

Green Synthesis of Silver Nanoparticles via the Aqueous Extracts of *Prunus africana* and their Antimicrobial Activities

Lemeitaron P. N.

lemeitaronnjenga@gmail.com

Jomo Kenyatta University of Agriculture and Technology, Kenya <https://orcid.org/0009-0007-9476-4464>

Madivoli E. S

Jomo Kenyatta University of Agriculture and Technology, Kenya <https://orcid.org/0000-0003-3992-5097>

Munuhe L. N

Jomo Kenyatta University of Agriculture and Technology, Kenya <https://orcid.org/0009-0007-6270-1805>

Sujee D.M

Karatina University, Kenya <https://orcid.org/0000-0002-6243-1952>

Kimani P. K

Nagoya Institute of Technology, Japan <https://orcid.org/0000-0002-1473-2689>

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Abstract

The alarming effect of antibiotic resistance prompted the search for alternative medicines to resolve the microbial resistance conflict. Over the last two decades, scientists have become increasingly interested in the new dimensions of metallic nanoparticles. *Prunus africana* is a traditional medicinal plant rich in phytochemicals. In this study, we expand this knowledge by synthesizing antibacterial silver nanoparticles (AgNPs) using *Prunus africana* stem bark extract as a reducing, capping, and stabilizing agent. The biosynthesis of AgNPs was carried out with 0.1 M silver nitrate and 2% w/v stem bark extract. The effects of temperature, contact time, and concentration on the synthesis of AgNPs were examined via UV–Vis spectroscopy. The formation of AgNPs was indicated by the development of a dark-brown color from red–brown. Using a UV–Vis spectrophotometer, the surface plasmon resonance observed at 432.5 nm indicated the formation of silver nanoparticles. Probable vibrational stretches that are characteristic of silver nanoparticles, such as OH and C=O vibrations, were identified via an FT-IR spectrophotometer. The characteristic peaks of the XRD pattern confirmed the synthesis of pure AgNPs with an average crystalline size of 17.07 nm. TEM (transmission electron microscopy) analysis confirmed that the synthesized AgNPs were spherical with sizes ranging from 15.95 nm to 43.04 nm. DLS analysis confirmed the stability of the AgNPs in solution at -12.44 mV. The synthesized silver nanoparticles (AgNPs) exhibited antibacterial activity against four bacterial strains (*Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus subtilis*) and one fungus (*Candida albicans*).

1. Introduction

The field of nanotechnology is expanding, and it can be utilized to make structures at the nanoscale. The approach and formulation of particles with diameters ranging from 1 to 100 nm are the focus of nanoparticles. Since nanoparticles (NPs) are not simple molecules, they are separated into three layers: (1) the shell layer, which is physically and chemically different from the core; (2) the surface layer, which can be made stable with a range of special polymers, emulsifiers, metal ions, and chemicals; and (3) the core, which may be the central component of the nanoparticle [1]. Innovations in nanobiotechnology have led to fascinating findings in materials science. This method now allows for the biosynthesis of environmentally and economically advantageous metal nanomaterials for use in the food, agricultural, cosmetics, defense, environmental safety, and health sectors [2].

Compared with physical (pyrolysis, high-energy irradiation, laser ablation, etc.) and chemical (microwave-assisted, electrochemical deposition, photoinduced reduction, etc.) procedures, these biological methods are quick, easy, affordable, and, most importantly, environmentally benign [3]. While these conventional techniques for producing nanoparticles are efficient, they are generally quite costly. To prevent the nanoparticles from aggregating, capping reagents or surface passivators are usually needed. However, several organic passivators, including mercaptoacetate, thiophenol, and thiourea, are hazardous enough to pollute the environment if large-scale nanoparticles are formed [4]. Biological methods reduce metal ions to generate corresponding nanoparticles by applying bioactive chemicals

from fruit peel waste, bacteria, and, primarily, plants [5]. Plants and microorganisms are safe, reproducible biological resources that do not harm people or the environment. They can be a better alternative to physical and chemical approaches for the development of silver nanoparticles (AgNPs) [6].

Furthermore, natural extracts provide a rich supply of bioactive molecules that can be used for the green fabrication of metallic NPs as well as antioxidant medications and dietary supplements. The components of the natural product can function as potent reducing and capping substrates, ensuring the stability of the produced nanoparticles [7]. Biosynthesis has been used in recent publications for the synthesis of silver nanoparticles, where medicinal plant extracts (*Scutellaria barbata*, *Abelmoschus esculentus*, etc.) have been used [8] [9], among others. All these studies agree that the biomolecules present in these materials reduce silver ions (Ag^+) to zerovalent silver (Ag^0).

The small particle size and high surface area of AgNPs provide them with unique biological, physical, and chemical characteristics [10]. Their optical characteristics, which result from localized LSPR (surface plasmon resonance), make them interesting [11]. As catalysts, biosensors, or antibacterial agents, they have a wide range of uses. In addition to their efficacy against inflammation, they are used in antiseptic sprays, topical creams, and wound dressings in biomedicine. Their application in the detection and treatment of cancer has shown success [12]. In addition to silver nanoparticles, noble metals such as iron, zinc, and gold exhibit a wide variety of material behaviors as well as amazing characteristic features that are dependent on size, shape, and application in a wide range of industries [13].

Silver nanoparticles are most frequently utilized in the textile industry as antibacterial agents for water treatment. Because they are nontoxic to animal cells and highly poisonous to bacteria, they are safe and efficient antibacterial agents [14]. Antimicrobial resistance is becoming a global issue with respect to the management of viral illnesses due to the improper and excessive use of antibiotics. The application of nanotechnologies in the production of potent antimicrobial agents is a novel and promising solution in response to the demand for novel antimicrobial drugs that can either eradicate or limit the growth of a broad spectrum of microorganisms [15]. Through the production of ions or superoxide radicals that can obstruct cell granules or damage membrane proteins, metallic nanoparticles have an antibacterial impact. These nanoparticles may prevent the production of advanced glycation products, which makes them useful for anticancer treatments [16].

The species *Prunus africana* (Hook f.) is a member of the genus *Prunus* and includes approximately 400 species. There are approximately 98 species that are very significant. A mature *Prunus africana* stem can have a diameter of up to 1 m, and the plant can reach a height of approximately 40 m. The leaves of the plant are alternating, oval shaped, and simple between a deep green topside and a shining, light green underside. The bark of the plant is dark brown in color. The flowers range in color from green to white. The fruits have a pink–brown hue [17]. As a therapeutic plant, *Prunus africana*'s high-value bark has led to harsh exploitation over time. It has several difficulties, including the intransigence of its seed and erratic fruiting, which hinders its ability to regenerate sexually. Thus, the proper channel for its

domestication has been determined to be asexual regeneration [18]. The findings revealed that aqueous/acetonic *Prunus africana* stem and root bark extracts outperformed other extracts and the reference antibiotic in their considerable ($p < 0.05$) antibacterial activity against *S. aureus* at 800 µg/ml [19]. The bark has been used traditionally to treat various illnesses, including malaria, renal abnormalities, stomach pain, urinary tract infections, and cardiac issues. One traditional way to consume the bark is to chew it or crush it into a fine powder for use in tea [20].

The current study aimed to investigate the potential of the medicinal plant *Prunus africana* in the green synthesis of silver nanoparticles. Biogenic silver nanoparticles have been explored for their antimicrobial potential against multidrug-resistant (MDR) bacterial strains.

2. Materials and methods

Silver nitrate (AgNO_3 , 99.8%) precursor salt, distilled water, Whatman (No. 1) filter papers, nutrient agar, Petri dishes, bacterial strains (*Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis*), one fungus (*Candida albicans*), antibiotic (erythromycin), and *Prunus africana* stem bark were used. All the microbiological media and reagents used for the chemical analyses and extraction process were of pure analytical and laboratory grade and were obtained from HiMedia.

2.1. Extraction of Biomolecules

The extraction method was adopted from [21] with minor modifications. The *Prunus africana* stem bark was washed with tap water, rinsed with distilled water, and left to dry for 15 days at room temperature. A mechanical grinder was used to pulverize the dried sample into a powder. A total of 10 g of powdered plant sample was dissolved in 500 mL of distilled water in a 1000 mL conical flask and heated at 60°C for 2.5 hrs on a hot plate with a magnetic stirrer. The extract solution was filtered through filter paper (Whatman No. 1). The filtrate was refrigerated at 4°C for further use.

