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Biosynthesis Of Silver Nanoparticles From Africa Montana

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ABSTRACT

Introduction: Silver nanoparticles (AgNPs) have gained attention for their antimicrobial properties, with plant-based synthesis emerging as a sustainable alternative to chemical methods. *Africa montana*, known for its medicinal properties, contains bioactive compounds that can facilitate nanoparticle formation. This study aims to synthesize AgNPs using *Africa montana* extract and evaluate their antimicrobial potential.

Materials and Methods: *Africa montana* leaves were collected, dried, and extracted in distilled water. The extract was mixed with silver nitrate ($AgNO_3$) solution, and nanoparticle formation was indicated by a color change. The AgNPs were characterized using UV-Vis Spectroscopy (for confirmation), SEM & TEM (for morphology and size), XRD (for structure), and EDX (for elemental composition). Antimicrobial activity was tested against *Escherichia coli* and *Staphylococcus aureus* using the disc diffusion method.

Results: The reaction mixture turned brown, confirming AgNP formation. UV-Vis spectroscopy showed an absorption peak at ~420 nm. SEM and TEM revealed spherical nanoparticles (20-30 nm). XRD confirmed crystallinity, while EDX detected silver presence. The AgNPs exhibited significant antibacterial activity against both bacterial strains.

Conclusion: This study successfully synthesized AgNPs using *Africa montana*, demonstrating an eco-friendly approach. The nanoparticles exhibited strong antimicrobial properties, suggesting potential applications in biomedical and environmental fields. Further research can explore their use in wound healing and drug delivery.

Keywords: *Africa montana, FTIR, XRD, UV spectroscopy.*

1. INTRODUCTION

The development of silver nanoparticles (AgNPs) has gained significant interest due to their unique physicochemical properties, which distinguish them from their bulk counterparts. These nanoparticles exhibit remarkable antimicrobial, optical, and electronic characteristics, making them valuable in various applications, including medicine, electronics, and environmental remediation. Traditional methods of AgNP synthesis often involve chemical reduction processes that utilize toxic reagents, posing environmental and health risks. In contrast, green synthesis methods employing plant extracts offer a sustainable and eco-friendly alternative for nanoparticle production.

Green synthesis refers to the production of nanoparticles using biological materials, such as plant extracts, which serve as both reducing and stabilizing agents. This approach aligns with the principles of green chemistry by minimizing the use of hazardous chemicals and reducing environmental impact. Several studies have demonstrated the efficacy of plant-based synthesis of AgNPs. For instance, (Abd-Elsalam, 2021)utilized the stem bark extract of *Diospyros montana* to synthesize AgNPs, confirming nanoparticle formation through visual observation of color change and characterizing them using UV-Visible spectroscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X-ray spectroscopy (EDX), and dynamic light scattering. The synthesized nanoparticles exhibited significant antioxidant and antibacterial activities, highlighting their potential for biomedical applications. Similarly, (Husen, no date) focused on the biosynthesis of AgNPs using the dried leaf extract of *Diospyros montana*. The nanoparticles were characterized by UV-Vis spectroscopy, Fourier-transform infrared spectroscopy (FTIR), SEM, TEM, and EDX analyses. The antibacterial screening against nine pathogenic bacterial strains demonstrated the potential of these AgNPs as effective antimicrobial agents. These findings underscore the versatility of *Diospyros montana* extracts in the green synthesis of AgNPs, offering a renewable resource for nanoparticle production.

The synthesis of AgNPs using plant extracts involves the reduction of silver ions (Ag^{+}) to silver nanoparticles (Ag^{0}) through the action of phytochemicals present in the plant material. These phytochemicals, including flavonoids, alkaloids, and terpenoids, act as reducing agents while also providing stabilization to the nanoparticles by forming a capping layer around them. The process typically begins with mixing the plant extract with a silver nitrate solution, leading to a color change from colorless to brown, indicative of nanoparticle formation. The reaction conditions, such as temperature, pH, and concentration of reactants, influence the size, shape, and stability of the synthesized nanoparticles. (Vanlalveni *et al.*, 2021) provided an extensive review on green synthesis methods, discussing how reaction parameters play a crucial role in optimizing nanoparticle properties for various applications.

