

Green Silver Nanoparticles: A Comprehensive Review of Synthesis, Characterization, and Applications

Ashwini M Bhurre¹, Pratibha Dawaande², Anita Wanjari³

¹Jawaharlal Nehru Medical College, Datta Meghe Institute of Higher Education and Research, deemed to be University, Sawangi (M), Wardha, 442001, India

²Datta Meghe Medical College, DMIHER (DU) Wanadongari, Hingna, Nagpur, 441110, India

³Mahatma Gandhi Ayurved College Hospital and Research Centre, DMIHER (DU), Salod(H), Wardha, 442001, India

Received: 24th Feb, 2025; Revised: 14th Apr, 2025; Accepted: 14th May, 2025; Available Online: 25th Jun, 2025

ABSTRACT

An eco-friendly substitute for traditional methods is herbal green synthesis, which produces silver nanoparticles (AgNPs) from plant extracts. The methods used to characterize the nanoparticles are examined in this review, including FTIR, TEM, XRD, and UV-Vis spectroscopy. The study emphasizes how herbal green AgNPs can be used for antibacterial, anticancer, and environmental remediation purposes. Scalability, uniformity, and toxicity evaluations present difficulties nonetheless. Studies on plant sources and sophisticated characterization techniques ought to be the main areas of future investigation.

Keywords: green synthesis, plant extracts, silver nanoparticles, antimicrobial activity, characterization methods.

How to cite this article: Ashwini M Bhurre, Pratibha Dawaande, Anita Wanjari. Green Silver Nanoparticles: A Comprehensive Review of Synthesis, Characterization, and Applications. *International Journal of Drug Delivery Technology*. 2025;15(2):849-54. doi:10.25258/ijddt.15.2.61

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Nanotechnology is the study of manipulating or allowing individual atoms, molecules, or molecular clusters to self-assemble to form new and unique materials and electronic devices. The unique qualities of materials that grow at the nanoscale are the subject of nanotechnology, which has become one of the most exciting areas of scientific inquiry in recent years. Nanotechnology is the study of materials and how to manipulate them at the nanoscale, or sizes between about 1 and 100 nm. Special phenomena like improved chemical, biological, and physical properties could here lead to novel application possibilities.¹ Crafting nanomaterials and nanoparticles (NPs) for applications in food technology, healthcare, sensors, electrochemistry, and other industries is the focus of the fast-expanding discipline of nanotechnology.² Materials with a size range of one to one hundred nanometers are called nanomaterials. Their plasmon excitation processes and vast surface area set them apart from their macroscale counterparts. The last twenty years have seen a huge increase in interest in silver nanoparticles, or AgNPs. When it comes to photochemical applications, AgNP is superior to other metal nanoparticles.³ Among other characteristics, nanoparticles are wholly new or better in terms of size, distribution, and form. A variety of sectors are rapidly finding new applications for nanomaterials and nanoparticles.⁴ Researchers have recently become interested in silver nanoparticles due to their exceptional resistance to a variety of bacteria and the growth in drug resistance to commonly used antibiotics. AgNPs' special properties have made them valuable in many different sectors, including agriculture, biomedicine, water treatment, and drug delivery.⁵ The

synthesis process and the particle's surface don't include any toxic substances. The production of AgNPs from ecologically safe materials, including plant leaf extract, has a number of benefits, including environmental friendliness and compatibility with biological and medicinal applications. By producing AgNPs using medical plant components including stem, root, leaf, flower, fruit, seed, bark, etc., this strategy is very different from other approaches like chemical and physical methods and contributes to true green chemistry. Because plant extract has reducing capabilities, it has been utilized to cap, stabilize, and reduce AgNPs during the biosynthetic process.⁶

This analysis focused on research conducted from 2013 to 2023 that investigated the synthesis and characterization of AgNPs generated by microorganisms and plants. This paper aims to provide a comprehensive analysis of the different ways in which green synthesis methods can be used to generate silver nanoparticles. The antibacterial activity of green silver nanoparticles is studied in relation to a range of microorganisms, such as bacteria, *Aspergillus niger*, and *Candida albicans*. *B. subtilis*, *S. aureus*, *P. aeruginosa*, *K. pneumoniae*, and *S. typhi* are a few of them. Lastly, the paper concludes with recommendations for further study.