2.2. Synthesis of AgNPs using *Prunus africana* extracts

Prunus africana-capped silver nanoparticles (AgNPs@PA) were synthesized via various protocols with minor modifications. The effects of temperature, reaction duration, and concentration of AgNO_3 solution as well as plant extract on the synthesis of AgNPs were studied to determine their impact during the reaction process. Eighteen milliliters (18 mL) of 2% (w/v) aqueous bark extract was added to 1 mL of (0.01, 0.1, 1 M) AgNO_3 solution, and the formulation of AgNPs was observed via a UV–Vis spectrophotometer (Shimadzu model, UV–Vis 1800 series) in the 200–800 nm range [22]. In addition, the experiment was conducted at room temperature (35, 40, 45, 50, 60, 65, 70, 80, 90, and 100°C) for 40 minutes to assess the significance of temperature during synthesis [23]. The transition from a colorless solution to a dark brown color indicates that AgNO_3 has been bio-reduced to form AgNPs. The mixture was subsequently centrifuged for 25 minutes at 10,000 rpm [24]. The solid masses were then dried in a vacuum oven at 60°C overnight after being individually rinsed with distilled water ($\text{DI-H}_2\text{O}$) in triplicate to remove unreacted precursor salts and biological particles [25].

2.3. Characterization of AgNPs

The absorption spectrum and SPR of the formed AgNPs were recorded via UV–Vis (UV-1800 series, Shimadzu model). The functional groups in the AgNPs samples and *Prunus africana* extract were investigated via Fourier transform infrared (FTIR) spectroscopy (IRAffinity-1S, SHIMADZU model) via the ATR technique. Transmission electron microscopy (TEM) (JEOL-JEM-1011, Japan) was used to examine the size and morphology of the biosynthesized AgNPs.

2.4. Antibacterial activity

The method was adopted from [26] with significant adjustments. Nutrient agar medium was prepared by dissolving 14 g of agar powder in 500 mL of distilled water and then autoclaving it. A total of 20 mL of prepared agar was poured into each Petri dish, which was left to stand for 15 min for the agar to solidify. Then, the plates were inoculated overnight with human pathogens, such as the gram-negative strains (*Escherichia coli* and *Pseudomonas aeruginosa*), gram-positive strains (*Staphylococcus aureus* and *Bacillus subtilis*), and one fungus (*Candida albicans*) obtained from MKU Laboratory, Kenya. All the organisms were tested simultaneously via the disc diffusion method. The green-synthesized AgNPs, positive control (ampicillin), and pure extract of *Prunus africana* were added steadily until the wells were confluent, followed by incubation at 37°C for 24 h. The diameter of the zone of inhibition was measured.

3. Results and Discussion

3.1. Green Synthesis of AgNPs

Currently, the green fabrication of silver nanoparticles is fascinating. An aqueous solution of silver nitrate precursor salt and aqueous *Prunus africana* stem bark extract was used for the synthesis of silver nanoparticles. The mixture was uniformly mixed via a mechanical shaker at regulated temperatures and times. The formation of AgNPs was indicated by color changes from red–brown to dark-brown (Fig. 1), as also reported by [22].

3.2. Optical analysis

UV–visible spectral analysis was performed via a UV–visible spectrophotometer (UV-1800 series, Shimadzu model). The analysis was carried out in a scan range of 200–800 nm with a resolution of 1 nm. Using distilled water as a blank, 300 microliters of the biogenic AgNP sample mixture was pipetted out and scanned with dilution in 3 mL standard quartz cuvettes. The process for monitoring the absorption patterns of the extracts and mixtures of extracts with silver nitrate was monitored at various concentration ratios, synthesis temperatures, and contact times. The peak broadening decreases as the concentrations of the reducing and capping agents in the plant extract increase (Fig. 2). The reaction time of Ag^+ ion reduction to Ag^0 by biomolecules present in *Prunus africana* aqueous extracts is concentration-, temperature- and time-dependent (Figs. 2, 3 and 4); therefore, as reported by [15], increasing the reaction temperature to 60°C increases the reduction rate and shortens the reaction time

necessary for AgNP synthesis (Fig. 3) [27]. Figure 4 shows that the maximum reaction time was 55 minutes since, at 65 minutes, peak broadening was noted, which can be a result of agglomeration [28]. A blueshift was revealed by the surface plasmon resonance (SPR) peak at 435–437.5 nm (Figs. 2, 3 and 4), which shifted to a lower wavelength (432.5 nm) (Fig. 6), indicating that the particle size decreased with optimized synthesis parameters, i.e., a temperature of 60°C, 0.1 M AgNO₃ and a reaction time of 55 minutes, whereas the redshifts indicate the production of large-sized particles or the presence of agglomerates [29]. The tauc plot shows that the biosynthesized AgNPs possessed a bandgap energy of 4.16 eV (Fig. 6). Increasing the temperature above 60°C results in agglomeration, disappearance of peaks, and peak broadening of the nanoparticles (Fig. 3). The common peak located at 278.5 nm (Figs. 2, 4, and 6) was a result of the chemical constituents present in the *Prunus africana* aqueous extract.

The formation of AgNPs can be monitored by the increased intensity of the absorbance band with respect to time (Figs. 4 and 5). The particle characteristics, including size, shape, type of metal, and dielectric compound around the medium, affect the surface plasmon resonance band wavelength and intensity [16].

3.3. FT-IR Analysis

The phytochemical constituents present in the stem bark extracts of *Prunus africana* that are responsible for reducing, capping, and stabilizing AgNPs were determined via FT-IR spectroscopy in the 4000–400 cm⁻¹ scan range [30]. The FT-IR spectra of the plant extracts and formulated AgNPs are shown in Figs. 7(a) and 7(b), respectively. The presence of a strong, broadband band (Fig. 7(a)) at 3209–3028 cm⁻¹ in the *Prunus africana* stem bark extract can be attributed to hydrogen-linked O-H stretching vibrations of phenol, alcohol, carboxylic groups, and other compounds [31].

Vibrational bands at 3446 cm⁻¹ and 1369 cm⁻¹ were also observed for the synthesized AgNPs (Fig. 7(b)), which were assigned to the O–H bands of carboxylic groups, phenolics, and alcohols [32][33]. The C–O stretching vibrations at 1060 cm⁻¹ indicate the presence of carbohydrates, terpenoids, and flavones in the *Prunus africana* extract [34]. Compared with those of the spectra of *Prunus africana* stem bark extracts, the intensities of the AgNP spectra at 769 cm⁻¹, 1060 cm⁻¹, 1211 cm⁻¹, 1369 cm⁻¹, 1600 cm⁻¹, and 3209 cm⁻¹ are lower [35]. The reason for the reduction and alteration of the spectra is that phytochemicals, such as alcohols, amides, and carboxylic groups, are involved in redox reactions during the synthesis of AgNPs [36]. The absorption peak at 1211 cm⁻¹ is assigned to the stretching of N–O [3].

A strong absorption spectrum for *Prunus africana* stem bark extract (Fig. 7(a)) was observed at 1600 cm⁻¹, which may be attributed to C = O bands and the N–H groups of proteins and enzymes [37]. The spectra of the C = O bands and the N–H groups of proteins and enzymes for the biosynthesized AgNPs shifted to 1597 cm⁻¹, and the intensity significantly decreased, confirming the role of enzymes, proteins, and other biomolecules in bio-reduction [38], stabilization, and capping of the silver nanoparticles (Fig. 7(b)) [31]. The presence of saturated aliphatic esters is attributed to the sharp absorption band at 1741 cm⁻¹ corresponding to carbonyl C = O bonds [39]. The reduced stretching vibration of Ag–O with an

absorption band at 769 cm^{-1} (Fig. 7(b)) confirms the production of silver nanoparticles (the stretching was attributed to the metal–ligand frequency that formed due to the interaction between the biomolecules and the AgNP surfaces) [40].