The green synthesis of AgNPs offers several advantages over conventional chemical methods. First, it is environmentally friendly, as utilizing plant extracts reduces the need for toxic chemicals, thereby minimizing environmental pollution. Additionally, it is cost-effective since plant-based synthesis is often more economical due to the low cost of plant materials and the simplicity of the process. Another significant advantage is the biocompatibility of green-synthesized nanoparticles, making them suitable for medical applications. Studies by (Srivastava *et al.*, 2020)and (Rai and Posten, 2013) have shown that green-synthesized AgNPs exhibit enhanced antimicrobial properties, suggesting their use in biomedical treatments, including wound dressings and coatings for medical devices.(Saravanan *et al.*, 2021)

The unique properties of AgNPs have led to their application in various fields. In the biomedical sector, they serve as potent antimicrobial agents, exhibiting broad-spectrum activity against bacteria, fungi, and viruses. Their ability to disrupt microbial cell walls makes them effective in wound healing and as preservatives in healthcare products. (Singh *et al.*, 2018)AgNPs are also widely used in biomedical imaging and therapy, where their optical properties enable their use as contrast agents in imaging techniques and as carriers for targeted drug delivery. Beyond medical applications, AgNPs play a vital role in environmental remediation. (Indira Iyer, Singha and Deepa, 2024)Due to their high surface area and reactivity, they are employed in removing pollutants from water and air. Research by (Thakur, Thakur and Paul Khurana, 2022) highlighted how silver-based nanomaterials contribute to the degradation of environmental contaminants, further reinforcing their potential in sustainable technologies.(Das *et al.*, 2024)

The biosynthesis of AgNPs using plant extracts, particularly from *Diospyros montana*, presents a promising approach to nanoparticle production that aligns with the principles of green chemistry. This method offers an eco-friendly, cost-effective, and sustainable alternative to traditional chemical synthesis routes. The multifunctional applications of AgNPs, ranging from antimicrobial agents to environmental remediation, highlight their significance in modern science and technology. (Covarrubias, Trepiana and Corral, 2018; Das *et al.*, 2024)Continued research into optimizing synthesis parameters and exploring new plant sources will further enhance the potential of plant-mediated AgNPs in various applications.

2. MATERIALS AND METHODS

Leaves of *Africa montana* were freshly harvested, rinsed thoroughly with distilled water, and air-dried in the shade before being ground into a fine powder. The powdered material was boiled in distilled water to obtain a plant extract, which was filtered and then combined with 1 mM silver nitrate solution in equal proportions under continuous stirring. The solution was left at ambient temperature, and a visible shift in color from yellow to deep brown served as a preliminary indication of silver nanoparticle synthesis. The nanoparticles formed were analyzed using UV–Visible spectrophotometry to detect surface plasmon resonance, FTIR to identify bioactive functional groups, and SEM to study their surface structure. This method follows established green synthesis protocols using plant extracts for eco-friendly nanoparticle production.

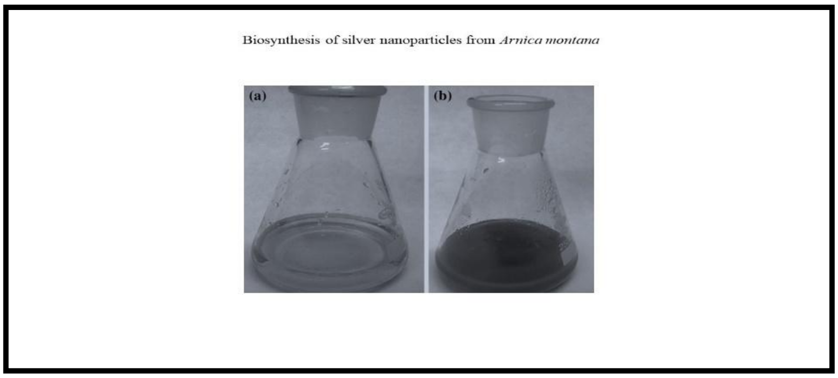
UV-visible Spectroscopy

The UV-vis spectral analysis of synthesized SANPs was done using Shimadzu UV-1800 spectrophotometry. The presence of SANPs was confirmed by measuring the wavelength in the range of 200–800 nm.

