



Review Article

A Review on The Biogenic Synthesis of Silver Nanoparticles and Nanotechnology

Eisha Ganju*, Sanjay, Bhaskar Kumar Gupta

School of Pharmacy & Research, People's University, Bhopal, Madhya Pradesh, India

ARTICLE INFO

Published: 28 Mar. 2025

Keywords:

Silver nanoparticles,
Biogenic synthesis,
Nanotechnology, Green
chemistry, Antimicrobial,
Drug delivery,
Environmental applications

DOI:

10.5281/zenodo.15098888

ABSTRACT

The biogenic synthesis of silver nanoparticles (AgNPs) has emerged as a sustainable and eco-friendly alternative to conventional physical and chemical methods. This review explores various biological entities, including plants, bacteria, fungi, and algae, as sources for synthesizing AgNPs. The biogenic process offers several advantages, such as low toxicity, cost-effectiveness, and enhanced biocompatibility, making it highly suitable for medical, pharmaceutical, agricultural, and environmental applications. The mechanism of AgNP biosynthesis involves the reduction of silver ions (Ag^+) to metallic silver (Ag^0) through bioactive compounds, followed by nanoparticle nucleation and stabilization. Characterization techniques such as UV-Vis spectroscopy, X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and electron microscopy help confirm the successful synthesis and properties of AgNPs. Due to their unique physicochemical properties, AgNPs have been widely applied in antimicrobial coatings, drug delivery systems, biosensors, water purification, and catalysis. However, challenges such as variability in nanoparticle size, large-scale production limitations, and potential cytotoxic effects necessitate further research. Future studies should focus on optimizing synthesis methods, improving nanoparticle stability, and assessing environmental and health risks to ensure their safe and effective use. This review highlights recent advancements in biogenic AgNP synthesis, its applications in nanotechnology, and potential future directions for enhancing its practical applications.

INTRODUCTION

Nanotechnology has revolutionized various scientific and industrial fields, offering innovative solutions for medicine, agriculture, environmental management, and material science. Among different types of nanoparticles, silver nanoparticles (AgNPs) are particularly significant

due to their unique physical, chemical, and biological properties, including antimicrobial, anticancer, and catalytic activities. Traditional synthesis methods of AgNPs involve physical and chemical processes that often require toxic reagents, high energy, and complex procedures. To address these challenges, biogenic synthesis has emerged as a sustainable and eco-friendly

***Corresponding Author:** Eisha Ganju

Address: School of Pharmacy & Research, People's University, Bhopal, Madhya Pradesh, India.

Email ✉: sanjayvishwakarma19549@gmail.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



alternative, utilizing plants, bacteria, fungi, and algae for nanoparticle production. "Nanotechnology" is the newest and one of the most promising and active areas of modern research. The technology deals with the design, synthesis, and manipulation of particles size ranging from 1–1000 nm. Within this size range, the chemical, physical, and biological properties change in the fundamental way of both individual atoms and their corresponding bulk material.

A **Nanoparticle** or **ultrafine particle** is a particle of matter 1 to 100 nanometres (nm) in diameter. The term is sometimes used for larger particles, up to 500 nm, or fibers and tubes that are less than 100 nm in only two directions. At the lowest range, metal particles smaller than 1 nm are usually called atom clusters instead. Nanoparticles are distinguished from microparticles (1-1000 μm), "fine particles" (sized between 100 and 2500 nm), and "coarse particles" (ranging from 2500 to 10,000 nm), because their smaller size drives very different physical or chemical properties, like colloidal properties and ultrafast optical effects or electric properties.

BIOGENIC SYNTHESIS OF SILVER NANOPARTICLES

Biogenic synthesis, also known as green synthesis, is a cost-effective and environmentally friendly method for producing AgNPs. This approach harnesses biological entities that naturally contain reducing and stabilizing agents capable of converting silver ions (Ag^+) into silver nanoparticles (Ag^0). AgNPs are among the most promising items in the nanotechnology business among the different metallic nanoparticles. The creation of reliable procedures for AgNP synthesis is a key area of contemporary nanotechnology research. AgNPs' special optical, electrical, and magnetic properties make them useful in a variety of applications, including antibacterial, antiviral, and antifungal ones; they can also be used in composite fibers, biosensor materials, cosmetics,

the food industry, and electronic components. AgNPs have also been identified as pharmaceutical and medicinal substances that have come into direct contact with human tissue in products like toothpaste, shampoos, detergents, soaps, and cosmetics.