The Necessity of Silver Nanoparticles and Green Synthesis As an example of a bottom-up approach, reduction, or oxidation, is the main chemical mechanism that produces nanoparticles. Given the high expense of the physical and chemical techniques, nanoparticle biosynthesis was required. A frequent byproduct of the chemical processing of several dangerous compounds that may have detrimental effects on medical applications is surface absorption. When

biosynthesised using the green synthesis method, this is not a problem for the nanoparticles. To make nanoparticles more inexpensively, scientists used microbial enzymes and phytochemicals, which are extracts from plants. Many times, they are the ones who reduce metal compounds into the right nanoparticles because of their reducing or antioxidant qualities. By virtue of its lack of energy, high temperatures, pressures, or hazardous ingredients, green synthesis is less expensive, more environmentally friendly, and easier to scale up for large-scale synthesis than chemical and physical procedures. Beyond the constraints of physiochemical techniques, a novel tactic called "green synthesis" makes use of safe, natural herbs. Many benefits arise from the synthesis of green nanosilver: higher efficiency (particularly helpful in large-scale manufacturing), avoidance of hazardous chemicals, high pressure, and energy, and the use of phytochemicals and antioxidants that act as naturally occurring reducing agents. Reduction, irradiation, electrochemical synthesis, and chrysochemical synthesis are a few methods that can be used to construct nanosilver. In contrast to regular metals, nanosilver possesses unique properties such as permeability to pH and dissolved ions, as well as the capacity to be molded into specific shapes. AgNPs increase the surface area per unit mass, which boosts the market for contact-time nanosilver clients. Numerous industries, including healthcare, food packaging, textiles, cosmetics, and more, have seen a substantial rise in demand as a result.⁷

Silver Nanoparticle Synthesis from Green Plant Extract

The majority of recent scientific efforts have been focused on creating efficient green chemistry methods that create silver nanoparticles with the right size and form by using stabilizing agents, organic reducing agents, and capping. Instead of using any harsh, costly, or dangerous chemicals, silver nanoparticles can be produced biologically. Plant extracts produce silver nanoparticles with a broader range of compounds than microbes do. They are also safer, easier to get, and usually harmless. Finally, their synthesis rate is faster. The principal mechanism investigated is phytochemical-induced plant-assisted reduction. The main phytochemicals involved are amides, carboxylic acids, aldehydes, ketones, flavones, and terpenoids. Water-soluble

phytochemicals such as quinones, flavones, and organic acids quickly decrease ions. Research indicates that one anthraquinone found in xerophytes is named emodin, and it tautomerizes to produce silver nanoparticles. Three different forms of benzoquinones were discovered to be present in mesophytes: cyperquinone, dietchequinone, and remirin. Phytochemicals may directly influence silver nanoparticle production and ion reduction, according to some theories. The eco-friendliness of green synthesis of AgNPs—a low-cost, environmentally benign process including plants, bacteria, fungi, algae, and yeast—has drawn a lot of interest.⁸ It is very time-consuming to obtain, isolate, purify, and maintain microbial cultures using costly nutrient media. For this reason, it has been demonstrated that the plant-mediated green synthetic process is a better alternative to the biological methods previously mentioned. Algae and bacteria are less favored than plants due to a number of other problems, including culture contamination and poorly understood biocapping agents. Therefore, nanobiotechnologists find that the manufacture of AgNPs using plants and their byproducts is the most attractive method since it uses readily available precursors and is fast, inexpensive, environmentally benign, and non-pathogenic. A wide range of phytomolecules, including proteins, amino acids, lipids, alkaloids, polyphenols, polysaccharides, vitamins, and enzymes, are used in the phytosynthesis process to create nanoparticles that have stabilizing and reducing properties. Moreover, the eco-friendly production of silver nanoparticles from plant extracts is a workable strategy that could eventually find use in the medical and environmental fields. This summary effectively conveys the scientific importance and potential of green silver nanoparticles. Here are some additional points that you might consider mentioning: i) Specific examples of plants used for green synthesis could be briefly mentioned. ii) Potential applications of green silver nanoparticles beyond their antibacterial properties could be touched upon (ex. wound healing, drug delivery).

