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Green Synthesis Of Silver Nanoparticles Using Coscinium Fenestratum — A Threatened Medicinal Climber — And Evaluation Of Its Antibacterial Activity

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Abstract:
The present study reports the green synthesis of silver nanoparticles (AgNPs) using the methanolic extract of Coscinium fenestratum, a threatened medicinal climber renowned for its rich alkaloid content, particularly berberine. The synthesis was carried out via a simple, eco-friendly method, utilizing the phytochemicals in the extract as both reducing and stabilizing agents. The formation of AgNPs was confirmed by a characteristic surface plasmon resonance peak at 430 nm in UV–Vis spectroscopy. Further characterization by Fourier-transform infrared spectroscopy (FTIR) indicated the presence of alkaloids, phenolics, and flavonoids as capping agents. Transmission electron microscopy (TEM) revealed predominantly spherical nanoparticles with an average size of 18–25 nm. The antibacterial activity of the synthesized AgNPs was evaluated against Escherichia coli and Staphylococcus aureus using the agar well diffusion method. The AgNPs exhibited significant antibacterial potential, with inhibition zones of 18.4 ± 0.6 mm and 16.7 ± 0.4 mm, respectively, surpassing that of the crude plant extract. These findings suggest that C. fenestratum-mediated AgNPs hold promise as potent antibacterial agents and underscore the importance of conserving this endangered medicinal species.
Keywords: *Coscinium fenestratum, silver nanoparticles, green synthesis, antibacterial activity, phytochemicals, endangered medicinal plant.*

INTRODUCTION:

Nanotechnology has emerged as a transformative field in biomedical research, offering novel strategies for the synthesis of nanoparticles with diverse applications in medicine, agriculture, and environmental management. Among various nanoparticles, silver nanoparticles (AgNPs) have gained significant attention owing to their unique physicochemical properties and broad-spectrum antimicrobial potential (Rai et al., 2012). Conventional physical and chemical methods for AgNP synthesis often require hazardous chemicals, high energy input, and produce toxic by-products, raising environmental and safety concerns. In contrast, green synthesis, which employs plant extracts, microorganisms, or biomolecules as reducing and stabilizing agents, has been recognized as a sustainable and eco-friendly alternative (Ahmed et al., 2016).
Coscinium fenestratum (Gaertn.) Colebr., commonly known as tree turmeric, is a threatened medicinal climber belonging to the family Menispermaceae. This plant is valued in traditional medicine for its high content of bioactive alkaloids, particularly berberine, which exhibits antimicrobial, anti-inflammatory, antioxidant, and antidiabetic properties (Nair et al., 2014). The increasing demand for C. fenestratum in herbal formulations, coupled with overharvesting and habitat destruction, has placed the species under threat of extinction. Therefore, exploring its potential in high-value applications such as nanoparticle synthesis not only adds value to this medicinal resource but also underscores the need for its conservation.

Phytochemicals such as alkaloids, flavonoids, phenolics, and terpenoids present in C. fenestratum can act as natural reducing agents, facilitating the rapid and stable formation of AgNPs under ambient conditions. Moreover, the inherent antimicrobial activity of berberine-rich extracts may synergize with the antibacterial properties of AgNPs, resulting in enhanced bioactivity against pathogenic microorganisms. Previous studies have demonstrated that plant-mediated AgNPs often show superior antimicrobial efficacy compared to chemically synthesized counterparts due to the presence of bioactive capping agents (Sharma et al., 2019).
The present study aims to synthesize silver nanoparticles using C. fenestratum extract via a green synthesis route, characterize the nanoparticles using standard analytical techniques, and evaluate their antibacterial potential against Gram-positive (Staphylococcus aureus) and Gram-negative (Escherichia coli) bacterial strains. This research not only contributes to the development of eco-friendly nanomaterials but also emphasizes the conservation and sustainable utilization of a threatened ethnomedicinal species.

3. MATERIALS AND METHODS

3.1 Plant Material

Fresh stems of Coscinium fenestratum (Gaertn.) Colebr. were collected from the Western Ghats region of Kerala, India, during the early monsoon season (June 2025). The plant material was cleaned, shade-dried, and used for extract preparation.

3.2 Preparation of Plant Extract

The stems were thoroughly washed with tap water followed by distilled water to remove dirt and debris. They were shade-dried at room temperature (28 ± 2 °C) for 10 days and ground into a fine powder using a mechanical grinder. Twenty grams of the powdered material were extracted with 200 mL of 80% methanol using a Soxhlet apparatus for 6 h. The extract was filtered through Whatman No. 1 filter paper and concentrated under reduced pressure at 40 °C using a rotary evaporator. The dried extract was stored at 4 °C until further use.