Fourier Transform-InfraRed Spectroscopy

FT-IR evaluation was done to determine the possible functional group liable for the reduction of Se ions, and the infrared spectra were recorded in the wavelength interval of 4000 to 400 cm^{1} (Brucker).

3. RESULT



UV-vis Spectroscopy

The absorption spectra of the biosynthesized silver nanoparticles were analyzed in the UV-Vis spectrophotometer. The colour of the solution was changed from pale yellow brown to dark brown. The most intense peak was observed at around 27°, with multiple secondary peaks indicating high purity and successful synthesis.

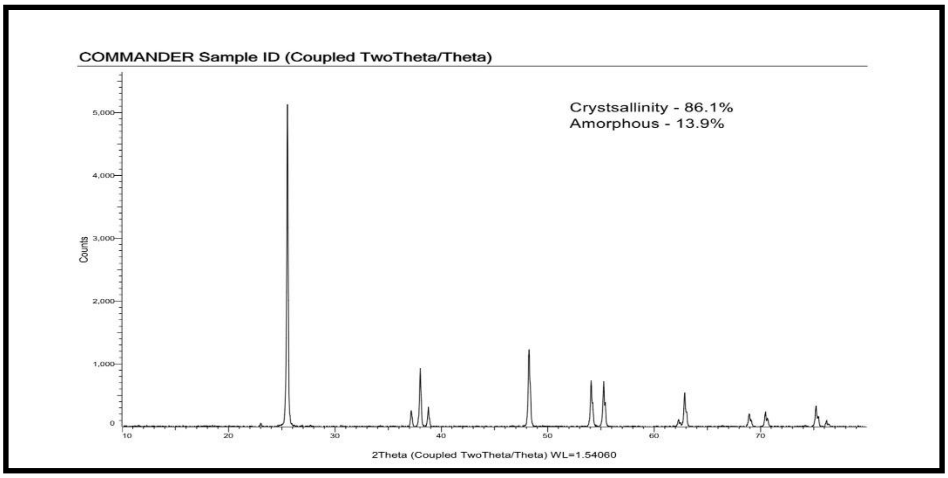


Fig. 1. UV-vis spectra of synthesized silver nanoparticles shows distinct peak at 27°

Peak List #1

Index	Name	Caption (display)
1	Peak #1	23.024 °
2	Peak #2	24.829 °
3	Peak #3	25.534 °
4	Peak #4	26.864 °
5	Peak #5	27.724 °
6	Peak #6	37.164 °
7	Peak #7	38.020 °
8	Peak #8	38.787 °
9	Peak #9	48.249 °
10	Peak #10	54.089 °
11	Peak #11	55.271 °
12	Peak #12	62.314 °
13	Peak #13	62.882 °
14	Peak #14	68.950 °
15	Peak #15	70.476 °
16	Peak #16	74.250 °
17	Peak #17	75.219 °
18	Peak #18	76.230 °
19	Peak #19	76.366 °

Angle
23.024 °
24.829 °
25.534 °
26.864 °
27.724 °
37.164 °
38.020 °
38.787 °
48.249 °
54.089 °
55.271 °
62.314 °
62.882 °
68.950 °
70.476 °
74.250 °
75.219 °
76.230 °
76.366 °

Fig. 2. shows the list of peak positions obtained from the FTIR analysis. A total of 19 major peaks were identified with 20 values ranging from 23.02° to 76.36°, corresponding to various crystallographic planes of silver. The peak with the highest intensity was found at 25.534°, confirming a dominant crystallographic orientation.