Objective

Reviewing the literature on a comprehensive review of herbal green silver nanoparticles antibacterial qualities was the aim of this study.

METHODS

A systematic review was conducted utilizing published literature that was retrieved from "pubmed, scopus, research gate, springer, google scholar" until 2024. The literature search was performed using the search phrases "TITLE-ABS-KEY (Antimicrobial Activity)" and "TITLE-ABS-KEY (Green Silver Nanoparticles)".

RESULTS

The antibacterial activity of green silver nanoparticles derived from plant extract was the subject of 37 publications, according to a review of the literature conducted using the databases of Springer, Google Scholar, Scopus, Research Gate, and PubMed. Of the 36 articles, 24 had a title, an abstract, and could be read. Studies on a range of activities, including anti-microbial activity.

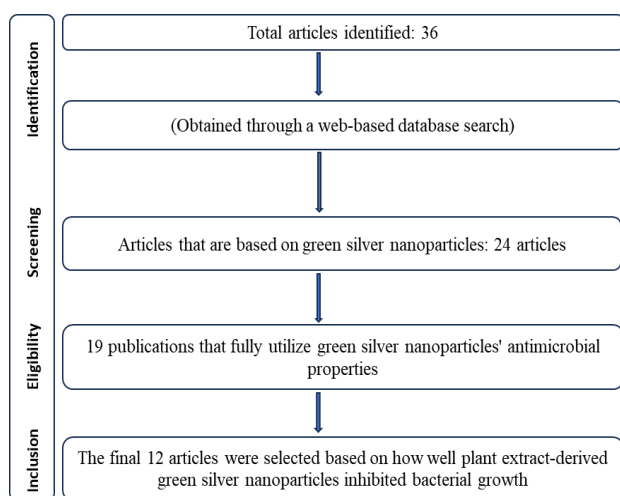


Figure 1: Flowchart analyzing the selection of studies and systematic search

Table 1: An overview of the data taken from the studies

Sr. No.	Plant Used	Plant Part Used	Finding
1.	<i>Anthemis pseudocotula</i> Boiss.	Aerial part	The study suggests that by employing aerial extracts from <i>A. pseudocotula</i> Boiss, AP-AgNPs could be produced in an environmentally safe manner. With regard to Gram-negative bacteria, these nanoparticles have strong antibacterial action, prevent the growth of biofilms, and have uses in biology.
2.	<i>Ocimum sanctum</i> Linn.	Leaves	The MDR of <i>A. baumannii</i> was considerably decreased by this study's sustainable method of producing silver nanoparticles (AgNPs) using <i>O. sanctum</i> leaf extract. This implies that using AgNPs as a viable substitute for antibiotic therapy may be accomplished.
3.	<i>Viscum orientale</i>	Leaves	The study makes use of a water extract from a parasitic plant to produce silver nanoparticles with antibacterial, radical-scavenging, and biocompatibility characteristics; size selection will be the main focus of future research.
4.	<i>Carissa bispinosa</i>	Leaves	In this work, the antibacterial, cytotoxic, antioxidant, and phytochemical activities of <i>C. bispinosa</i> leaf and stem extracts were evaluated. It was discovered that these extracts exhibited low minimum inhibitory concentrations (MICs) and good synergistic effects against oral infections.
5.	<i>Rubus caesius</i> L.	Leaves and stem	The study indicates that more research is necessary because immature <i>Rubus caesius</i> leaves and stems, particularly those extracted with ethanol, have physiologically active chemicals and antibacterial capabilities.
6.	<i>Hippeastrum hybridum</i>	Whole plant	Utilizing HH extract, the study produced Ag/Au BNPs, HH-AgNPs, and HH-AuNPs—three physiologically active phytochemicals—in Pakistan. The findings indicated that Ag and Au were great options for antibacterial action. By combining microbiology and nanotechnology, this approach may result in improved antibacterial agents.
7.	<i>Aloe vera</i>	Leaves	Research on the creation of Ag-NPs with biological components and plant extracts has shown that they are antibacterial against a variety of microorganisms. Biosynthesis is environmentally sustainable, although surface chemistry still has to be better understood.
8.	<i>Lysiloma acapulcensis</i>	Leaves	The study found that at lower dosages, biogenic AgNPs derived from <i>L. acapulcensis</i> extract exhibit potent antibacterial action against a variety of bacteria while preserving cell viability.
9.	<i>Clerodendrum inerme</i>	Leaves	Studies reveal that <i>C. inerme</i> extract can be effectively processed to yield CI-Au and CI-Ag nanoparticles with biomedical applications in an environmentally benign manner. The green-produced Au and Ag NPs exhibit superior antioxidant, antibacterial, and antimycotoxin properties in comparison to their commercial counterparts. They also appear to be more biocompatible.
10.	<i>Artemisia vulgaris</i>	Leaves	Green chemistry uses plant extracts because of their extensive metabolite viability, ease of handling, and availability in order to eliminate hazardous chemicals. According to recent research, green nanoparticles have antibacterial and anticancer properties that are on par with chemical therapies.
11.	<i>Saraca indica</i>	Flower	AgNPs can be produced at room temperature using a cheap, fast, and ecologically safe biological reducing agent—aqueous plant extract stabilized by alcohol, phenolics, and proteins—according to research.
12.	<i>Chrysanthemum indicum</i> L	Flower	AgNPs were synthesized from <i>C. indicum</i> without the use of hazardous chemicals by employing XRD, TEM, EDX, and UV-Vis spectrophotometer techniques. When it came to <i>K. pneumoniae</i> and <i>E. coli</i> , the MIC values for the spherical, smooth, and polydispersed particles were the lowest.

