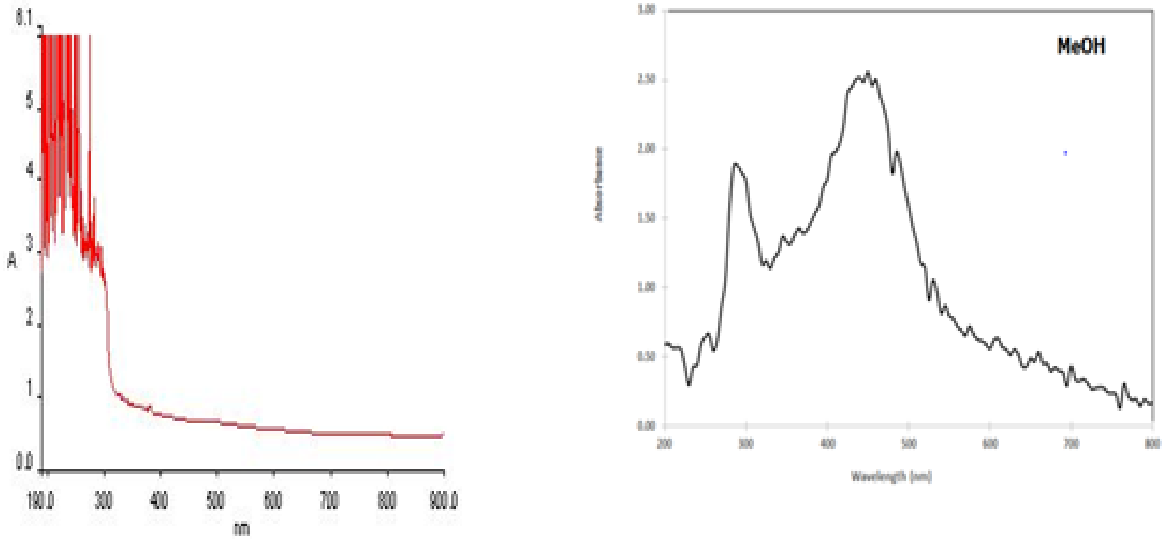
Determination of total flavonoid content
The quantitative determination of the total flavonoid concentration in the crude extract was conducted using an aluminum chloride colorimetric assay. Briefly, 2.8mL of double distilled water was mixed with 1 ml of the crude extract and 0.1mL of a 1 mg/mL potassium acetate solution. 10% of aluminum chloride was added to the solution (0.1mL). According to Hajrawati et al. 2021, the mixture was left to stand for 30 min and the absorbance was measured at 415 nm with a Shimadzu UV-visible spectrophotometer. The result of total flavonoid content was expressed as Gallic acid equivalents (GAE) in milligrams per gram of dry weight. Gallic acid was used as standard and all determinants were done in triplicates.

Antibacterial Activity of both the methanol extract and synthesized silver nanoparticles
The antibacterial activity of the methanol extract and synthesized nanoparticles was measured using agar well-diffusion, and this was used to evaluate the potency of the synthesized silver nanoparticles (VPAgNPs) mediated from *V. paradoxa* extract- and methanol extract against identified clinical strains. A day old culture of each isolate cultivated in peptone broth was standardized, inoculated on Mueller Hinton agar plate and were allowed to diffuse well into the agar plates. The holes on the inoculated plate were made using a sterile cork borer with a diameter of 6 mm, these holes were then labeled as 50 µg/ml and 100 µg/ml, respectively. The resulting holes were then filled with 100 µl of different concentrations from the synthesized VPAgNP, methanol extract (MPV), silver nitrate (positive control) and water (negative control). The zone of inhibition was measured and recorded after 18-24 h of incubation at 37oC of the plates.

Statistical Analysis
Data were analyzed using SPSS version 23.0 (Corporation, Chicago, IL) and reported as mean± standard deviation of three replicates. P < 0.05 was considered significant.