1. BIOLOGICAL SOURCES FOR BIOGENIC SYNTHESIS

Different biological sources are used in the synthesis of AgNPs, each offering unique advantages:

Plants: Plant extracts are rich in bioactive compounds such as flavonoids, polyphenols, tannins, alkaloids, and proteins, which serve as reducing and stabilizing agents. Examples of plants used include:

Azadirachta indica (Neem) – Known for its strong antioxidant properties.

Ocimum sanctum (Tulsi) – Contains phenolic compounds that aid in nanoparticle synthesis.

Aloe vera – Contains enzymes and polysaccharides beneficial for stabilization.

Bacteria: Several bacterial strains have been explored for AgNP biosynthesis, including:

Pseudomonas aeruginosa – Produces extracellular enzymes that facilitate silver ion reduction.

Bacillus subtilis – Known for its high efficiency in AgNP production.

Fungi: Fungi offer a high yield of extracellular enzymes and proteins for AgNP stabilization. Notable examples include:

Aspergillus niger – Produces AgNPs with strong antimicrobial activity.



Fusarium oxysporum – Generates well-dispersed nanoparticles.

Algae: Algae-based synthesis is gaining interest due to their high bioaccumulation potential. Examples include:

Chlorella vulgaris – A green algae species capable of synthesizing nanoparticles under mild conditions.

Sargassum sp. – A marine algae known for its ability to reduce metal ions.

2. MECHANISM OF BIOGENIC SYNTHESIS

The synthesis of AgNPs follows three primary steps:

1. Reduction of Silver Ions (Ag^+ to Ag^0): Biomolecules in the biological medium donate electrons to Ag^+ , reducing them to metallic silver (Ag^0).

2. Nucleation and Growth: Reduced silver atoms aggregate to form small nuclei, which then grow into stable nanoparticles.

3. Capping and Stabilization: Organic compounds such as proteins, polysaccharides, and secondary metabolites act as stabilizers, preventing agglomeration.

CHARACTERIZATION OF SILVER NANOPARTICLES

To confirm successful synthesis, various characterization techniques are used:

UV-Vis Spectroscopy: Measures surface plasmon resonance (SPR), indicating nanoparticle formation.

X-ray Diffraction (XRD): Determines crystalline structure.

Fourier Transform Infrared Spectroscopy (FTIR): Identifies functional groups responsible for stabilization.

Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM): Examine morphology and size distribution.

Dynamic Light Scattering (DLS): Assesses nanoparticle size and stability.

APPLICATIONS OF SILVER NANOPARTICLES IN NANOTECHNOLOGY

The unique properties of AgNPs enable their use in various fields:

1. Medical and Pharmaceutical Applications

Antimicrobial agents: Effective against bacteria (*E. coli*, *S. aureus*), fungi, and viruses.

Wound healing and dressings: Silver-impregnated dressings prevent infections.

Cancer therapy: AgNPs induce cytotoxic effects in cancer cells.

Drug delivery: Functionalized AgNPs improve targeted drug delivery.

2. Environmental Applications

Water purification: AgNP-based filters remove pathogens and pollutants.

Bioremediation: Helps degrade toxic heavy metals and dyes.

3. Agricultural Applications

Nano-fertilizers and nano-pesticides: Enhance crop yield and pest resistance.

Antimicrobial coatings for food packaging: Extends shelf life by preventing microbial contamination.

4. Industrial Applications

Catalysis: Used in chemical reactions for efficient synthesis of organic compounds.



Textile coatings: Antibacterial fabrics with AgNPs prevent microbial growth.

CHALLENGES AND FUTURE PERSPECTIVES

Despite the promising benefits, some challenges need to be addressed:

Variability in Synthesis: Differences in biological sources lead to variations in nanoparticle size and stability.

Scalability: Large-scale production requires process optimization.