Based on the green silver nanoparticles' ability to combat bacteria when derived from plant extract, a final 12 articles were chosen. Articles that satisfied the eligibility requirements were chosen and examined. The inclusion criteria that did not match were eliminated. Each abstract was given a thorough screening, and attempts were made to locate full-text publications for research purposes. Articles that met the qualifying requirements were chosen for the analysis.⁹

Characterization of AgNPs

AgNPs have been characterized and controlled by a variety of techniques, such as:

- UV-Vis spectrophotometry
- X-ray diffractometry (XRD)
- Fourier transform infrared (FTIR) spectroscopy
- Transmission electron microscopy (TEM)
- Scanning electron microscopy (SEM)
- Dynamic light scattering (DLS)
- Atomic force microscopy (AFM)¹⁰

UV-Vis Spectra Analysis

A UV-Vis double beam spectrophotometer was used to measure the maximum absorbance of a produced zinc oxide nanoparticle in the 200–700 nm wavelength range.¹¹ The extinction coefficient, which is determined using noble metal nanoparticles, represents the total amount of light absorbed and scattered within a sample.

X-Ray Diffraction (XRD) Analysis

A PAN analytical Xpert Pro Model running at 45 kV and 40 mA was used to analyze ZnO nanopowder under Cu K α radiation by XRD.

Fourier Transform Infrared Spectroscopy (FTIR)

ZnO NPs biosynthesized by *B. aristate* were examined in the 400–4000 cm⁻¹ range using an FTIR spectrophotometer.¹¹ An analysis of the capping ligand of nanoparticles with FTIR spectroscopy revealed that proteins and amino acid residues have greater metal-binding capacities.

Transmission Electron Microscopy

Grain distribution, size, and form can be measured using the widely used transmission electron microscopy (TEM) technique. The distance measured between the picture plane, the specimen, and the objective lens determines the specimen's magnification.¹²

Scanning Electron Microscopy

The smallest nanoparticles are studied in nanotechnology and nanoscience using high-resolution imaging techniques like scanning electron microscopy (SEM). This allows the forms, sizes, and morphologies of the particles' surfaces to be determined.

Dyanamic Light Scattering

The size distribution of tiny particles on a submicron to nanometer scale, mainly between 2 and 500 nm, is examined using DLS, a method that is commonly used for characterizing nanoparticles.

Atomic Force Microscopy

AFM is used to examine the sorption, structure, size, shape, and dispersion of nanomaterials. Unlike previous EM techniques, it has three scanning modes and allows real-time interaction with supported lipid bilayers.¹³

Biological Applications of Green Silver Nanoparticles

The Antibacterial Characteristics of Green Silver Nanoparticles

In the industrial domain, silver nanoparticles are highly desirable non-materials. Water purification and the cleaning of medical and residential equipment have greatly benefited from the antibacterial qualities of silver nanoparticles. Healthcare products, medical equipment, textiles, and food storage are just a few industries where AgNPs show promise.¹⁴ AgNPs have a wider surface area and release free silver ions more slowly, which provides an unpleasant environment and is a major factor in their broad-spectrum antibacterial activity.