Results
The synthesized nanoparticles using *V. paradoxa* change its colour from colourless to light brown. This colour change indicated the formation of Ag nanoparticles as shown in Figure 1. The Ultraviolet-Visible spectrometry spectra of methanol extract of *V.paradoxa* (MVP) and synthesized silver nanoparticles *V. paradoxa* (VPAgNP) is depicted in figure 2. The UV-visible spectrophotometry analysis of nanoparticles revealed that the nanoparticles exhibited their highest level of absorption at a wavelength of 320 nm. Figure 3 **showed the SEM of both** methanol extract of *V. paradoxa* (MVP) and synthesized silver nanoparticles of *V. paradoxa* (VPAgNP). Spherical shape of the AgNPs were discovered through the utilization of field emission scanning electron microscopy (SEM) (Fig. 3). The average diameter of the nanoparticles was observed to be 50 nm, as depicted in Figure 3.

Figure 1: Colour change formation of *V. paradoxa* synthesized silver nanoparticles



A B

Figure 2: Ultraviolet-Visible Spectrometry spectra of methanol Extract of *V.paradoxa* (MVP) and synthesized silver nanoparticles *V. paradoxa* (VPAgNP)

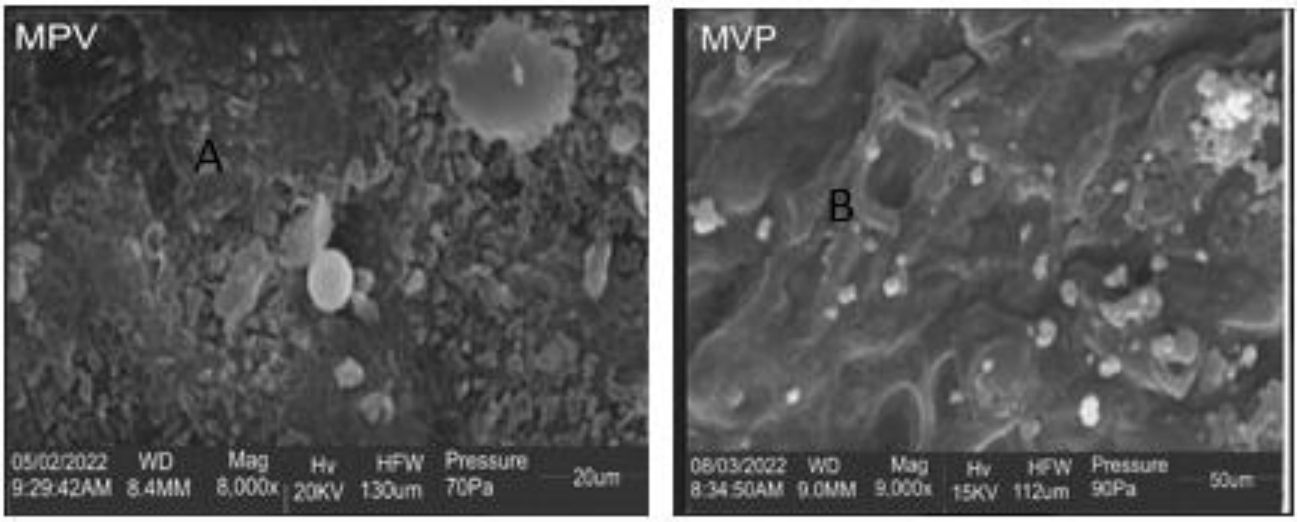


Figure 3: SEM of both methanol extract of *V. paradoxa* (MVP) and synthesized silver nanoparticles of *V. paradoxa* (VPAgNP)

Figure 4 showed the Energy-dispersive spectroscopy (EDS) spectra of synthesized *V. paradoxa* (VPAgNP) and Methanol extract of *V. paradosa* (MPV). The elemental composition in the synthesized nanoparticles revealed nine elements including silver (67.35wt %) while eight elements were revealed in the methanol extract with silver having 48.68 wt%. as shown in figure 4. The X-Ray Diffraction spectrum of synthesized *V. paradoxa* (VPAgNP) and Methanol extract of *V. paradosa* (MPV) is shown in figure 5. Figure 6 showed the Fourier Transforms Infrared spectrum of synthesized *V. paradoxa* (VPAgNP) and Methanol extract of *V. paradoxa* (MPV). The (FTIR) spectrum provided information regarding the identification of functional groups and their corresponding peak intensities.

The antioxidant activity (DPPH, FRAP, TAC, TFC and TPC) of both the synthesized and methanol extract of *V. paradoxa* is shown in figure 7-10.