Toxicity Concerns: Potential cytotoxic and genotoxic effects of AgNPs need thorough investigation.

Regulatory Issues: Standardization and safety assessments are essential for commercialization.

Future research should focus on optimizing synthesis parameters, exploring novel biological sources, and conducting in-depth toxicological studies to enhance the safety and efficiency of AgNPs.

CONCLUSION

Biogenic synthesis of silver nanoparticles is a sustainable and efficient method in nanotechnology. The use of plant extracts, microbes, and algae offers a green alternative to conventional synthesis methods. AgNPs exhibit remarkable properties suitable for applications in medicine, environment, agriculture, and industry. However, further research is required to overcome synthesis challenges and ensure the safe and effective application of AgNPs in various fields.

REFERENCES

1. Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2014). Synthesis of silver nanoparticles: Chemical, physical and

biological methods. *Research in Pharmaceutical Sciences*, 9(6), 385–406.

2. Singh, P., Kim, Y. J., Zhang, D., & Yang, D. C. (2016). Biological synthesis of nanoparticles from plants and microorganisms. *Trends in Biotechnology*, 34(7), 588–599.
3. Gahlawat, G., & Choudhury, A. R. (2019). A review on the biosynthesis of metal and metal salt nanoparticles by microbes. *RSC Advances*, 9(23), 12944–12967.
4. Mittal, A. K., Chisti, Y., & Banerjee, U. C. (2013). Synthesis of metallic nanoparticles using plant extracts. *Biotechnology Advances*, 31(2), 346–356.
5. Rai, M., Yadav, A., & Gade, A. (2009). Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances*, 27(1), 76–83.
6. Santos, V. E., Targino, A. G. R., Flores, M. A. P., Pessoa, H. D. L. F., Galembeck, A., & Rosenblatt, A. (2013). Antimicrobial activity of silver nanoparticles in treating dental caries. *Revista da Faculdade de Odontologia-UPF*, 18(3).
7. Sriram, M. I., Kanth, S. B. M., Kalishwaralal, K., & Gurunathan, S. (2010). Antitumor activity of silver nanoparticles in Dalton's lymphoma ascites tumor model. *International journal of nanomedicine*, 753-762.
8. Chethan, h., mohapatra, d., sahu, a., & hemalatha, S. (2023). Formulation Development and Evaluation of Hydrogel Containing Silver Nanoparticles with *Withania coagulans* Aqueous Extract. *Indian Journal of Pharmaceutical Sciences*, 85(4).
9. Singh, A., & Maheshwari, S. (2023). Formulation, development and evaluation of *Woodfordia fruticosa* and β -sitosterol mediated silver nanoparticles gel for synergistic effect. *Intelligent Pharmacy*.
10. Adeleye, O. A., Aremu, O. K., Iqbal, H., Adedokun, M. O., Bamiro, O. A., Okunye, O. L., & Awolesi, A. O. (2023). Green Synthesis of Silver Nanoparticles Using Extracts of