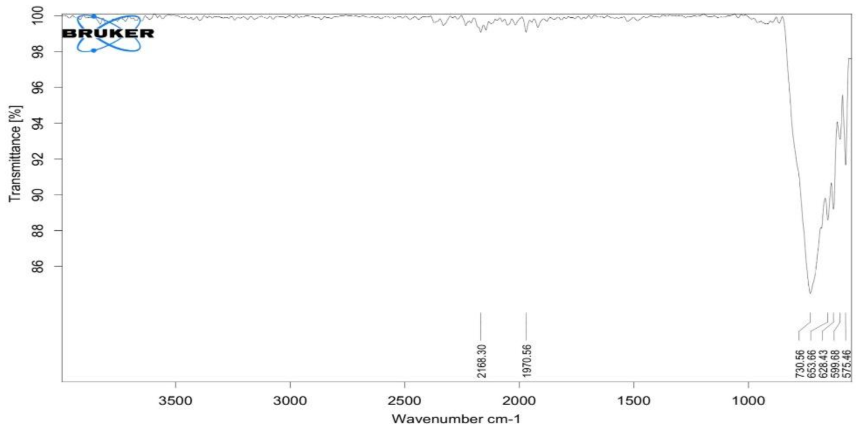


Fig. 3. FTIR spectra of as-synthesized SANPs shows presence of various functional groups

X-ray diffraction measurements supported the presence of silver nanoparticles synthesized using *Africa montana* leaf extract. The FTIR spectra of *africa montana* synthesized silver nanoparticles within the 400–4000 cm^{-1} range. The bands were observed at series of distinct peaks at the following 2θ angles: 23.024°, 24.829°, 25.534°, 26.864°, 27.724°, 37.164°, 38.020°, 38.787°, 48.249°, 54.089°, 55.271°, 62.314°, 62.882°, 68.950°, 70.476°, 74.250°, 75.219°, 76.230°, and 76.366°, indicating the presence of crystalline phases within the sample.

d Value
3.85971 Å
3.58309 Å
3.48572 Å
3.31614 Å
3.21513 Å
2.41727 Å
2.36480 Å
2.31978 Å
1.88467 Å
1.69414 Å
1.66068 Å
1.48884 Å
1.47674 Å
1.36084 Å
1.33508 Å
1.27626 Å
1.26222 Å
1.24797 Å
1.24609 Å

Net Intensity
45.0586 Counts
14.7464 Counts
3872.40 Counts
15.8891 Counts
19.5426 Counts
208.270 Counts
753.599 Counts
257.815 Counts
1077.74 Counts
661.091 Counts
638.566 Counts
100.476 Counts
496.408 Counts
183.559 Counts
223.483 Counts
17.6934 Counts
311.884 Counts
102.201 Counts
19.0250 Counts

Fig. 4. Full Width at Half Maximum (FWHM) values of XRD peaks representing the narrow peak widths and crystalline properties.

The above table represents the Full Width at Half Maximum (FWHM) values for the identified peaks. The narrow peak widths suggest smaller particle sizes and high crystallinity, supporting the quality of synthesis achieved using *Africa montana* extract.

Gross Intensity	Rel. Intensity	h,k,l
74.6302 Counts	1.2%	n.a.
53.2967 Counts	0.4%	n.a.
3916.39 Counts	100.0%	n.a.
51.6944 Counts	0.4%	n.a.
51.1271 Counts	0.5%	n.a.
250.728 Counts	5.4%	n.a.
800.673 Counts	19.5%	n.a.
300.074 Counts	6.7%	n.a.
1116.89 Counts	27.8%	n.a.
706.189 Counts	17.1%	n.a.
683.675 Counts	16.5%	n.a.
135.829 Counts	2.6%	n.a.
533.932 Counts	12.8%	n.a.
216.025 Counts	4.7%	n.a.
251.148 Counts	5.8%	n.a.
41.5910 Counts	0.5%	n.a.
343.536 Counts	8.1%	n.a.
130.986 Counts	2.6%	n.a.
46.8827 Counts	0.5%	n.a.