3.4. Structural analysis of AgNPs

The XRD pattern of the AgNPs prepared from *Prunus africana* is shown in Fig. 8. XRD analysis was conducted to determine the purity, size, and crystalline structure of the biosynthesized AgNPs. In the XRD spectrum, three prominent diffraction bands were observed at $2\theta = 38.26^\circ$, 44.45° , and 64.76° , which could be indexed to the (111), (200), and (220) diffraction planes, respectively [41]. All the diffraction peaks were attributed to the cubic structure of pure Bragg's reflections of the FCC (face-centered cubic) structure of the metallic silver powder phase. These planes confirmed the crystalline nature of the green-synthesized AgNPs. The highest peak intensity of the (111) plane with a narrow full width at half maximum (FWHM) illustrates the good crystalline nature of the synthesized AgNPs, as observed from the XRD patterns. The resulting peaks and their corresponding Bragg reflections strongly agreed with the Joint Committee on Powder Diffraction Standards (JCPDS, file no. 04–0783) [42]. The prominent characteristic peaks of the green synthesized silver nanoparticles indicate the purity of the synthesized nanoparticles without any additional diffraction peaks [43]. The average crystallite sizes of the particles were calculated via the Debye–Scherrer equation (Eq. (1)):

$$x = \frac{K\lambda}{\beta \cos \theta} \text{ Eq. 1}$$

where x is the estimated crystal size in the nanometer (nm) from the XRD patterns, θ is Bragg's angle (in radians), λ is the wavelength of the X-ray maximum of the diffraction peak (in radians), K is the shape factor or source used ($\text{CuK}\alpha = 1.5419\text{ \AA}$), and β is the angular width at the half-Scherrer constant (0.9) of Debye–Scherrer's equation [34]. The estimated average crystalline size (x) of the synthesized silver nanoparticles was found to be 17.07 nm.

3.5. Transmission electron microscopy analysis of AgNPs

The TEM image of the AgNPs synthesized via *Prunus africana* revealed that the nanoparticles are predominantly spherical and of different sizes (Fig. 9 (a)). In addition to the spherical shape, a few other shapes, such as oval and triangular, were also observed. The aggregation of particles was also observed. A study by [44] also reported spherical AgNPs synthesized from *Aloe vera* gel extract. The clear boundaries observed around the nanoparticles indicate the occurrence of phytochemicals as capping agents that stabilize the silver nanoparticles. Figure 9 (b) shows the particle size distribution of the synthesized AgNPs. The synthesized nanoparticles are polydisperse and range in size from 15.95 nm to 43.04 nm, with an average size of 32.04 nm. Our findings followed those of previous reports, where plant extract was used as a reducing and capping agent in the synthesis of AgNPs, and similar results have been reported for AgNPs with sizes ranging from 18.23 to 53.68 nm [43].

3.6. EDS Analysis

The EDS spectrum reveals the purity and elemental composition of the biosynthesized AgNPs, as shown in Fig. 10. The strong signal for Ag, with higher atom percentages, was located at 3 keV, confirming the formation of silver nanoparticles biosynthesized with an aqueous extract of *Prunus africana*. Additionally, a few weaker signals of O and C were also obtained, indicating the existence of biomolecules capping and stabilizing the AgNPs [3].

3.7. DLS analysis

The zeta potential, which provides important information about nanoparticle dispersion through the magnitude of the charge, reflects the mutual repulsion between particles. The particle sizes range from 100 to 1000 nm in diameter. The measured zeta potential of the AgNPs was – 12.44 mV (Fig. 11), preventing agglomeration and improving their stability in solution [35].

3.8. Antibacterial activity

The in vitro antibacterial potential of the synthesized AgNPs was examined against two types of selected human pathogenic microbes, namely, fungus (*Candida albicans*), gram-positive bacteria (*Staphylococcus aureus* and *Bacillus subtilis*), and gram-negative bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*) (Table 1 and Fig. 12). The clear zones of inhibition around the discs impregnated with the biosynthesized AgNPs, plant extract, and erythromycin (positive control) are shown in Fig. 12. Erythromycin is a commonly used antibacterial agent against superficial and deep infections caused by human pathogens [45]. AgNPs exhibited superior antibacterial properties against all the test microbes, as evidenced by the calculated zones of inhibition (Table 1), which may be due to the synergistic effects of the bioactive capped nanoparticles. The structures that make up bacterial cells include proteins, DNA, and cell membranes. These structures contain phosphorus and sulfur. Since silver is a Lewis acid and these substances are Lewis bases, sulfur proteins and silver ions are attracted to each other electrostatically, which could be the antibacterial action mechanism of silver nanoparticles [46]. Therefore, AgNPs can bind to the cell wall and penetrate bacterial cells. The internalization of silver nanostructures disrupts respiratory function, inactivating respiratory enzymes and generating reactive oxygen species (ROS). This overproduction of ROS damages intercellular components, including DNA, lipids, and proteins. The destruction of the cellular membrane causes loss of cytoplasm, leading to cell death [33]. In addition, cell wall thickness affects how effectively different bacteria respond to silver nanoparticles. Compared with gram-positive bacteria such as *S. aureus*, which have a thicker cell wall, gram-negative *E. coli* have a thinner cell wall, making it more vulnerable to silver nanoparticle penetration [47]. In general, nanoparticles have a high surface area-to-volume ratio, which enables them to interact more with microbes than larger particles do, resulting in improved microbial activity [48].

Table 1: Zones of inhibition (mm) of AgNP-, plant extract-, and erythromycin (positive control)-impregnated discs against *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans* (Fungus) according to the disc diffusion method

Sample Name	AgNPs	Plant extract	Positive (erythromycin)	Control
Microbial Strains				
<i>Bacillus subtilis</i>	10.67±1.25	7.67±0.94	10.67±0.47	
<i>Pseudomonas aeruginosa</i>	9.00±0.82	7.533±0.47	7.67±0.47	
<i>Escherichia coli</i>	11.00±0.82	8.33±0.47	7.83±0.24	
<i>Staphylococcus aureus</i>	11.33±01.25	5.33±0.47	7.33±0.47	
<i>Candida albicans</i>	10.00±0.82	9.33±0.47	9.83±0.24	

3.9. Statistical analysis: one-way ANOVA

Table 2
ANOVA of the antibacterial and antifungal (zones of inhibition) results

ANOVA of the antibacterial and antifungal (Zones of inhibition) results						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	5	52	10.4	0.85445		
Column 2	5	38.33	7.666	2.50668		
Column 3	5	41.33	8.266	3.49768		
ANOVA						
Source of Variation	SS	df	MS	F	P value	F crit
Between Groups	20.64785	2	10.32393	4.51562	0.034506	3.885294
Within Groups	27.43524	12	2.28627			
Total	48.08309	14				

The acquired antibacterial and antifungal results were significant because the p value was less than 0.05 (Table 2).

Conclusions

Silver nanoparticles were successfully fabricated via a simple and eco-friendly green synthesis method using *Prunus africana* aqueous extract. AgNP formation was confirmed by the change in color of the reaction mixture and the appearance of the SPR band at 432.5 nm. The biomolecules, which act as

reducing, capping, and stabilizing agents, were recognized in the FTIR spectrum. The synthesized AgNPs were stable and small in size, as described in the XRD and TEM analyses. The XRD pattern revealed a fcc crystal structure of the AgNPs. The synthesized silver nanoparticles were found to be highly stable, as shown via DLS analysis, crystalline, polydispersed, and mostly spherical in shape, as determined via TEM analysis. The AgNPs showed excellent antimicrobial activity against the microbial strains studied and therefore can be considered a promising opportunity for developing antimicrobial medications.

Declarations

Conflicts of interest:

The authors declare no conflicts of interest.

