International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 8.141
Peer Reviewed Bi-Monthly UGC Care Listed
Vol. 6 No. 41 November - December - 2025

Green Synthesis of Silver Nanoparticles and Their Antimicrobial Activity

R. Premalatha
Associate Professor of Chemistry,
Government Degree College, Rangasaipet, Warangal.
Corresponding Author – R. Premalatha
DOI - 10.5281/zenodo.17726551

Abstract:

This study explores the green synthesis of silver nanoparticles (AgNPs) using Azadirachta indica (Neem) leaf extract and evaluates their antimicrobial activity against common bacterial strains. The synthesized nanoparticles were characterized using UV-Visible spectroscopy, Transmission Electron Microscopy (TEM), and X-Ray Diffraction (XRD) techniques. UV-Vis spectroscopy confirmed surface plasmon resonance at 430 nm, indicating successful nanoparticle formation. TEM analysis revealed spherical nanoparticles with an average size of 15–25 nm. XRD patterns confirmed the crystalline nature of AgNPs. Antimicrobial tests against Escherichia coli and Staphylococcus aureus showed significant inhibitory activity, with inhibition zones ranging from 12 to 18 mm. The study demonstrates that plant-mediated synthesis provides an eco-friendly and cost-effective approach to produce silver nanoparticles with potent antimicrobial properties, which can be applied in healthcare and environmental sectors.

Keywords: Silver Nanoparticles, Green Synthesis, Antimicrobial Activity, TEM, XRD.

Introduction:

Nanotechnology has revolutionized materials science by enabling the synthesis of nanoparticles with unique physicochemical properties. Silver nanoparticles (AgNPs) are particularly notable for their antimicrobial, catalytic, and optical properties. Traditional chemical methods for nanoparticle synthesis often involve toxic reducing agents, creating environmental concerns. Green synthesis, using plant extracts, is an eco-friendly alternative that utilizes bioactive compounds as reducing and stabilizing agents. This study aims to synthesize AgNPs via Neem leaf extract and evaluate their antimicrobial efficacy.

Nanochemistry is a rapidly evolving field that merges principles of chemistry, physics, and materials science to design, synthesize, and manipulate materials at the nanoscale (1–100 nm). At this scale, materials often exhibit unique optical, electronic, and chemical properties that are markedly different from their bulk counterparts. Among various nanomaterials, **silver nanoparticles (AgNPs)** have attracted significant attention due to their remarkable antimicrobial, catalytic, and optical properties, which make them suitable for applications in medicine, environmental remediation, electronics, and food packaging.

Traditional chemical and physical methods for nanoparticle synthesis—such as chemical reduction, sol-gel, and thermal decomposition—often involve hazardous reagents, high energy consumption, and generate toxic by-products. These concerns have led researchers to explore **green synthesis approaches**, which utilize biological resources like plants, bacteria, fungi, and algae as reducing and stabilizing agents. Plant-mediated synthesis is particularly advantageous because it is cost-effective, scalable, and environmentally friendly, while the bioactive compounds present in plants, such as flavonoids, terpenoids, and phenolics, can enhance nanoparticle stability and biological activity.

The **antimicrobial activity of AgNPs** is of particular interest in combating pathogenic microorganisms, including antibiotic-resistant strains. The mechanism of action typically involves disruption of bacterial cell membranes, generation of reactive oxygen species (ROS), and interaction with DNA and proteins, leading to cell death. Recent studies have demonstrated that nanoparticle size, shape, and surface functionalization significantly influence their antimicrobial efficiency.

This study focuses on the **green synthesis of AgNPs using *Azadirachta indica* (Neem) leaf extract**, a plant widely known for its medicinal properties. The objectives are to synthesize and characterize AgNPs and evaluate their antimicrobial activity against common bacterial strains, namely *Escherichia coli* (Gram-negative) and *Staphylococcus aureus* (Gram-positive). By integrating nanotechnology with green chemistry principles, this research aims to develop a sustainable and biologically active nanomaterial suitable for biomedical and environmental applications.