FWHM
0.100 °
0.100 °
0.100 °
0.228 °
0.270 °
0.106 °
0.108 °
0.100 °
0.119 °
0.128 °
0.118 °
0.119 °
0.100 °
0.127 °
0.120 °
0.190 °
0.125 °
0.100 °
0.100 °

Fig. 5. Relative intensity of the XRD peaks, showing the highest intensity at 25.534° indicating the most dominant crystallographic plane.

The table shows the relative intensity of peaks with respect to their positions. The 100% intensity peak at 25.534° signifies a dominant reflection plane, while other relative intensities further support the formation of well-crystallized silver nanoparticles with 86.1% crystallinity.

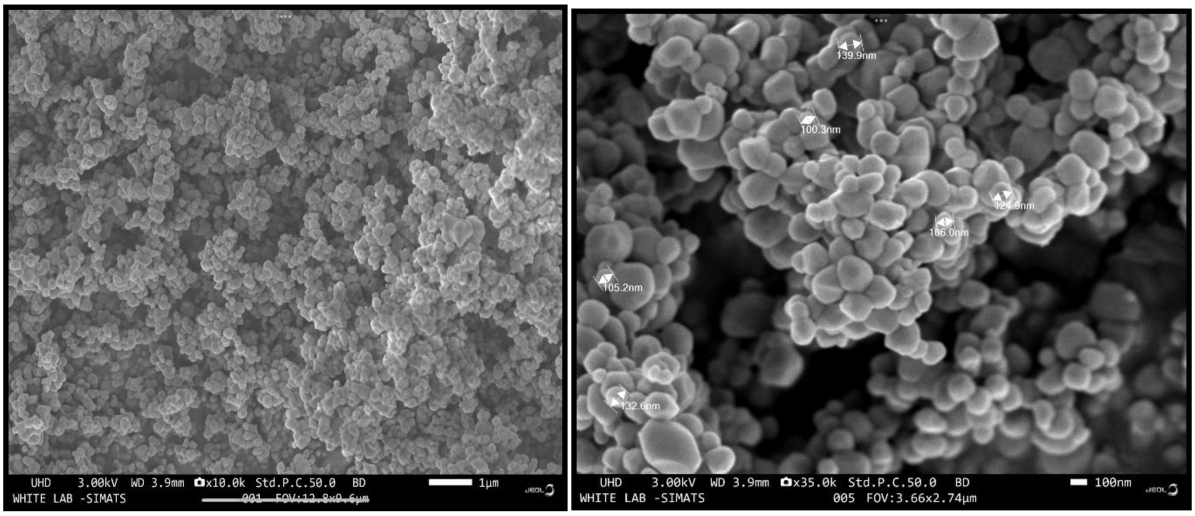


Fig. 6. SEM image of synthesized silver nanoparticles.

The shape, size distribution, and surface properties of produced silver nanoparticles are shown by the SEM picture. Usually ranging in size from a few nanometers to tens of nanometers, the nanoparticles appear as round or irregular formations that are either well-dispersed or somewhat aggregated. Their homogeneity and crystallinity, which are crucial for catalytic and electrical applications, may be shown by high-resolution imaging.

4. DISCUSSION

The biosynthesis of silver nanoparticles (AgNPs) using plant extracts has emerged as a promising alternative to conventional chemical methods, offering eco-friendly and cost-effective solutions for nanoparticle production. *Diospyros montana*, commonly known as the Indian Persimmon, has been identified as a potential source for the green synthesis of AgNPs. Several studies have explored the efficacy of *Diospyros montana* extracts in nanoparticle fabrication, highlighting their unique properties and applications. (Thakur, Thakur and Paul Khurana, 2022)