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References

1. Habeeb Rahuman HB et al (2022) Medicinal plants mediated the green synthesis of silver nanoparticles and their biomedical applications. IET Nanobiotechnol 16(4):115–144. 10.1049/nbt2.12078
2. Baran MF, Keskin C (2023) Green Synthesis of Silver Nanoparticles from *Allium cepa* L. Peel Extract. Their Antioxidant, Antipathogenic, and Anticholinesterase Activity
3. Khane Y et al (2022) Green Synthesis of Silver Nanoparticles Using Aqueous Citrus limon Zest Extract. Characterization and Evaluation of Their Antioxidant and Antimicrobial Properties
4. Fatemeh S, Tasharro N, Mahmoudi M (2020) Green synthesis of silver nanoparticles using *Teucrium polium* leaf extract and assessment of their antitumour effects against MNK45 human gastric cancer cell line. 1208. 10.1016/j.molstruc.2020.127889
5. Njenga L, Ayabei K, Akenga T, Onyambu Z, Kiptoo J, Onani M (2023) Antibacterial Activities of Green Synthesized ZnO and CuO Nanoparticles from Leaf Extracts of *Warburgia ugandensis*. 11(1):10–18. 10.11648/j.nano.20231101.12

6. Gomathi M, Prakasam A, Rajkumar PV, Rajeshkumar S, Chandrasekaran R (2019) South African Journal of Chemical Engineering Green synthesis of silver nanoparticles using *Gymnema sylvestre* leaf extract and evaluation of its antibacterial activity, *South African J. Chem. Eng.*, vol. 32, no. November pp. 1–4, 2020. 10.1016/j.sajce.2019.11.005
7. Flieger W, Flieger J, Franus W, Panek R, Szyma M (2021) Green Synthesis of Silver Nanoparticles Using Natural Extracts with Proven Antioxidant Activity
8. Priya V, Devi N, Karunakaran T, Hussain S, Mohan K, Jiao X (2021) Saudi Journal of Biological Sciences Green synthesis of silver nanoparticles from aqueous extract of *Scutellaria barbata* and coating on the cotton fabric for antimicrobial applications and wound healing activity in fibroblasts (L929). *Saudi J Biol Sci* 28(7):3633–3640. 10.1016/j.sjbs.2021.05.007
9. Devanesan S, AlSalhi MS (2021) Green Synthesis of Silver Nanoparticles Using the Flower Extract of *Abelmoschus esculentus* for Cytotoxicity and Antimicrobial Studies. *Int J Nanomed* 16:3343–3356. 10.2147/ijn.s307676
10. Kareru AONPG, Wanakai ESMIS, Gachui E (2020) Formation of Silver Nanoparticles via *Aspilia pluriseta* Extracts Their Antimicrobial and Catalytic Activity. *J Inorg Organomet Polym Mater* 012345678910.1007/s10904-020-01497-7
11. Audtarat S et al (2022) Green synthesis of silver nanoparticles loaded into bacterial cellulose for antimicrobial application. *Nanocomposites* 8(1):34–46. 10.1080/20550324.2022.2055375
12. Jalab J, Abdelwahed W, Kitaz A, Al-kayali R (2021) Heliyon Green synthesis of silver nanoparticles using aqueous extract of *Acacia cyanophylla* and its antibacterial activity, *Heliyon*, vol. 7, no. September, p. e08033. 10.1016/j.heliyon.2021.e08033
13. Patel RR, Singh SK, Singh M (2023) Materials Advances biological applications, delivery and toxicity. 1831–1849. 10.1039/d2ma01105k
14. Yousaf H, Mehmood A, Shafique K, Raffi M (2020) Materials Science & Engineering C Green synthesis of silver nanoparticles and their applications as an alternative antibacterial and antioxidant agents. *Mater Sci Eng C* 112:110901. 10.1016/j.msec.2020.110901
15. Salayov A, Bedlovi Z (2021) Green Synthesis of Silver Nanoparticles with Antibacterial Activity Using Various Medicinal Plant Extracts. Morphology and Antibacterial Efficacy
16. Shigwenya E et al (2020) Facile Synthesis of Silver Nanoparticles Using *Lantana trifolia* Aqueous Extracts and Their Antibacterial Activity. *J Inorg Organomet Polym Mater* 012345678910.1007/s10904-019-01432-5
17. Mutuma GG, Joseph N, Alex M, Silas K (2020) Phytochemical and Anti-Inflammatory Analysis of *Prunus africana* Bark Extract, vol. 7, no. May, pp. 31–38. 10.22127/rjp.2020.229941.1583
18. Tchatat M et al (2020) Effect of Arbuscular Mycorrhizal Fungi Used as Biofertilizer for the Vegetative Propagation of *Prunus africana* (Hook. f.) Kalkman. 10(3):53–60. 10.5923/j.plant.20201003.02
19. April M-, Ndung J, Nguta J, Mapenay I, Moriasi G (2024) Antimicrobial Activity, Cytotoxicity, and Qualitative Phytochemistry of Leaf, stem bark, and root bark extracts from *Prunus africana* (Hook. F.) Kalkman. 13(2):122–132. 10.31254/phyto.2024.13206

20. Nyamai DW, Burugu MW, A MMNGANG, Muchugi AN (2022) The phytochemical profiles and growth of *Prunus africana* in Kenya. 20(2):63–74. 10.13057/biofar/f200204
21. Widadalla HA et al (2022) Green synthesis of silver nanoparticles using green tea leaf extract, characterization and evaluation of antimicrobial activity. *Nanoscale Adv* 4(3):911–915. 10.1039/d1na00509j
22. Hashemi Z, Mizwari ZM, Mohammadi-aghdam S (2022) Sustainable green synthesis of silver nanoparticles using *Sambucus ebulus* phenolic extract (AgNPs @ SEE): Optimization and assessment of photocatalytic degradation of methyl orange and their in vitro antibacterial and anticancer activity. *Arab J Chem* 15(1):103525. 10.1016/j.arabjc.2021.103525
23. Kumar T et al (2023) Green synthesis of silver nanoparticles using *Eupatorium adenophorum* leaf extract: characterizations, antioxidant, antibacterial and photocatalytic activities. *Chem Pap* 77:2947–2956. 10.1007/s11696-023-02676-9
24. Al-shabib NA, Husain M, Nadeem M (2020) RSC Advances Bioinspired facile fabrication of silver nanoparticles from in vitro grown shoots of *Tamarix nilotica*: explication of its potential in impeding growth and bio film of *Listeria monocytogenes* and assessment of wound healing. 30139–30149. 10.1039/d0ra04587j
25. Asghar MA, Zahir E, Arif M, Id A, Iqbal J, Rehman A (2020) characterization of iron, copper and silver nanoparticles using *Syzygium cumini* leaf extract : As an effective antimicrobial and aflatoxin B 1 adsorption agents. 1–17. 10.1371/journal.pone.0234964
26. Chandhru M, Logesh R, Kutti Rani S, Ahmed N, Vasimalai N (2022) Green synthesis of silver nanoparticles from plant latex and their antibacterial and photocatalytic studies. *Environ Technol (United Kingdom)* 43(20):3064–3074. 10.1080/09593330.2021.1914181
27. Mehata MS (2021) Green synthesis of silver nanoparticles using *Kalanchoe pinnata* leaves (life plant) and their antibacterial and photocatalytic activities. *Chem Phys Lett* 778:138760. 10.1016/j.cplett.2021.138760
28. Alahmad A, Feldhoff A, Bigall NC, Rusch P, Scheper T, Walter J (2021) *Hypericum perforatum* L. - Mediated Green Synthesis of Silver Nanoparticles Exhibiting Antioxidant and Anticancer Activities
29. Shoaib M et al (2021) Green synthesis and characterization of silver-entecavir nanoparticles with stability determination. *Arab J Chem* 14(3):102974. 10.1016/j.arabjc.2020.102974
30. Pallavi SS, Rudayni HA, Bepari A, Niazi SK, Nayaka S (2022) Green synthesis of Silver nanoparticles using *Streptomyces hirsutus* strain SNPGA-8 and their characterization, antimicrobial activity, and anticancer activity against human lung carcinoma cell line A549. *Saudi J Biol Sci* 29(1):228–238. 10.1016/j.sjbs.2021.08.084
31. Balčiūnaitienė A et al (2022) *Eucalyptus globulus* and *Salvia officinalis* Extracts Mediated Green Synthesis of Silver Nanoparticles and Their Application as an Antioxidant and Antimicrobial Agent. *Plants* 11(8):1–16. 10.3390/plants11081085
32. Characterization T, Activity B, Khan M, Karuppiyah P, Alkhathlan HZ, Kuniyil M (2022) Green Synthesis of Silver Nanoparticles Using *Juniperus*