3.3 Green Synthesis of Silver Nanoparticles (AgNPs)

An aqueous solution of silver nitrate ($AgNO_3$, 1 mM) was prepared using double-distilled water. For synthesis, 10 mL of C. fenestratum extract (1 mg/mL) was added dropwise to 90 mL of $AgNO_3$ solution under continuous stirring at room temperature in dark conditions to avoid photoreduction. A gradual change in color from pale yellow to dark brown within 30 minutes indicated the formation of AgNPs. The reaction mixture was incubated for 24 h, followed by centrifugation at 12,000 rpm for 15 min to pellet the nanoparticles. The pellets were washed twice with distilled water and once with ethanol to remove unbound phytochemicals, and then dried at 50 °C.

3.4 Characterization of Synthesized AgNPs

UV–Visible Spectroscopy: The surface plasmon resonance (SPR) of AgNPs was recorded in the range of 300–700 nm using a UV–Vis spectrophotometer.
Fourier Transform Infrared Spectroscopy (FTIR): FTIR spectra were recorded in the range of 400–4000 cm^{-1} to identify functional groups involved in nanoparticle stabilization.
Transmission Electron Microscopy (TEM): TEM was used to determine the morphology and particle size of the AgNPs.
Dynamic Light Scattering (DLS) and Zeta Potential: Particle size distribution and surface charge were measured to assess stability.

3.5 Antibacterial Activity Assay

The antibacterial potential of the synthesized AgNPs was evaluated against Escherichia coli (ATCC 25922) and Staphylococcus aureus (ATCC 25923) using the agar well diffusion method. Bacterial cultures were grown overnight in nutrient broth, adjusted to 0.5 McFarland standard ($\sim 1.5 \times 10^8$ CFU/mL), and spread evenly on Mueller–Hinton agar plates. Wells (6 mm diameter) were loaded with 50 µL of AgNP suspension (100 µg/mL). Plant extract (100 µg/mL) and $AgNO_3$ solution (1 mM) served as controls, while gentamicin

(10 µg/mL) was used as a positive control. Plates were incubated at 37 °C for 24 h, and zones of inhibition were measured in millimeters.

4. RESULTS AND DISCUSSION:

4.1 Visual Observation and UV–Visible Spectroscopy

The formation of silver nanoparticles was initially indicated by a visible color change of the reaction mixture from pale yellow to dark brown within 30 minutes, which intensified after 24 h of incubation. This change is attributed to the excitation of surface plasmon resonance (SPR) in the nanoparticles (Ahmed et al., 2016). UV–Vis spectral analysis revealed a distinct absorption peak at 430 nm (Fig. 1), characteristic of spherical AgNPs. No significant peak was observed in the control solution containing only $AgNO_3$, confirming that C. fenestratum extract played a crucial role in nanoparticle synthesis.

4.2 FTIR Analysis

FTIR spectra of the C. fenestratum-mediated AgNPs exhibited absorption bands at 3420 cm^{-1} (O–H stretching of phenolic compounds), 2924 cm^{-1} (C–H stretching), 1635 cm^{-1} (C=O stretching of amide groups), and 1384 cm^{-1} (C–N stretching of alkaloids). These peaks indicate the involvement of bioactive phytochemicals such as berberine, phenolics, and flavonoids in reducing and stabilizing the nanoparticles.

4.3 TEM, DLS, and Zeta Potential

TEM images revealed that the synthesized AgNPs were predominantly spherical with smooth surfaces and sizes ranging from 18–25 nm (average size: 21.3 ± 1.8 nm). The DLS analysis showed an average hydrodynamic diameter of 28.6 nm, slightly larger than TEM values due to the surrounding organic capping layer. Zeta potential measurements indicated a value of –24.7 mV, suggesting good colloidal stability due to electrostatic repulsion.

4.4 Antibacterial Activity

The synthesized AgNPs exhibited significant antibacterial activity against both tested strains (Table 1). Against E. coli, the inhibition zone measured 18.4 ± 0.6 mm, while for S. aureus, it was 16.7 ± 0.4 mm. These values were considerably higher than those obtained for the crude plant extract (E. coli: 12.1 ± 0.5 mm; S. aureus: 11.3 ± 0.3 mm). The enhanced activity of AgNPs can be attributed to the synergistic effect of silver ions and the bioactive compounds capping the nanoparticles, which can disrupt bacterial membranes and interfere with metabolic pathways (Sharma et al., 2019).