Green Silver Nanoparticles' Antifungal Activity

As a powerful and fast-acting fungicide, nanosilver works well against a variety of common fungi, such as those in the *Aspergillus*, *Candida*, and *Saccharomyces* genera. AgNPs possess antifungal properties against various kinds of fungi. The true mechanism underlying the antifungal action is not fully understood. AgNPs have been shown to have an antifungal impact on *C. albicans* species through the

disruption of membrane integrity, which causes the cell membrane to become disrupted and inhibits budding. AgNPs' ability to inhibit microbes is significantly influenced by their form.¹⁵

Potential Applications of Green Silver Nanoparticles

Nanoparticles can treat infections as well as unsuccessful medicines; they are of tremendous interest in the current state of bacterial infection and disease therapy.^{16,17} Of all the nanoparticles that have been used, AgNPs have proven to be particularly useful in treating microbial illnesses and reducing harmful bacteria.^{18,19} Researchers looking at AgNPs therapeutic potential as possible antimicrobial agents have had to refocus their work due to the recent and noticeable rise in antibiotic resistance.^{20,21} The overview of the data is given in table 1.

DISCUSSION

A web search engine retrieved a total of 36 items. Researchers looked at the antibacterial capabilities of green silver nanoparticles using Google Scholar, Springer, Research Gate, Scopus, and PubMed. After screening the number of articles, 12 articles were selected with match criteria. The different articles show green silver nanoparticles in plant extract. In addition to showing significant antibacterial action against Gram-negative bacteria, AP-AgNPs are synthesized in an environmentally benign manner utilizing aerial extract from *A. pseudocotula Boiss*, preventing the formation of biofilms and perhaps having biological benefits. The paper presents a green method that uses less hazardous organic solvents to synthesize silver nanoparticles from *O. sanctum* leaf extract. Clinically isolated MDR *A. baumannii* was successfully combated by the stable and effective nanoparticles. Mammalian cells were subjected to moderate levels of AgNPs and *O. sanctum* extract cytotoxicity. AgNPs appear to be a viable substitute therapy approach that could help lower the number of bacteria resistant to antibiotics. To demonstrate their effectiveness more convincingly, more research is required. The research uses a water extract from a parasitic plant with therapeutic qualities to create silver nanoparticles. The nanoparticles have anthelmintic, radical-scavenging, and antibacterial qualities. Through hemagglutination, they also demonstrate biocompatibility. Future research aims to comprehend the antioxidant mechanism of action of functionalized AgNPs and make selective use of them based on size.

Microorganisms and plants are examples of nanomaterials that have been developed as a result of the increased demand for green nanotechnology and chemistry. Research has demonstrated the potential of plant extracts in a number of disciplines, such as biotechnology and bioengineering. The special chemicals in these nanoparticles are either harmful or benign and speed up the synthesis process. Future research and comprehension of the technology can be enhanced by the results of these nanoresearch projects. The creation of pure green environments for all living things, lower costs associated with medication research, and enhanced health are all potential benefits of producing green materials.^{22,23} According to the study, bioactive substances with antibacterial, anti-inflammatory, and

anticancer effects, such as flavonoids and biiflavonoids, are found in *Selaginella species*. The benefits of nano-formulations made from *Selaginella* extracts without any processing, however, have not been well studied. According to the review, *Selaginella* nanoparticles have superior antibacterial activity in comparison to their raw extracts. These nanoparticles show promise in pharmaceuticals, environmental preservation, and clinical settings. They can be applied to clean water environments and monuments to get rid of fungus and algae growth. AgNPs with antibacterial properties in plant extracts have been synthesized in a green way, which is encouraging, but nothing is known about how they work or how they inhibit. AgNPs have antibacterial activity in a manner that is correlated with their morphologies, which include spherical, hexagonal, pentagonal, cubic, nano-rod, and hexagonal. The research shows that *L. acapulcensis* extract can be used to create biogenic AgNPs, which preserve cell viability and show notable antibacterial activity against a variety of bacteria at lower concentrations. Research indicates that CI-Au and CI-Ag nanoparticles with biomedical applications have been successfully fabricated from *C. inermis* extract using an environmentally friendly green method. The green-produced Au and Ag NPs exhibit superior antioxidant, antibacterial, and antimycotoxin properties in comparison to their commercial counterparts. They also appear to be more biocompatible. In this study, low-cost, non-toxic green ZnO nanoparticles are produced using *B. aristata* leaves. Numerous businesses could benefit from this technology.^{24,25}