33. Aklilu M (2022) Khat (*Catha edulis*) Leaf Extract-Based Zinc Oxide Nanoparticles and Evaluation of Their Antibacterial Activity, vol. 2022
34. Labulo AH, David OA, Terna AD (2022) Green synthesis and characterization of silver nanoparticles using *Morinda lucida* leaf extract and evaluation of its antioxidant and antimicrobial activity. *Chem Pap* 76(12):7313–7325. 10.1007/s11696-022-02392-w
35. Singla S, Jana A, Thakur R, Kumari C, Goyal S, Pradhan J (2022) Green synthesis of silver nanoparticles using *Oxalis griffithii* extract and assessing their antimicrobial activity. *OpenNano* 7:100047. 10.1016/j.onano.2022.100047
36. Aygün A, Özdemir S, Gülcan M, Yalçın MS, Uçar M, Şen F (2022) Characterization and antioxidant-antimicrobial activity of silver nanoparticles synthesized using *Punica granatum* extract. *Int J Environ Sci Technol* 19(4):2781–2788. 10.1007/s13762-021-03246-w
37. Pungle R, Nile SH, Makwana N, Singh R, Singh RP, Kharat AS (2022) Green Synthesis of Silver Nanoparticles Using the *Tridax procumbens* Plant Extract and Screening of Its Antimicrobial and Anticancer Activities, *Oxid. Med. Cell. Longev.*, vol. 2022. 10.1155/2022/9671594
38. Alamier WM, Oteef MDY, Bakry AM, Hasan N, Ismail KS, Awad FS (2023) Green Synthesis of Silver Nanoparticles Using *Acacia ehrenbergiana* Plant Cortex Extract for Efficient Removal of Rhodamine B Cationic Dye from Wastewater and the Evaluation of Antimicrobial Activity. *ACS Omega* 8(21):18901–18914. 10.1021/acsomega.3c01292
39. Constantin M et al (2023) *Ganoderma lucidum* -Mediated Green Synthesis of Silver Nanoparticles with Antimicrobial Activity, pp. 1–15
40. Alahmad A et al (2022) Green Synthesis of Silver Nanoparticles Using *Hypericum perforatum* L. Aqueous Extract with the Evaluation of Its Antibacterial Activity against Clinical and Food Pathogens. *Pharmaceutics* 14(5). 10.3390/pharmaceutics14051104
41. Wasilewska A, Klekotka U, Zambrzycka M, Zambrowski G, Świącicka I, Kalska-Szostko B (2022) Physico-chemical properties and antimicrobial activity of silver nanoparticles fabricated by green synthesis, *Food Chem.*, vol. 400, no. August 2023. 10.1016/j.foodchem.2022.133960
42. Sharma A, Sagar A, Rana J, Rani R (2022) Green synthesis of silver nanoparticles and its antibacterial activity using fungus *Talaromyces purpureogenus* isolated from *Taxus*. *Micro Nano Syst Lett* 9. 10.1186/s40486-022-00144-9
43. Basavarajappa DS, Nagaraja SK, Chakraborty B (2022) *Plumeria alba* -Mediated Green Synthesis of Silver Nanoparticles Exhibits Antimicrobial Effect and Anti-Oncogenic Activity against Glioblastoma U118 MG Cancer Cell Line
44. Alwhibi MS, Soliman DA, Awad MA, Alangery AB, Dehaish HA, Alwasel YA (2021) Green synthesis of silver nanoparticles: Characterization and its potential biomedical applications, pp. 412–420
45. Naskar A, Lee S, Lee Y, Kim S, Kim KS (2020) A new nanoplatform of erythromycin combined with ag nanoparticle ZnO nanostructure against methicillin-resistant *Staphylococcus aureus*. *Pharmaceutics* 12(9):1–14. 10.3390/pharmaceutics12090841

46. Shafiq A, Deshmukh AR, Abouaitah K (2023) Green Synthesis of Controlled Shape Silver Nanostructures and Their Peroxidase, Catalytic Degradation, and Antibacterial Activity
47. Lopez-Miranda JL et al (2023) Antibacterial and Anti-Inflammatory Properties of ZnO Nanoparticles Synthesized by a Green. Method Using Sargassum Extracts
48. Alao II, Oyekunle IP, Iwuozor KO (2022) Green synthesis of Copper Nanoparticles and Investigation of its Antimicrobial Properties. 4(1):39–52

Figures

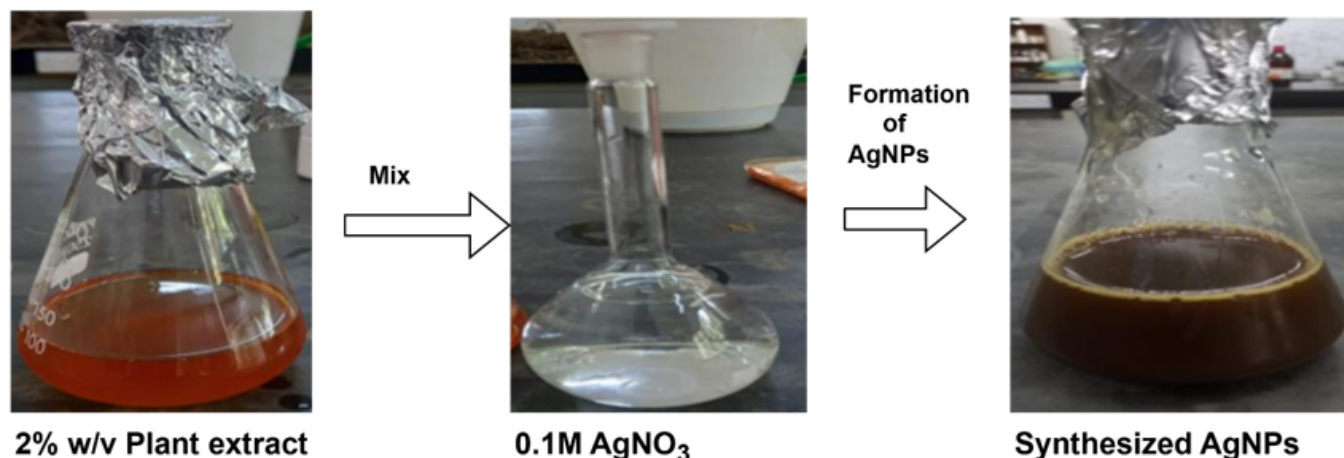


Figure 1

Graphical flowchart for the green synthesis of AgNPs using *Prunus africana* stem bark extract