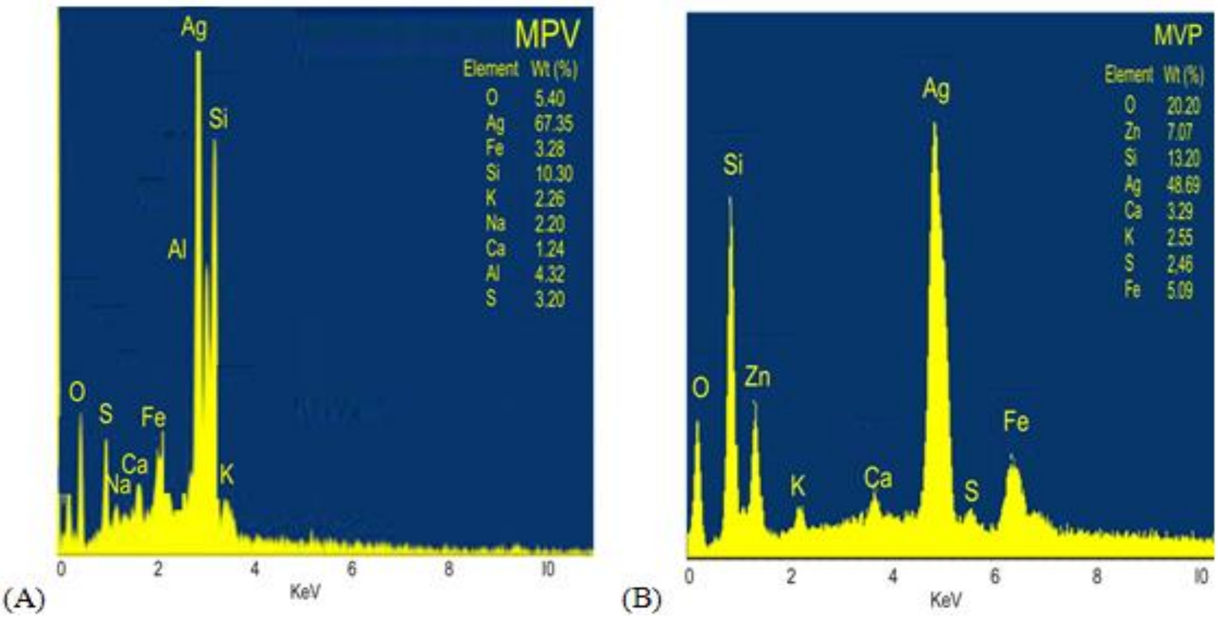


Figure 4: Energy-dispersive spectroscopy (EDS) spectra of (A) synthesized *V. paradoxa* (VPAgNP) and (B) Methanol extract of *V. paradosa* (MPV)

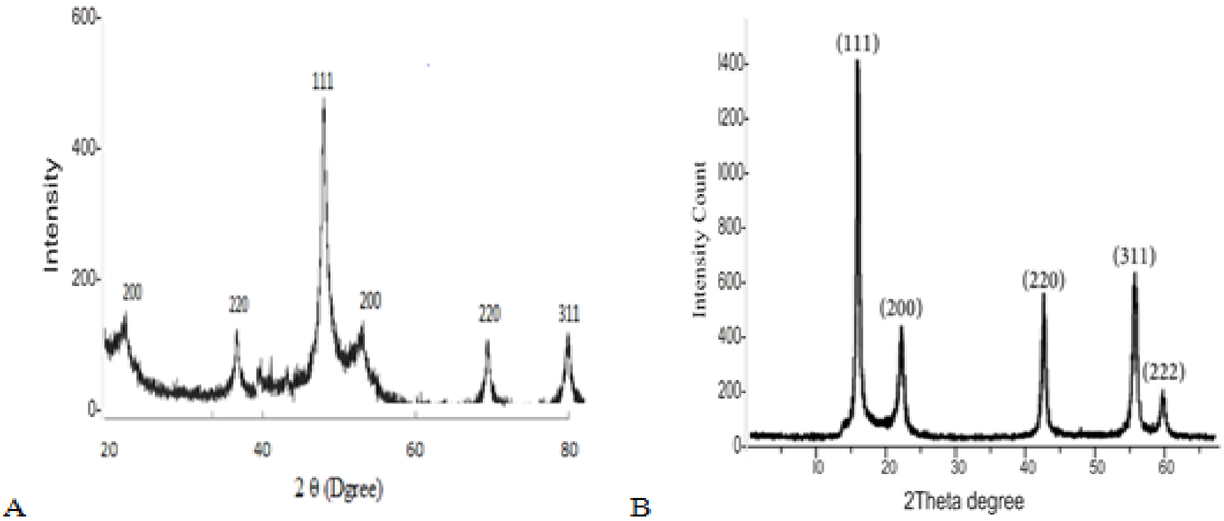


Figure 5: X-Ray Diffraction spectrum of (A) synthesized *V. paradoxa* (VPAgNP) and (B) Methanol extract of *V. paradosa* (MPV)