CONCLUSIONS

Herbal green silver nanoparticles, or AgNPs, are an environmentally friendly development in nanotechnology. Their special qualities, such as their antibacterial, antioxidant, anticancer, and anti-inflammatory characteristics, make them useful in environmental research, agriculture, and medicine. The physicochemical features of herbal green AgNPs are revealed by comprehensive characterization approaches, which facilitate their optimization and tailored application. Particle size control, toxicity testing, and scalability are among the difficulties. Future studies should examine the synergistic effects of herbal extracts and broaden the range of applications for nanoparticles to fully realize their promise in sustainable development, enhancing human health, and enhancing environmental quality.

REFERENCES

- Chandra H, Patel D, Kumari P, Jangwan JS, Yadav S. Phyto-mediated synthesis of zinc oxide nanoparticles of *Berberis aristata*: Characterization, antioxidant activity and antibacterial activity with special reference to urinary tract pathogens. *Materials Science and Engineering: C*. 2019 Sep 1;102:212-20.
- Aldakheel FM, Sayed MM, Mohsen D, Fagir MH, El Dein DK. Green synthesis of silver nanoparticles loaded hydrogel for wound healing; systematic review. *Gels*. 2023 Jun 29;9(7):530.
- Patel RR, Singh SK, Singh M. Green synthesis of silver nanoparticles: methods, biological applications, delivery and toxicity. *Materials Advances*. 2023;4(8):1831-49.
- Nie P, Zhao Y, Xu H. Synthesis, applications, toxicity and toxicity mechanisms of silver nanoparticles: A review. *Ecotoxicology and Environmental Safety*. 2023 Mar 15;253:114636.
- Dubey RK, Shukla S, Hussain Z. Green synthesis of silver nanoparticles; A sustainable approach with diverse applications. *Zhongguo Ying Yong Sheng Li Xue Za Zhi*. 2023 Dec 21;39:e20230007.
- Kareem EA, Sultan AE, Oraibi HM. Synthesis and characterization of silver nanoparticles: A review. *Ibn AL-Haitham Journal For Pure and Applied Sciences*. 2023 Jul 20;36(3):177-200.
- Shahzadi S, Fatima S, Shafiq Z, Janjua MR. A review on green synthesis of silver nanoparticles (SNPs) using plant extracts: a multifaceted approach in photocatalysis, environmental remediation, and biomedicine. *RSC advances*. 2025;15(5):3858-903.
- Hamad I, Aleidi SM, Alshaer W, Twal S, Al Olabi M, Bustanji Y. Advancements and global perspectives in the green synthesis of silver nanoparticles: A two-decade analysis. *Pharmacia*. 2025 Feb 14;72:1-3.
- Albao MJ, Calsis JR, Dancel JO, De Juan-Corpuz LM, Corpuz RD. Silver nanoparticle-infused hydrogels for biomedical applications: A comprehensive review. *Journal of the Chinese Chemical Society*. 2025 Feb;72(2):124-62.
- Bhavi SM, Thokchom B, Singh SR, Bajire SK, Shastry RP, Srinath BS, Bhat SS, Dupadahalli K, Govindasamy C, Chalekar SR, Harini BP. *Syzygium malaccense* leaf extract-mediated silver nanoparticles: synthesis, characterization, and biomedical evaluation in *Caenorhabditis elegans* and lung cancer cell line. *Green Chemistry Letters and Reviews*. 2025 Dec 31;18(1):2456624.
- Durairaju P, Raja G, Venkatesh G, Govindasamy C, El Newehy AS, Haseena S, Vennila P, Balasubramanian S. Green synthesis, characterization, antimicrobial and anti-cancer activity of silver nanoparticles using *Aristolochia bracteolata* plant leaf extract: experimental and theoretical calculations. *Bulletin of the Chemical Society of Ethiopia*. 2025;39(2):271-86.
- Sheerswal A, Singh A, Sharma V, Trivedi B. Microbial synthesis of nanoparticles for sustainable agricultural advancements: a comprehensive review. *Nanotechnology for Environmental Engineering*. 2025 Mar;10(1):1-29.
- Oyebamiji AK, Akintelu SA, Afolabi SO, Ebenezer O, Akintayo ET, Akintayo CO. A Comprehensive Review on Mycosynthesis of Nanoparticles, Characteristics, Applications, and Limitations. *Plasmonics*. 2025 Jan 8:1-9.
- Moges W, Misskire Y. Green synthesis, characterization and antibacterial activities of silver nanoparticles using *Sida schimperiana* Hochst. ex A. Rich (Chifrig) leaves extract. *Discover Materials*. 2025 Feb 13;5(1):34.