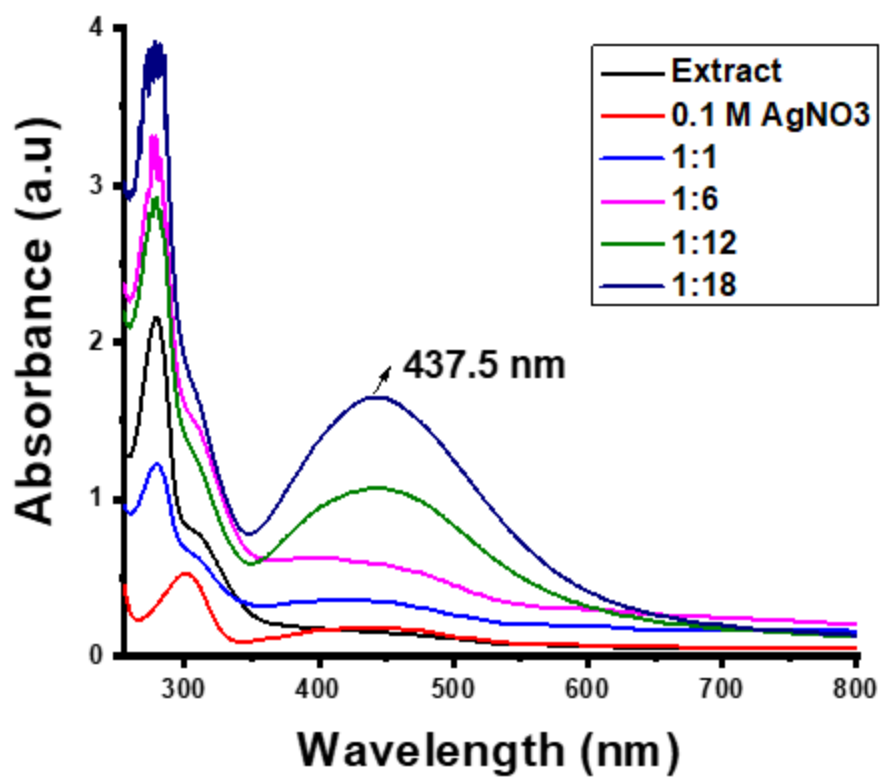


Figure 2

Effect of extract concentration on the synthesis of AgNPs

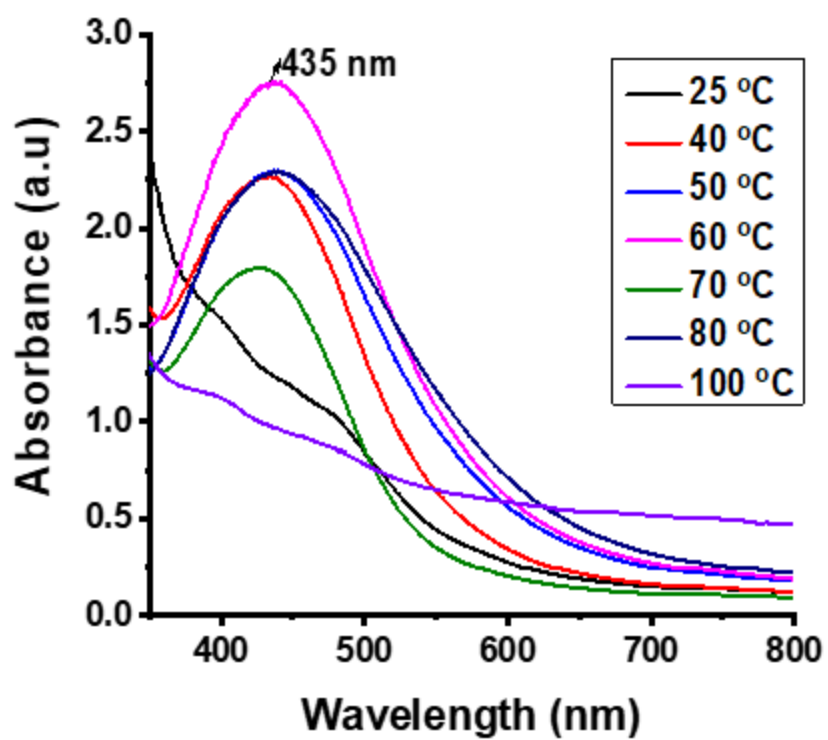


Figure 3

Effect of temperature variation on the synthesis of AgNPs

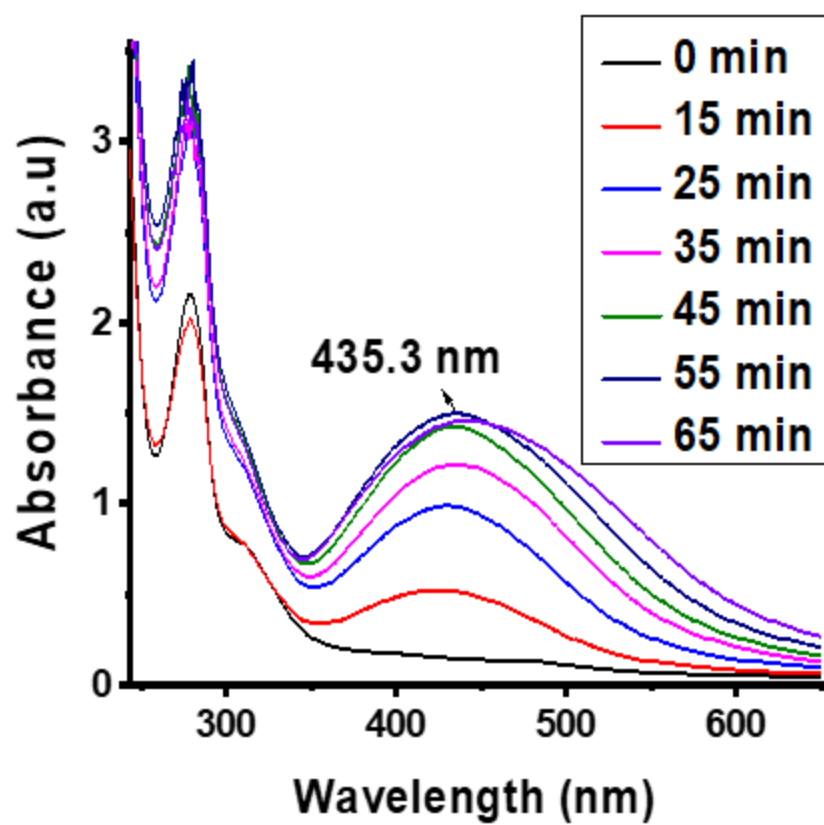


Figure 4

Effect of time on the synthesis of AgNPs

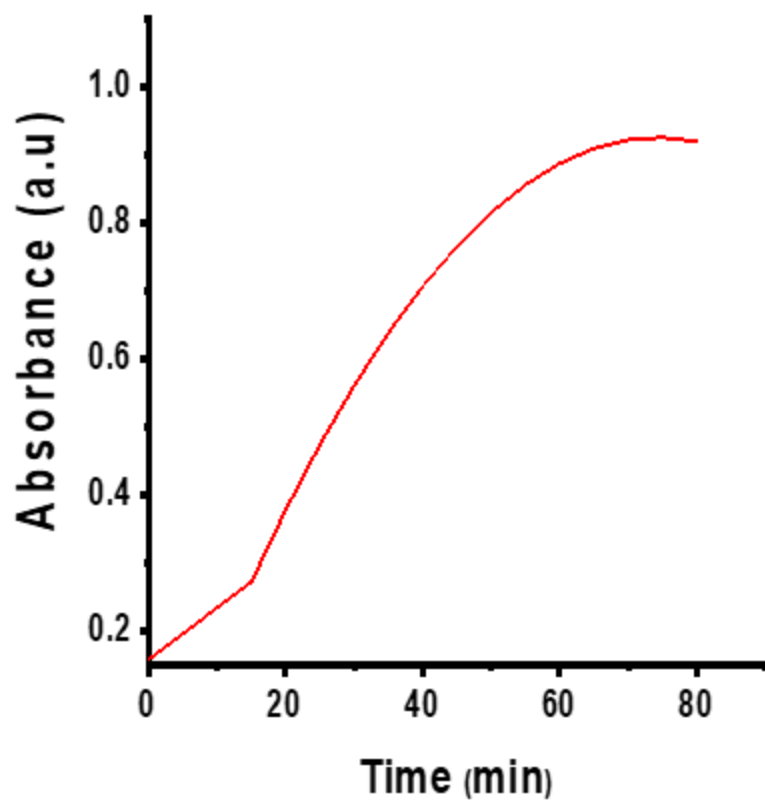


Figure 5

Curve of absorbance versus temperature

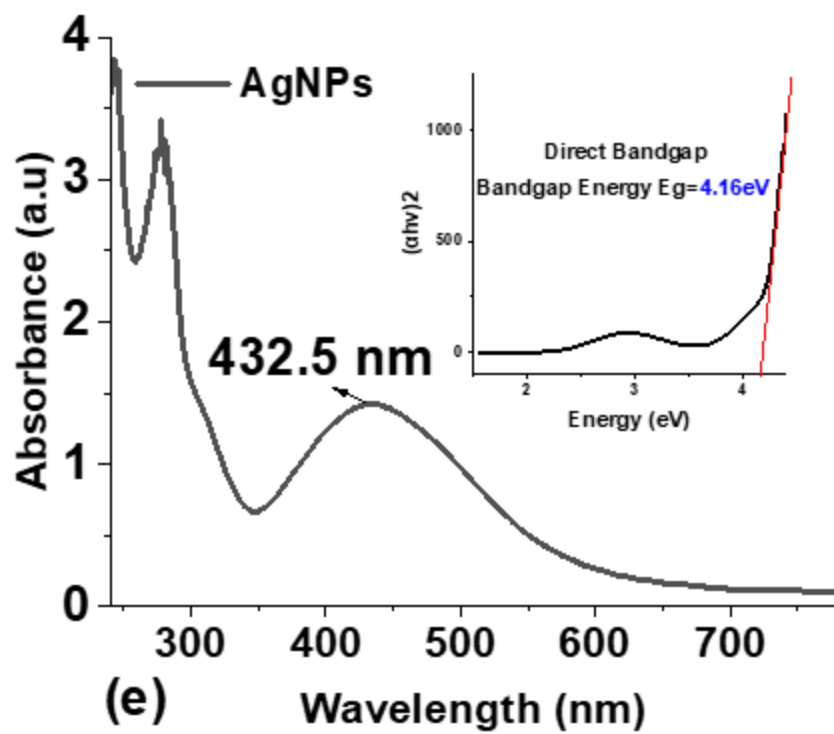


Figure 6