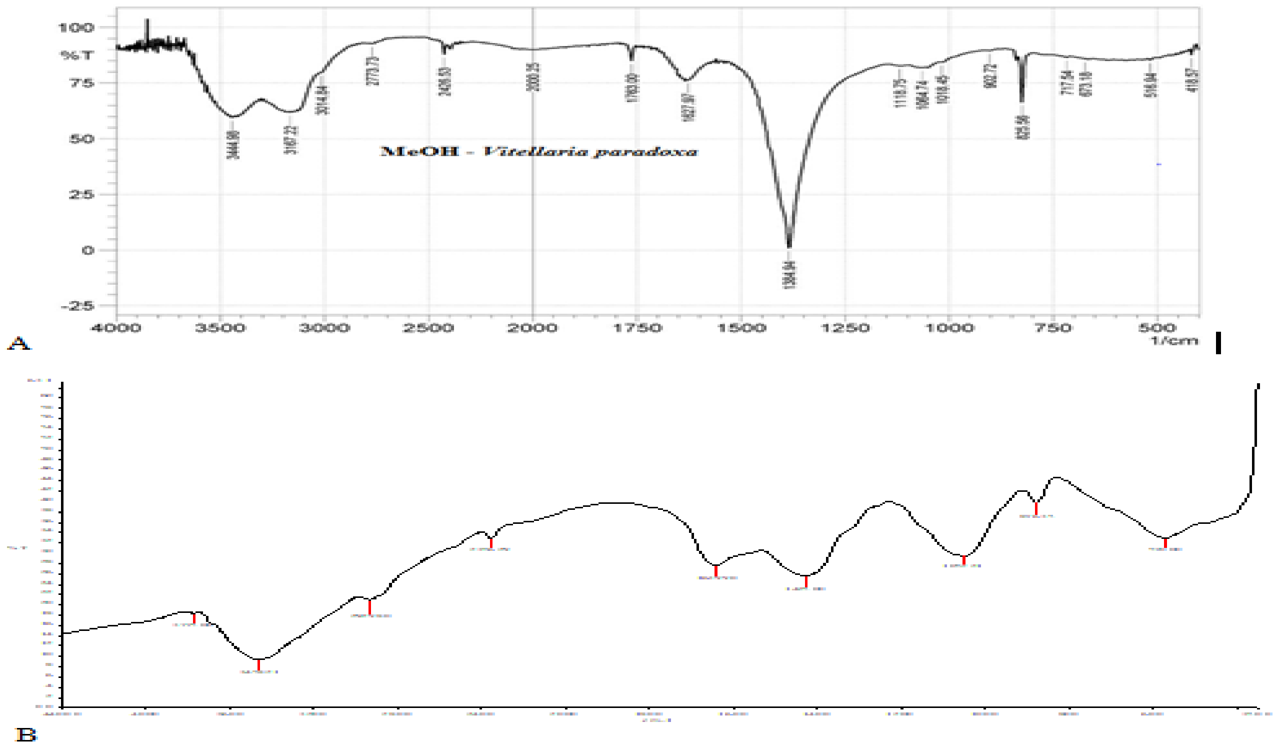


Figure 6: Fourier Transforms Infrared Spectroscopy of (A) synthesized *V. paradoxa* (VPAgNP) and (B) Methanol extract of *V. paradosa* (MPV)