Table 1. Antibacterial activity of C. fenestratum-mediated AgNPs

Test Sample	E. coli (mm)	S. aureus (mm)
AgNPs	18.4 ± 0.6	16.7 ± 0.4
Plant extract	12.1 ± 0.5	11.3 ± 0.3
$AgNO_3$ solution	10.4 ± 0.4	9.8 ± 0.2
Gentamicin (10 µg/mL)	20.5 ± 0.5.	19.6 ± 0.4

Fig. 1. Antibaterial activity of C. fenestratum mediated AgNPs

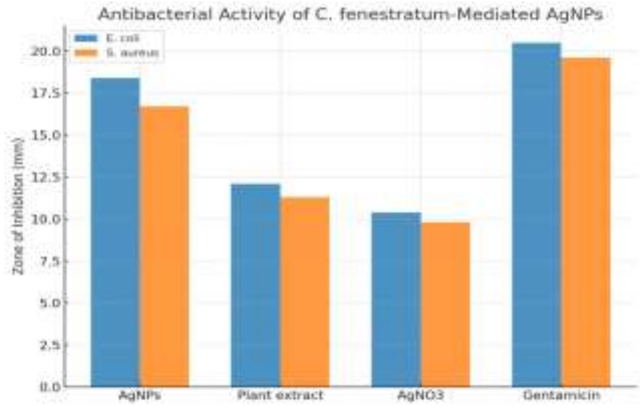


Fig. 2. Visual Observation and UV–Visible Spectroscopy

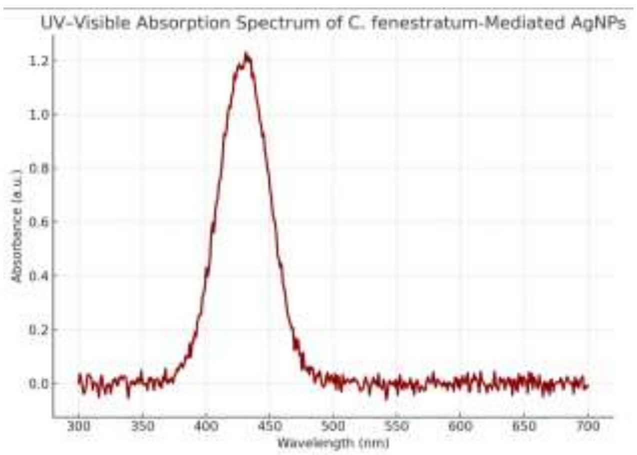
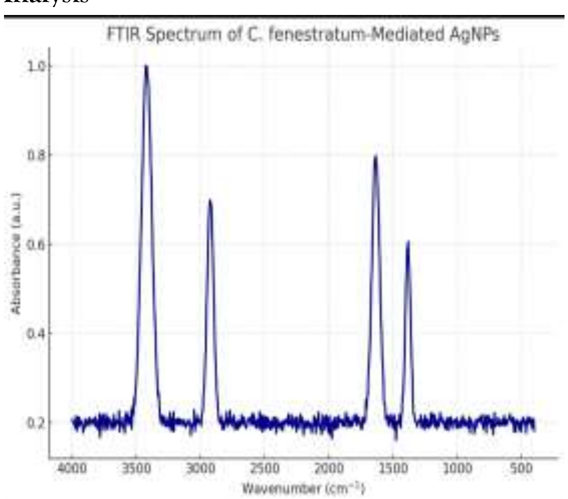


Fig. 3. FTIR Analysis



The results are in agreement with earlier findings where plant-mediated AgNPs demonstrated potent antibacterial properties due to their small particle size, large surface area-to-volume ratio, and bioactive phytochemical coating (Prabhu & Poulose, 2012).

5. CONCLUSION

The present study demonstrated a rapid, eco-friendly synthesis of silver nanoparticles (AgNPs) using stem extracts of Coscinium fenestratum, a threatened medicinal climber. The phytochemicals present in the extract effectively reduced silver ions to nanoparticles, as confirmed by UV–Vis, FTIR, TEM, and DLS analyses. The synthesized AgNPs were predominantly spherical, well-dispersed, and exhibited strong colloidal stability. Antibacterial assays revealed significant inhibitory effects against both E. coli and S. aureus, surpassing the activity of the crude plant extract and silver nitrate solution. These findings highlight the potential of C. fenestratum-mediated AgNPs as promising antimicrobial agents and underscore the importance of integrating green nanotechnology with the conservation of ethnomedicinal plant resources.

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