Optimized plot of the AgNP formation peak

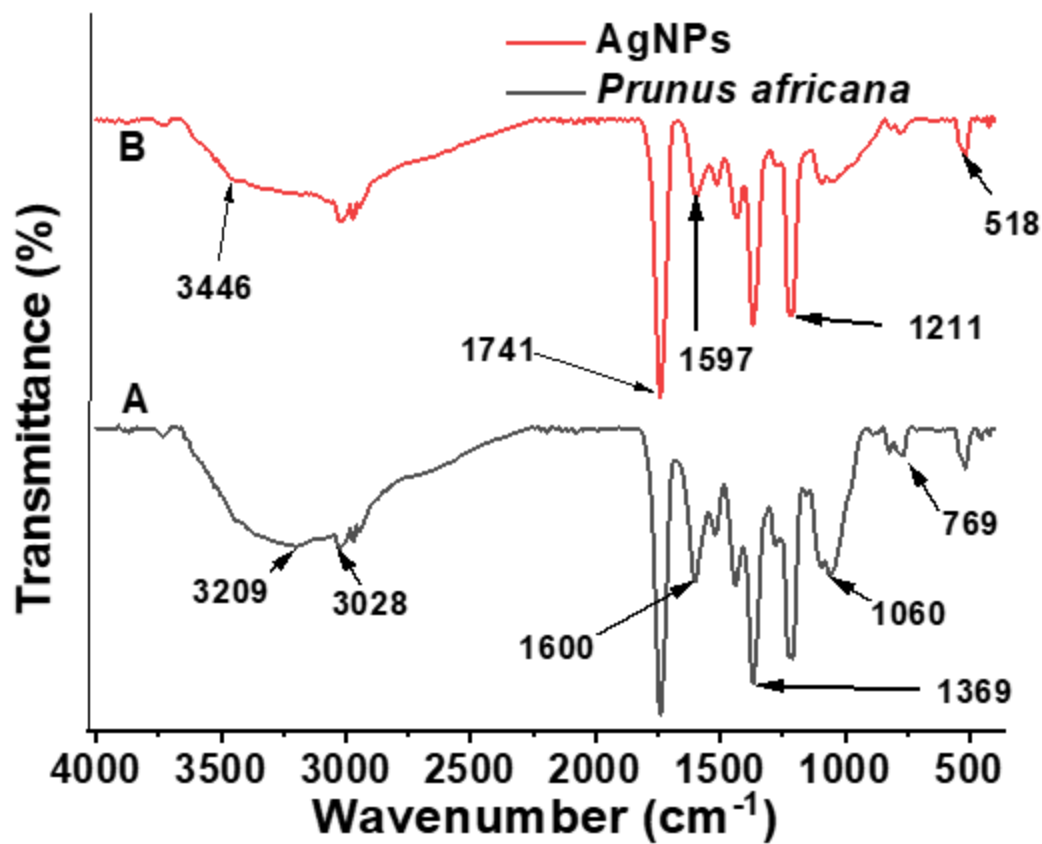


Figure 7

FT-IR spectra of (a) *Prunus africana* stem bark extract and (b) AgNPs

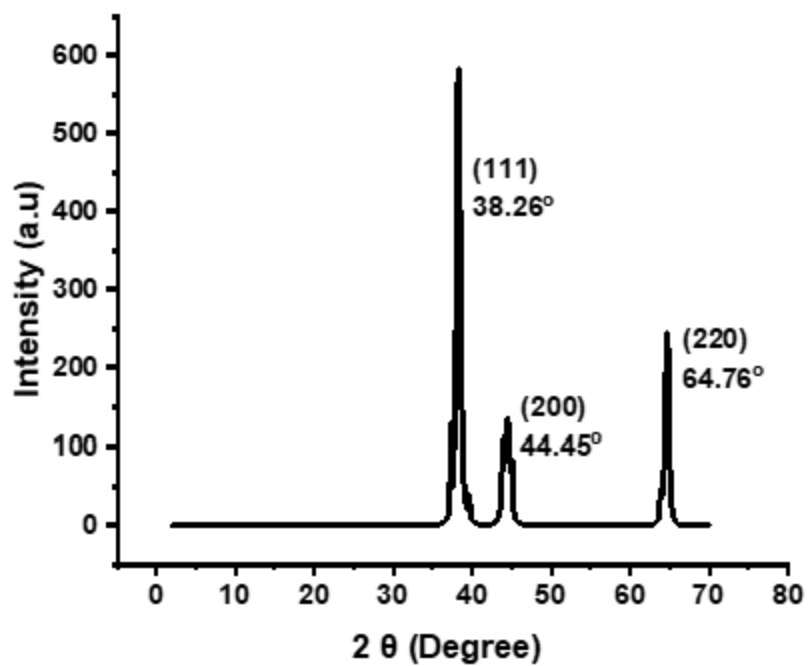


Figure 8

X-ray diffraction pattern of the biosynthesized AgNPs

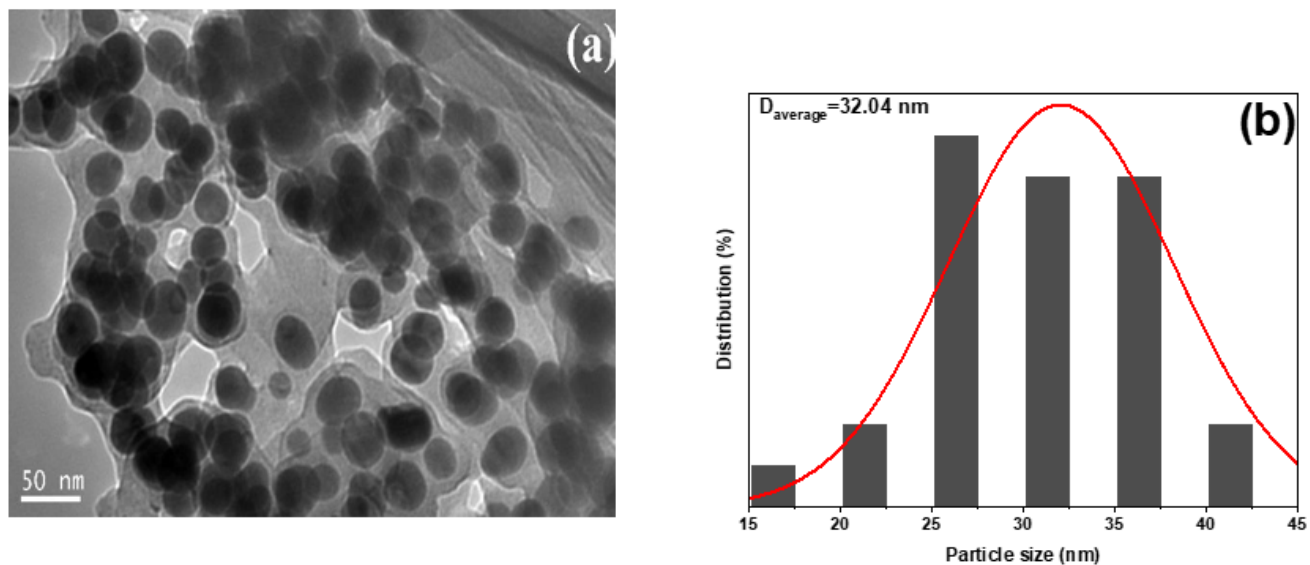


Figure 9

TEM micrograph of the synthesized AgNPs, including (a) an analysis of the morphology of the AgNPs and (b) a histogram that shows the size distribution of the AgNPs