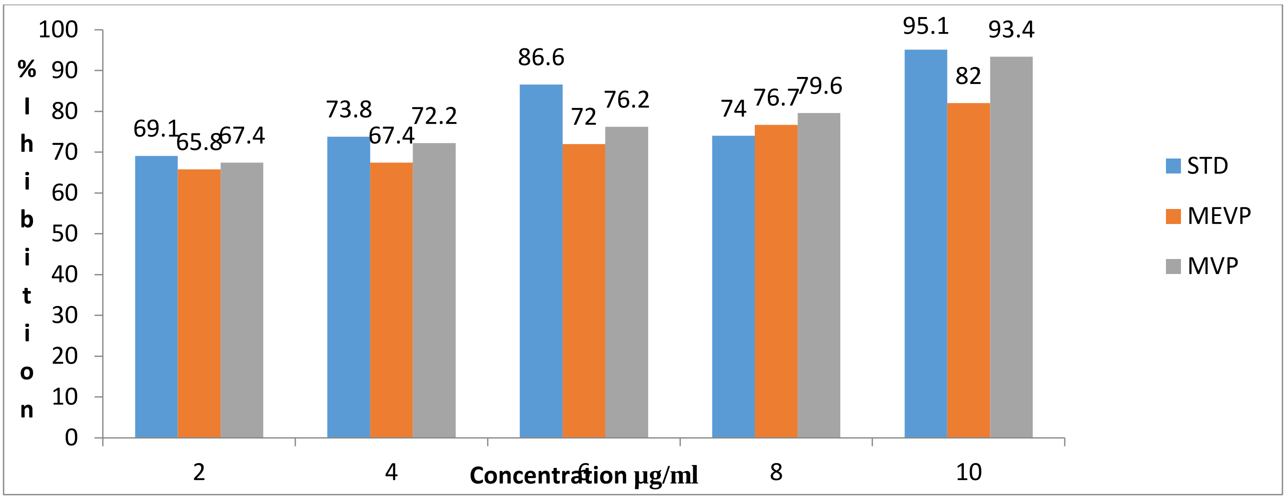


Figure 7: 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH) of synthesized *V. paradoxa* and Methanol extract of *V. paradosa*

Key- STD- standard, MEVP- synthesized *V. paradoxa*. MVP- Methanol extract of *V. paradosa*

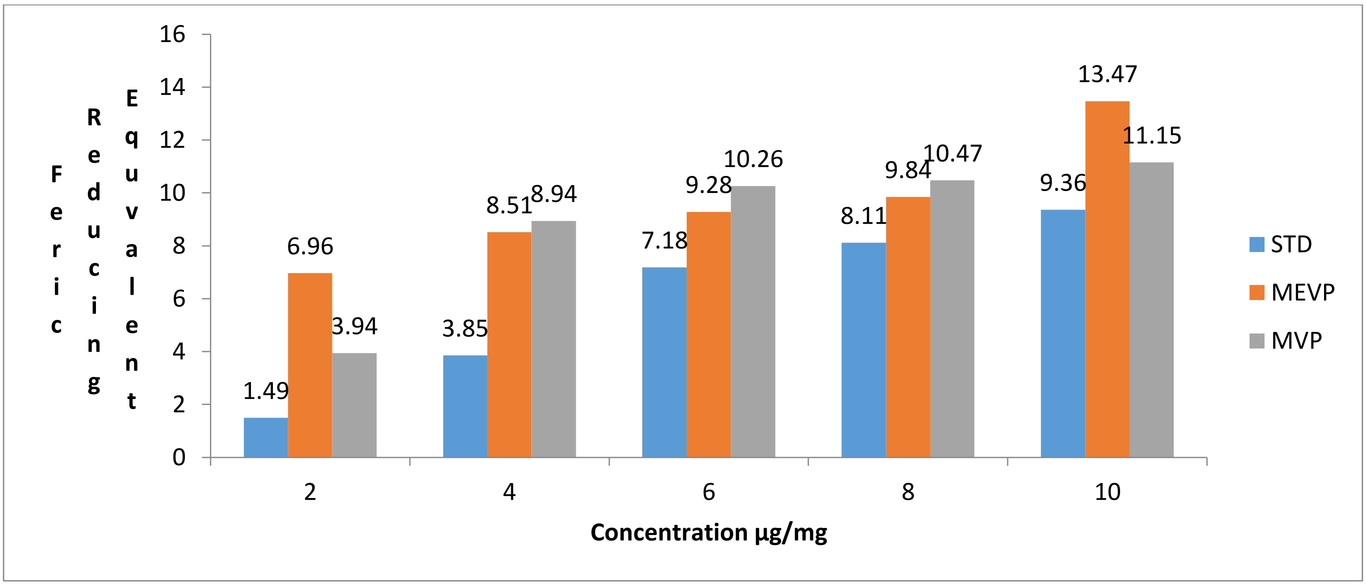


Figure 8: Ferric reducing antioxidant power (FRAP) of synthesized *V. paradoxa* and Methanol extract of *V. paradosa*