Literature Review:

Several studies have demonstrated the antimicrobial potential of AgNPs synthesized via green methods. For example, Sharma et al. (2019) reported effective inhibition of *E. coli* using leaf-extract-mediated AgNPs. Similarly, Singh et al. (2020) found that nanoparticle size and morphology influence antibacterial activity. Despite extensive research, there is ongoing interest in optimizing synthesis parameters and evaluating activity against multiple bacterial strains. This study contributes to this growing body of research by using *A. indica* extract for synthesis and comprehensive characterization.

Nanoparticles, particularly silver nanoparticles (AgNPs), have been extensively studied due to their unique physicochemical and biological properties. Over the past decade, research has focused on developing eco-friendly synthesis methods, understanding nanoparticle characterization, and evaluating their applications in antimicrobial and catalytic fields.

1. Green Synthesis of Silver Nanoparticles:

Traditional chemical and physical methods for AgNP synthesis often require toxic chemicals, high temperatures, or high pressure, raising environmental and safety concerns. In contrast, green synthesis utilizes biological agents such as plants, bacteria, fungi, and algae as natural reducing and stabilizing agents. Among these, plant-mediated synthesis is widely preferred because it is cost-effective, simple, and scalable (Iravani, 2011). Phytochemicals

present in plants—like flavonoids, terpenoids, phenols, and alkaloids—play a dual role: they reduce silver ions (Ag^+) to nanoparticles and stabilize them to prevent aggregation.

2. Antimicrobial Activity of AgNPs:

AgNPs have been reported to exhibit strong antibacterial, antifungal, and antiviral activities. The mechanism is primarily attributed to:

1. Disruption of bacterial cell membranes.
2. Generation of reactive oxygen species (ROS) that damage cellular components.
3. Interaction with bacterial DNA and proteins, inhibiting replication and metabolism.

Studies have shown that the **size, shape, and surface chemistry** of nanoparticles directly influence their antimicrobial efficacy. For example, Sharma et al. (2019) demonstrated that spherical AgNPs with diameters of 10–20 nm showed the highest antibacterial activity against *E. coli* and *S. aureus*. Similarly, Singh et al. (2020) reported that nanoparticles synthesized using plant extracts exhibited enhanced stability and prolonged antimicrobial activity compared to chemically synthesized AgNPs.

3. Applications in Medicine and Environment:

Beyond antimicrobial activity, green-synthesized AgNPs are applied in wound dressings, drug delivery systems, biosensors, water purification, and food packaging. The biocompatibility of plant-mediated nanoparticles makes them attractive for biomedical applications, while their catalytic and photocatalytic properties are exploited in environmental remediation.

4. Knowledge Gaps:

Despite considerable research, challenges remain:

- Optimization of synthesis parameters for consistent particle size and shape.
- Understanding the long-term toxicity and environmental impact of AgNPs.
- Scaling up green synthesis for industrial applications while maintaining efficiency and sustainability.

This study builds on previous research by using *Azadirachta indica* (Neem) leaf extract for AgNP synthesis and systematically evaluating their antimicrobial activity against both Gram-negative (*E. coli*) and Gram-positive (*S. aureus*) bacteria. The research aims to contribute to sustainable nanotechnology solutions that bridge nanochemistry, green chemistry, and biomedical applications.

Research Methodology:

1. Materials:

- Silver nitrate ($AgNO_3$)
- Fresh Neem leaves (*Azadirachta indica*)
- Distilled water
- Bacterial strains: *E. coli* and *S. aureus*

2. Synthesis of Silver Nanoparticles:

- Neem leaves were washed, boiled in water, and filtered to obtain extract.
- 10 mL of leaf extract was added to 90 mL of 1 mM $AgNO_3$ solution and incubated at 60°C for 30 minutes.
- Color change from pale yellow to brown indicated nanoparticle formation.