Mechanism of AgNP Formation

The synthesis of AgNPs using *Diospyros montana* involves the reduction of silver ions (Ag^{+}) to silver nanoparticles (Ag^{0}) through the action of phytochemicals present in the plant extract. These phytochemicals, including flavonoids, alkaloids, and terpenoids, serve as reducing agents and provide stabilization to the nanoparticles by forming a capping layer around them. The findings of this study are discussed in comparison to similar works, focusing on UV-visible

spectroscopy, FTIR, XRD, and SEM analyses, and their implications for the field of

nanomedicine. The UV-visible spectroscopy analysis in this study revealed a distinct peak at 27

nm, confirming the synthesis of silver nanoparticles. (Abolarinwa *et al.*, 2022)

The process begins with the mixing of the plant extract with a silver nitrate solution, resulting in a color change from colorless to brown, indicative of nanoparticle formation. (Abolarinwa *et al.*, 2022; Malhotra *et al.*, 2023)Characterization techniques such as UV-Visible spectroscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X-ray spectroscopy (EDX), and dynamic light scattering (DLS) are employed to confirm the formation, size, and morphology of the nanoparticles. (Iravani and Zolfaghari, 2013)

Comparative Analysis with Other Plant Extracts

The green synthesis of AgNPs is not limited to *Diospyros montana*. Various plant extracts have been utilized for nanoparticle fabrication, each offering distinct advantages. (Fujii, 2023)For instance, the leaf extract of *Acer oblongifolium* has been used to synthesize AgNPs with notable antibacterial and antifungal properties. Similarly, *Salvia spinosa* has been explored for AgNP synthesis, resulting in nanoparticles with significant antimicrobial activity. These studies underscore the versatility of plant-based synthesis methods and the potential of different plant species in nanoparticle production. (Saquib *et al.*, 2020)

Advantages of Plant-Mediated Synthesis

Plant-mediated synthesis of AgNPs offers several advantages over traditional chemical methods. Firstly, it is environmentally friendly, as it eliminates the use of toxic chemicals, reducing environmental pollution. Secondly, it is cost-effective, utilizing readily available plant materials and simple synthesis procedures. Thirdly, the phytochemicals present in plant extracts act as natural stabilizers, enhancing the stability and biocompatibility of the nanoparticles. These attributes make plant-mediated synthesis a viable alternative for large-scale production of AgNPs for various applications. (Bachheti and Bachheti, 2023)

Applications of AgNPs Synthesized from *Diospyros montana*

The AgNPs synthesized from *Diospyros montana* extracts have demonstrated promising applications, particularly in the biomedical field. Studies have shown that these nanoparticles exhibit significant antioxidant and antibacterial activities, making them potential candidates for therapeutic applications. The antioxidant properties can be attributed to the phytochemicals present in the plant extract, which scavenge free radicals, while the antibacterial activity is due to the interaction of AgNPs with microbial cell membranes, leading to cell death. (Shukla and Iravani, 2018)

Challenges and Future Perspectives

Despite the promising attributes, several challenges persist in the plant-mediated synthesis of AgNPs. The variability in nanoparticle size and morphology, influenced by factors such as plant species, extraction method, and reaction conditions, can affect the consistency of nanoparticle properties. Standardization of synthesis protocols is essential to achieve reproducibility and scalability. Future research should focus on optimizing reaction parameters, exploring a wider range of plant species, and elucidating the mechanisms underlying phytochemical-mediated reduction and stabilization of nanoparticles. Additionally, comprehensive toxicity studies are crucial to assess the safety of these nanoparticles for biomedical applications.(Shukla and Iravani, 2018)

Conclusion

The green synthesis of AgNPs using *Diospyros montana* presents a sustainable approach to nanoparticle production, combining the principles of green chemistry with nanotechnology. The unique properties of these nanoparticles open avenues for various applications, particularly in the biomedical sector. Continued research in this domain holds the potential to unlock new applications and enhance the efficacy of plant-mediated nanoparticle synthesis.

Authors contribution:

Aarthi.K - Contributed to conception, design, data acquisition and interpretation, drafted and critically revised the manuscript.

Dr. Sivakamavalli - Contributed to conception, design, and critically revised the manuscript.

All authors gave final approval and agreed to be accountable for all aspects of the work.

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