Key- STD- standard, MEVP- synthesized *V. paradoxa*. MVP- Methanol extract of *V. paradosa*

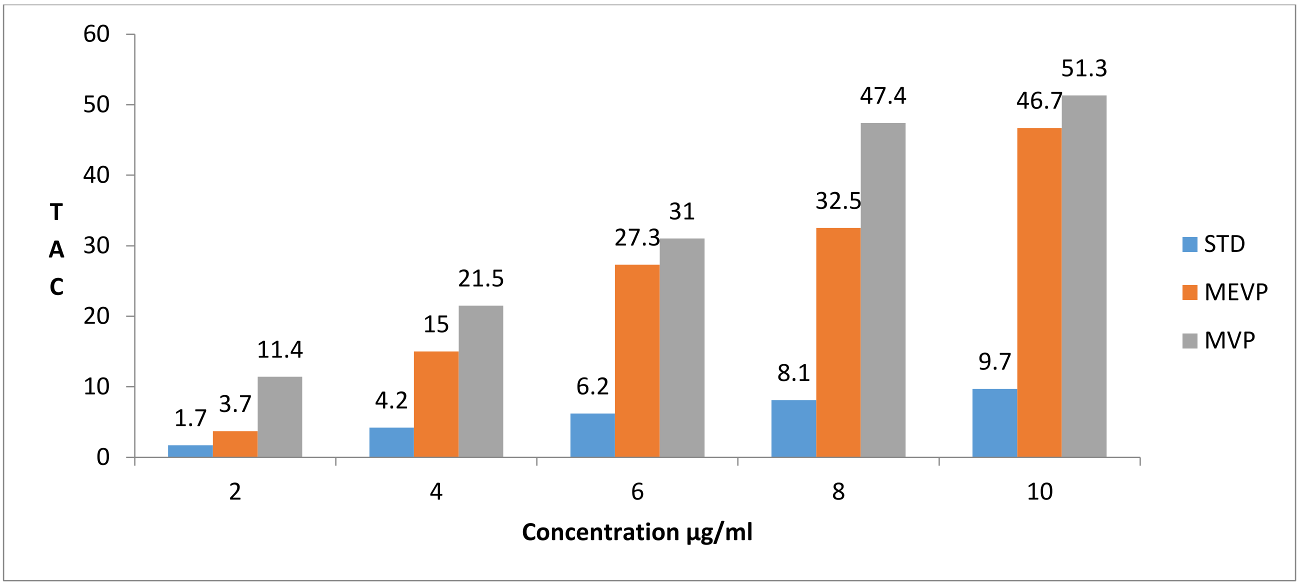
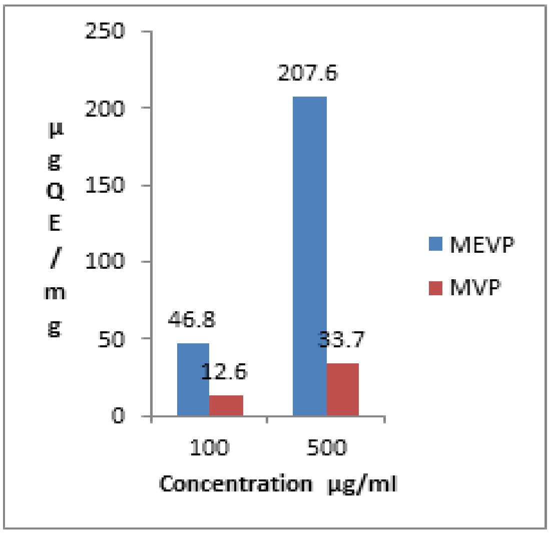


Figure 9: Total Antioxidant Capacity (TAC) of synthesized *V. paradoxa* and Methanol extract of *V. paradosa*

Key- STD- Standard, MEVP- synthesized *V. paradoxa*. MVP- Methanol extract of *V. paradosa*

a) 