- Ehretia cymosa and Evaluation of Its Antibacterial Activity in Cream and Ointment Drug Delivery Systems. *Journal of Nanotechnology*, 2023.
11. Bharali, A., Sarma, H., Biswas, N., Kalita, J. M., Das, B., Sahu, B. P., & Laloo, D. (2023). Green synthesis of silver nanoparticles using hydroalcoholic root extract of *Potentilla fulgens* and evaluation of its cutaneous wound healing potential. *Materials Today Communications*, 35, 106050.
 12. Alara, O. R., Abdurahman, N. H., Ukaegbu, C. I., & Kabbashi, N. A. (2019). Extraction and characterization of bioactive compounds in *Vernonia amygdalina* leaf ethanolic extract comparing Soxhlet and microwave-assisted extraction techniques. *Journal of Taibah University for Science*, 13(1), 414-422.
 13. Gutteridge, R. C. (1997). *Senna siarnea* (Lark) Irwin & Bameby. Plant Resources of South- East Asia, (1), 232-36.
 14. Nadembega, P., Boussim, J. I., Nikiema, J. B., Poli, F., & Antognoni, F. (2011). Medicinal plants in Baskoure, Kourittenga province, Burkina Faso: an ethnobotanical study. *Journal of ethnopharmacology*, 133(2), 378-395.
 15. Sanon, S., Ollivier, E., Azas, N., Mahiou, V., Gasquet, M., Ouattara, C. T., ... & Fumoux, F. (2003). Ethnobotanical survey and in vitro antiplasmodial activity of plants used in traditional medicine in Burkina Faso. *Journal of Ethnopharmacology*, 86(2-3), 143-147.
 16. Odason, E. E., & Kolawole, J. A. (2007). Of the Aqueous Extract of the Root of *Cassia siamea* Lam. (*Ceasalpiniaceae*). *Nigerian Journal of Pharmaceutical Research*, 6(1), 66-69.
 17. Kamatenesi, M. M., Acipa, A., & Oryem-Origa, H. (2011). Medicinal plants of Otwal and Ngai sub counties in Oyam district, Northern Uganda. *Journal of Ethnobiology and Ethnomedicine*, 7(1), 1-14.
 18. Kamagaté, M., Koffi, C., Kouamé, N. M., Akoubet, A., Yao, N. A. R., & Die-Kakou, H. M. (2014). Ethnobotany, phytochemistry, pharmacology and toxicology profiles of *Cassia siamea* Lam. *The Journal of Phytopharmacology*, 3(1), 57-76.
 19. Yadav, J. P., Arya, V., Yadav, S., Panghal, M., Kumar, S., & Dhankhar, S. (2010). *Cassia occidentalis* L.: A review on its ethnobotany, phytochemical and pharmacological profile. *Fitoterapia*, 81(4), 223-230.
 20. Saenbuaphan, N. (2006). Hypoglycemic effect of *Senna siamea* (Lam.) leaf extract in rats. *Warasan Wichai Mokho*.
 21. Chanda, S., & Dave, R. (2009). *In vitro* models for antioxidant activity evaluation and some medicinal plants possessing antioxidant properties: An overview. *African Journal of Microbiology Research*, 3(13), 981-996.
 22. Nanasombat, S., & Teckchuen, N. (2009). Antimicrobial, antioxidant and anticancer activities of Thai local vegetables. *J Med Plants Res*, 3(5), 443-449.
 23. Majji, L. N., Battu, G. R., Jangiti, R. K., & Talluri, M. R. (2013). Evaluation of *in-vitro* antibacterial activity of *Cassia siamea* leaves. *International journal of pharmacy and pharmaceutical sciences*, 5(3), 263-265.
 24. Nsonde-Ntandou G.F., Banzouzi J.T, Mbatchi B, Elion-Itou RD, Etou-Ossibi AW, Ramos S, Benoit-Vical F, Abena AA and. Ouamba J.M. Analgesic and anti-inflammatory effects of *Cassia siamea* Lam. stem bark extracts. *Journal of Ethnopharmacology* 2010; 127: 108-111.
 25. Cheeptham, N., & Towers, G. H. N. (2002). Light-mediated activities of some Thai medicinal plant teas. *Fitoterapia*, 73(7-8), 651-662.
 26. Prem, P., Naveenkumar, S., Kamaraj, C., Ragavendran, C., Priyadharsan, A., Manimaran, K., & Subramaniyan, V. (2024). *Valeriana jatamansi* root extract a potent source for biosynthesis of silver nanoparticles and their biomedical applications, and photocatalytic decomposition. *Green*



Chemistry Letters and Reviews, 17(1), 2305142.

27. Mejía-Méndez, J. L., Sánchez-Ante, G., Cerro-López, M., Minutti-Calva, Y., Navarro-López, D. E., Lozada-Ramírez, J. D., ... & Sánchez-Arreola, E. (2024). Green Synthesis of Silver Nanoparticles with Extracts from *Kalanchoe fedtschenkoi*: Characterization and Bioactivities. *Biomolecules*, 14(7), 782

HOW TO CITE: Eisha Ganju*, Sanjay, Bhaskar Kumar Gupta, A Review on The Biogenic Synthesis of Silver Nanoparticles and Nanotechnology, *Int. J. of Pharm. Sci.*, 2025, Vol 3, Issue 3, 2733-2738. <https://doi.org/10.5281/zenodo.15098888>