15. Khalid MU, Rudokaite A, da Silva AM, Kirsnyte-Snioke M, Stirke A, Melo WC. A Comprehensive Review of Niobium Nanoparticles: Synthesis, Characterization, Applications in Health Sciences, and Future Challenges. *Nanomaterials*. 2025 Jan 12;15(2):106.
16. Alam MW, Dhanda N, Almutairi HH, Al-Sowayan NS, Mushtaq S, Ansari SA. Green Ferrites: Eco-Friendly Synthesis to Applications in Environmental Remediation, Antimicrobial Activity, and Catalysis—A Comprehensive Review. *Applied Organometallic Chemistry*. 2025 Feb;39(2):e7962.
17. Thoms S, Gonsalves RA, Jose J, Zyoud SH, Prasad AR, Garvasis J. Plant-based synthesis, characterization approaches, applications and toxicity of silver nanoparticles: A comprehensive review. *Journal of Biotechnology*. 2024 Aug 17.
18. Zulfiqar Z, Khan RR, Summer M, Saeed Z, Pervaiz M, Rasheed S, Shehzad B, Kabir F, Ishaq S. Plant-mediated green synthesis of silver nanoparticles: synthesis, characterization, biological applications, and toxicological considerations: a review. *Biocatalysis and Agricultural Biotechnology*. 2024 Mar 19:103121.
19. Nkosi NC, Basson AK, Ntombela ZG, Dlamini NG, Pullabhotla RV. Green synthesis, characterization and application of silver nanoparticles using bioflocculant: A review. *Bioengineering*. 2024 May 15;11(5):492.
20. Duman H, Eker F, Akdaşçi E, Witkowska AM, Bechelany M, Karav S. Silver nanoparticles: A comprehensive review of synthesis methods and chemical and physical properties. *Nanomaterials*. 2024 Sep 20;14(18):1527.
21. Dhir R, Chauhan S, Subham P, Kumar S, Sharma P, Shidiki A, Kumar G. Plant-mediated synthesis of silver nanoparticles: unlocking their pharmacological potential—a comprehensive review. *Frontiers in Bioengineering and Biotechnology*. 2024 Jan 9;11:1324805.
22. Vijayaram S, Razafindralambo H, Sun YZ, Vasantharaj S, Ghafarifarsani H, Hoseinifar SH, Raeeszadeh M. Applications of green synthesized metal nanoparticles—a review. *Biological Trace Element Research*. 2024 Jan;202(1):360-86.
23. Abbas R, Luo J, Qi X, Naz A, Khan IA, Liu H, Yu S, Wei J. Silver nanoparticles: Synthesis, structure, properties and applications. *Nanomaterials*. 2024 Aug 31;14(17):1425.
24. Yadav J, Tare H. Silver Nanoparticles as Antimicrobial Agents: Mechanisms, Challenges, and Applications. *International Journal of Pharmaceutical Quality Assurance*. 2024;15(1):546-553.
25. Khan MR, Urmi MA, Kamaraj C, Malafaia G, Ragavendran C, Rahman MM. Green synthesis of silver nanoparticles with its bioactivity, toxicity and environmental applications: A comprehensive literature review. *Environmental Nanotechnology, Monitoring & Management*. 2023 Dec 1;20:100872.