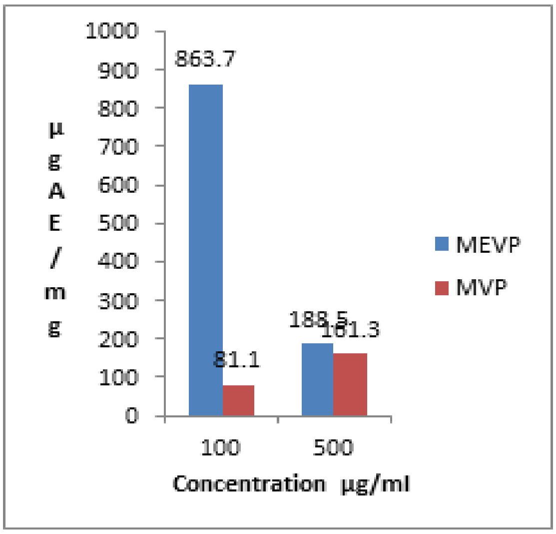
b) 

Figure 10: The total flavonoid content (TFC) and Total Phenolic Content (TPC) of synthesized *V. paradoxa* and Methanol extract of *V. paradoxa*

Key- MEVP- synthesized *V. paradoxa*. MVP- Methanol extract of *V. paradosa*

Antibacterial activities of the synthesized silver *V. paradoxa* and Methanol extract of *V. paradoxa* is depicted in table 1. The synthesized nanoparticles showed more and higher activities when compared to the methanolic extract of *V. paradoxa*. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) is shown in table 1.

Table 1: Antibacterial activities of the synthesized silver *V. paradoxa* and Methanol extract of *V. paradoxa*

Name of Organisms	VP-AgNP		MVP		MIC		MBC	
	100mg/ ml	**50mg/ml**	**100mg/ml**	**50mg/ml**	**VP-AgNP** (mg/ml)	**MVP** (mg/ml)	**VP-AgNP** (mg/ml)	**MVP** (mg/m l)
Proteus mirabilis	45mm	18mm	0	0	0.625	2.5	1.25	5.0
Klebsiella pneumoniae	17mm	40mm	0	0	0.625	5.0	1.25	10
Pseudomonas aeruginosa	20mm	11mm	0	18mm	0.625	5.0	2.5	10
Serratia marcescens	30mm	24mm	0	25mm	1.25	5.0	2.5	10
Pseudomonas aeruginosa	27mm	45mm	8mm	0	0.625	5.0	1.25	5.0

Discussion

Silver nanoparticles are quite well known as among the most universal antimicrobial compounds owing to their powerful bactericidal impact against pathogens, they have been used for years to prevent and manage different ailments (Ma et al., 2012). Silver nanoparticles that were generated from methanol extract were less than 500 nm in size which is in accordance to the report of Barathikannan et al., 2023.

The colour changes of $AgNO_3$ solutions from colourless to light brown confirmed the synthesis of nanoparticles and this correspond to the study of Shah et al., (2020). According to earlier reports, the activation of surface plasmon vibrations caused the color changes in the solution and that indicated the presence of AgNPs (Rai et al., 2006). The UV-Vis spectrum analysis also confirmed the synthesis of the synthesized silver nanoparticles *V. paradoxa*. The reduction of AgNO3 is facilitated by plant extracts, resulting in the subsequent synthesis of AgNPs. Free electrons exist in metallic nanoparticles like silver, and they create the surface plasmon resonance (SPR) absorption band. (Noginov et al., 2007). The XRD peaks exhibited high intensity, indicating the synthesis of AgNPs in a nanoscale domain with a crystalline structure, and the sharpening of the peaks clearly indicated that the particles are the spherical nanoparticles. The XRD peaks obtained from both the methanol extract and the synthesized AgNPs are 111, 200, 220, 311, 222 except 222 which was not in the methanol extract, Kathiravan et al., (2015) have also reported a similar pattern of peaks. The XRD patterns obtained were similar to those in previous reports (Khan et al., 2017; Shah et al., 2020). The EDX report of the synthesized nanoparticles revealed nine elements including silver (67.35 wt%) while eight elements were revealed in the methanol extract with silver having 48.68 wt%. In SEM, the spherical nanoparticles have sizes ranging from 20 to 50 nm with a variety of morphology for both the methanol and synthesized nanoparticles. According to Savithramma et al. (2011), *Boswellia ovalifoliolata* and *Shorea tumbuggaia* both produced moderately spherical-shaped silver nanoparticles with diameters between 30 and 40 nm.