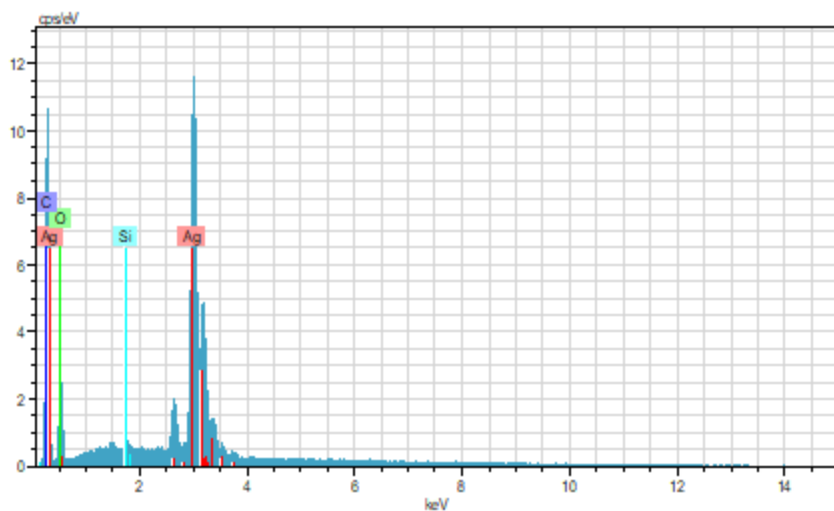


Figure 10

EDS spectrum analysis showing major peaks of the synthesized AgNPs at 3 keV

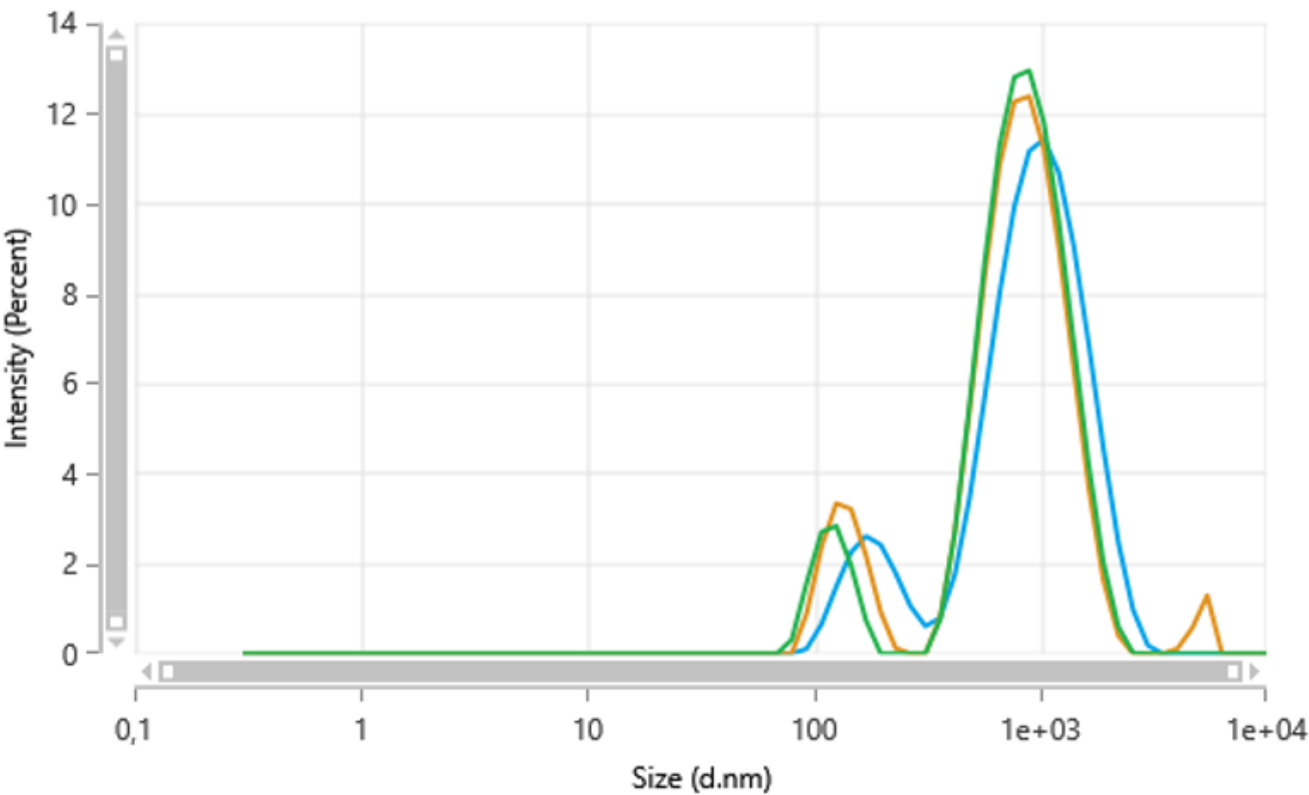


Figure 11

Particle size distribution of the AgNPs

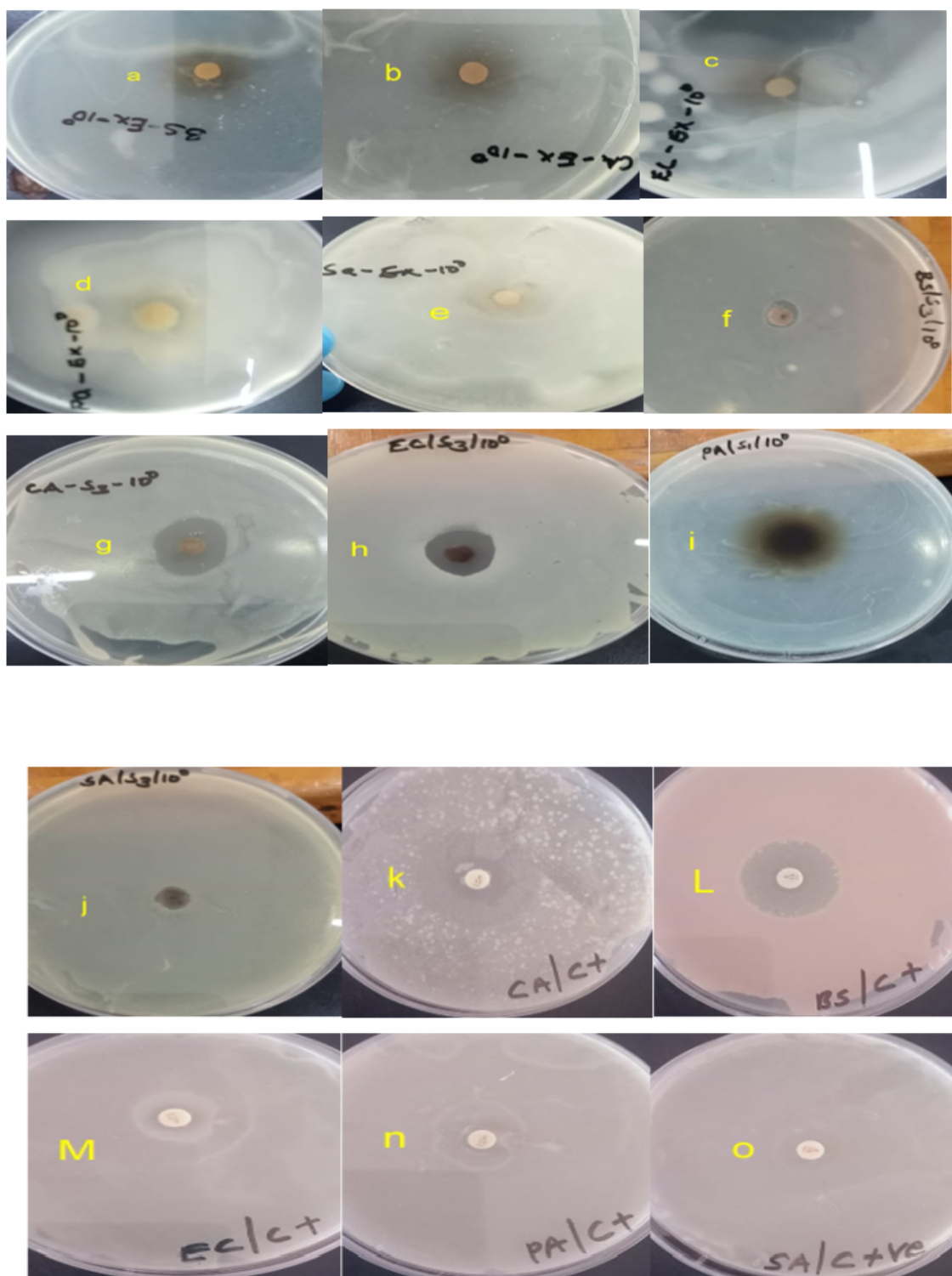


Figure 12

Zones of inhibition of (i) plant extract against (a) *Bacillus subtilis*; (b) *Candida albicans* (Fungus); (c) *Escherichia coli*; (d) *Pseudomonas aeruginosa*; (e) *Staphylococcus aureus* and (ii) AgNPs against (f) *Bacillus subtilis*; (g) *Candida albicans* (Fungus); (h) *Escherichia coli*; (i) *Pseudomonas aeruginosa*; (j) *Staphylococcus aureus*; and (iii) erythromycin against (k) *Candida albicans* (Fungus), (l) *Bacillus subtilis*; (m) *Escherichia coli*; (n) *Pseudomonas aeruginosa*; and (o) *Staphylococcus aureus*