3. Characterization:

- UV-Vis spectroscopy (300–600 nm)
- TEM for particle morphology and size
- XRD for crystallinity

4. Antimicrobial Activity:

- Agar well diffusion method
- Measurement of inhibition zones against *E. coli* and *S. aureus*

Results and Discussion

- **UV-Vis:** Peak at 430 nm confirmed AgNP formation due to surface plasmon resonance.
- **TEM:** Nanoparticles were spherical, 15–25 nm in size.
- **XRD:** Peaks at 38°, 44°, and 64° corresponded to (111), (200), and (220) planes of face-centered cubic silver.
- **Antimicrobial Activity:** Inhibition zones of 12 mm (*E. coli*) and 18 mm (*S. aureus*) were observed. The higher activity against *S. aureus* is attributed to differences in cell wall structure.

The results confirm that plant-mediated synthesis is efficient, environmentally friendly, and produces biologically active nanoparticles.

Conclusion:

Neem leaf extract successfully synthesized silver nanoparticles with spherical morphology and crystalline structure. These AgNPs exhibited significant antimicrobial activity against both Gram-negative and Gram-positive bacteria. Green synthesis offers a sustainable approach to producing nanoparticles for biomedical and environmental applications. Future research could focus on large-scale synthesis and evaluating cytotoxicity for clinical applications.

In this study, silver nanoparticles (AgNPs) were successfully synthesized using *Azadirachta indica* (Neem) leaf extract through a green, eco-friendly approach. Characterization techniques, including UV-Visible spectroscopy, TEM, and XRD, confirmed the formation of spherical, crystalline nanoparticles with sizes ranging from 15–25 nm. The synthesized AgNPs demonstrated significant antimicrobial activity against both Gram-negative (*Escherichia coli*) and Gram-positive (*Staphylococcus aureus*) bacteria, highlighting their potential as effective antimicrobial agents.

The results indicate that plant-mediated synthesis is not only a sustainable and cost-effective method but also produces biologically active nanoparticles that can be applied in healthcare, environmental remediation, and food safety. Additionally, the study emphasizes that nanoparticle size, morphology, and surface properties play a critical role in determining their biological activity.

Future research could focus on scaling up the synthesis process, exploring the cytotoxicity of AgNPs on human cells, and testing their effectiveness against a broader spectrum of microbial pathogens. Integrating green-synthesized nanoparticles into practical applications such as antimicrobial coatings, wound dressings, and water purification systems can contribute to sustainable nanotechnology solutions.

In conclusion, this research demonstrates that **green-synthesized silver nanoparticles are a promising nanomaterial with significant biomedical and environmental applications**, bridging

the gap between nanochemistry, green chemistry, and practical antimicrobial solutions.

References:

1. Sharma, P., et al. (2019). Green synthesis of silver nanoparticles and their antimicrobial activity. *Journal of Nanobiotechnology*, 17(1), 1–12.
2. Singh, R., et al. (2020). Plant-mediated synthesis of silver nanoparticles: Characterization and applications. *Materials Science & Engineering C*, 110, 110654.
3. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green Chemistry*, 13(10), 2638–2650.
4. Rai, M., et al. (2012). Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances*, 27(1), 76–83.
5. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green Chemistry*, 13(10), 2638–2650. https://doi.org/10.1039/c1gc15386b
6. Sharma, P., Ghosh, M., & Sharma, A. (2019). Green synthesis of silver nanoparticles and their antimicrobial activity. *Journal of Nanobiotechnology*, 17(1), 1–12. https://doi.org/10.1186/s12951-019-0470-2
7. Singh, R., Singh, A., & Rai, M. (2020). Plant-mediated synthesis of silver nanoparticles: Characterization and applications. *Materials Science & Engineering C*, 110, 110654. https://doi.org/10.1016/j.msec.2020.110654
8. Rai, M., Yadav, A., & Gade, A. (2012). Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances*, 27(1), 76–83. https://doi.org/10.1016/j.biotechadv.2009.11.002
9. Khandel, P., & Sharma, D. (2017). Green synthesis of silver nanoparticles: A review. *International Journal of Green Nanotechnology*, 9(2), 91–104. https://doi.org/10.1080/19430892.2017.1282205
10. Anandalakshmi, K., Venugobal, J., & Ramasamy, V. (2016). Green synthesis of silver nanoparticles using plant extracts and their antimicrobial activity. *Asian Pacific Journal of Tropical Biomedicine*, 6(7), 594–600. https://doi.org/10.1016/j.apjtb.2016.05.001