The presence of several functional groups and phytochemicals in the nanoparticles was indicated by the FT-IR spectra. The peaks found in the AgNPs are 3444 cm^{-1} and 3452 cm^{-1} representing those of N-H stretching linked to N-substituted amide the 3167 cm^{-1} with more intensity in MVP AgNPs, indicating N—H vibration. The 1633/1627 cm^{-1} corresponding to C-C and C-N stretching or the N-H stretch vibration, suggest the presence of amide linkages and strong and sharp 1384 cm^{-1} peaks, which is assigned to C – O from the interaction of the NPs with oxygen or carbon dioxide. However, the functional group identified in the methanolic extract differs from that of the AgNPs. Peak values bands observed in the silver nanoparticles showed similar pattern to those reported by Joshi et al. (2018). FTIR study confirmed that plant extract capping material reduces Ag+ ions then to silver nanoparticles production (Rajoriya et al., 2017).

The energy dispersive spectrum (EDX) of the synthesized nanoparticles showed the presence of silver as the main ingredient in the nanoparticles synthesized with other elements. Silver peaks are perhaps the most notable element in all of the synthesized AgNPs, no nitrogen peaks were visible in the EDX patterns of the prepared samples. The silver element percentage weight in the AgNPs is higher than that in the methanol extract. This shows the absence of detectable traces of ions from the preliminary $AgNO_3$ used, confirming the presence of metallic silver in the samples and proof of effective reduction of silver ion supported by the noticeable visual color changes. Apart from the silver peaks, EDX revealed the presence of carbon, oxygen, sulfur, sodium, silicon, iron, zinc and gold atoms in the nanoparticle samples.

Antioxidant study was carried out on Ferric Reducing Antioxidant Power (FRAP), DPPH radical scavenging activity, total phenolic content (TPC), Total flavonoid content (TFC) and total antioxidant capacity (TAC), were used to assay the AgNPs and methanol extract of *V. paradoxa.* The AgNPs obtained showed high antioxidant potential. The silver nanoparticles showed high antioxidant potential to FRAP, TFC and TPC compared to the methanol extract, while the methanol extracts showed higher antioxidant activities to DPPH and TAC compared to the standard. Oxidative stress and disease are caused on by an excess of free radicals or reactive oxygen species (ROS) (Bhatti et al., 2022). It has been demonstrated that these free radicals and reactive oxygen species oxidize biomolecules such as proteins, amino acids, lipids, and DNA, and their excessive generation has been connected to a number of disorders (Wintola et al., 2021). The antioxidant activity exhibits an exponential increasing pattern with respect to the reducing capacity, on the other hand, it demonstrated that antioxidant potentials are associated with reducing power because the ability of antioxidant activity to reduce ferric ion indicated the potential antioxidant activity. Earlier researchers have found a greater antioxidant activity of silver nanoparticles (AgNPs) generated from plant-based sources (Nadeem et al., 2020 and Jan et al., 2020). The result of the antioxidant activities of the AgNPs seen in this study also corroborates with the findings of Odunola et al., (2019) and Ojo et al., (2021) who have documented on the antioxidant analyses of Nigerian medicinal plants,

AgNPs demonstrated strong antibacterial efficacy against all selected microorganisms which are *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Serratia mercescens*, *Klebsiella pneumoniae*. AgNPs exhibited the most significant inhibitory zones when tested against Proteus mirabilis. *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Serratia mercescens* in comparison to the methanol extract. The results of the antibacterial activity assay indicated that the AgNPs synthesized from V. paradoxa leaf extract exhibited a higher potential to impede the proliferation of gram-negative bacteria, such as *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Serratia mercescens*. However, the methanol extract was active against *Klebsiella pneumoniae*. Silver is widely recognized for its antimicrobial properties. (Khan et al., 2017). Antibacterial activity of plant-based AgNPs has been reported by many workers (Joshi et al., 2018; Shah et al., 2020; Singh et al., 2021).

CONCLUSION

In conclusion, synthesized silver nanoparticles generated in this study showed potential bacterial growth inhibition against the pathogenic organisms used. These nanoparticles' antioxidant capability can be applied in a variety of ways to scavenge free radicals. In contrast to the methanol extract, the silver nanoparticles produced by V. paradoxa showed a very good inhibitory action against the bacteria.

RECOMMENDATIONS

Medicinal plants should be given special attention since they contain unique compounds and have pharmacological actions that can be used to treat a variety of ailments.

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