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Green Synthesis of Silver Nanoparticles Using Medicinal Plants: A Sustainable Approach for Nanomedicine

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Abstract

Nanotechnology has emerged as one of the most promising interdisciplinary fields with significant applications in medicine, biotechnology, agriculture, and environmental science. Among various nanomaterials, silver nanoparticles (AgNPs) have attracted considerable attention because of their unique physicochemical properties, including high surface area, antimicrobial activity, antioxidant potential, and biocompatibility. Conventional methods for synthesizing silver nanoparticles often involve hazardous chemicals, high energy consumption, and environmentally harmful by-products. Consequently, green synthesis has gained recognition as an eco-friendly and sustainable alternative for nanoparticle production. The present study explores the green synthesis of silver nanoparticles using medicinal plant extracts as reducing and stabilizing agents. Bioactive compounds such as flavonoids, phenolics, alkaloids, terpenoids, and proteins present in medicinal plants facilitate the reduction of silver ions into nanoparticles while simultaneously providing stability. This approach eliminates the need for toxic chemicals and promotes environmentally responsible nanomaterial production. Various medicinal plants, including Azadirachta indica (Neem), Ocimum sanctum (Tulsi), Aloe vera, and Moringa oleifera, have demonstrated remarkable efficiency in synthesizing biologically active silver nanoparticles. The synthesized AgNPs exhibit potent antimicrobial, antioxidant, anti-inflammatory, wound-healing, and anticancer properties, making them valuable candidates for nanomedicine applications. Characterization techniques such as UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and X-ray Diffraction (XRD) confirm nanoparticle formation, morphology, crystallinity, and stability. The study highlights the role of plant-mediated synthesis in producing nanoparticles with enhanced therapeutic efficacy and reduced environmental impact. The findings suggest that medicinal plant-based synthesis represents a sustainable, cost-effective, and scalable strategy for nanoparticle production. Green-synthesized silver nanoparticles offer immense potential for developing advanced drug delivery systems, antimicrobial coatings, biomedical devices, and targeted therapies. Therefore, integrating medicinal plant resources with nanotechnology can significantly contribute to the advancement of sustainable nanomedicine and environmentally friendly healthcare solutions.

Keywords

Green Synthesis; Silver Nanoparticles; Medicinal Plants; Nanomedicine; Sustainable Nanotechnology

1. Introduction

Nanotechnology has revolutionized modern science by enabling the manipulation of materials at the nanoscale, typically ranging from 1 to 100 nanometers. Nanoparticles possess unique physical, chemical, optical, and biological properties that differ significantly from their bulk counterparts due to their high surface-area-to-volume ratio and quantum effects. Among various metallic nanoparticles, silver nanoparticles (AgNPs) have gained considerable scientific and industrial attention because of their remarkable antimicrobial, antioxidant, anti-inflammatory, anticancer, and catalytic properties. These characteristics have made AgNPs highly valuable in diverse fields, including medicine, pharmaceuticals, biotechnology, agriculture, food packaging, and environmental remediation.

Traditional methods for synthesizing silver nanoparticles generally involve physical and chemical techniques. Physical methods such as evaporation-condensation and laser ablation require sophisticated equipment and high energy consumption. Chemical synthesis often employs reducing agents such as sodium borohydride, hydrazine, and citrate, which may generate toxic residues and pose environmental and health hazards. The growing concern regarding environmental sustainability and green chemistry has stimulated interest in alternative synthesis methods that are safer, cost-effective, and environmentally friendly.

Green synthesis has emerged as a sustainable approach for producing nanoparticles using biological resources such as plants, microorganisms, algae, and fungi. Among these biological systems, medicinal plants are particularly attractive because they contain a wide variety of bioactive compounds capable of reducing metal ions and stabilizing the resulting nanoparticles. Phytochemicals such as flavonoids, phenolics, tannins, alkaloids, terpenoids, and proteins act as natural reducing and capping agents, eliminating the need for hazardous chemicals. This plant-mediated synthesis process is simple, rapid, economical, and suitable for large-scale production.

Medicinal plants have long been utilized in traditional healthcare systems due to their therapeutic properties. Species such as Azadirachta indica (Neem), Ocimum sanctum (Tulsi), Aloe vera, Moringa oleifera, and Curcuma longa (Turmeric) contain biologically active constituents that facilitate nanoparticle synthesis while enhancing their biomedical effectiveness. The resulting silver nanoparticles often exhibit improved biological activity because plant-derived molecules remain associated with the nanoparticle surface, contributing additional therapeutic benefits.

In recent years, green-synthesized silver nanoparticles have shown immense potential in nanomedicine. Their applications include antimicrobial agents against drug-resistant pathogens, wound-healing materials, anticancer therapies, biosensors, targeted drug delivery systems, and biomedical coatings. Furthermore, plant-mediated AgNPs generally demonstrate improved biocompatibility and reduced toxicity compared to chemically synthesized nanoparticles, making them attractive candidates for clinical and pharmaceutical applications.

Characterization of silver nanoparticles is crucial for understanding their physicochemical properties and biological performance. Techniques such as UV–Visible Spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Scanning Electron

Microscopy (SEM), and Transmission Electron Microscopy (TEM) provide valuable information regarding nanoparticle size, shape, crystallinity, surface chemistry, and stability.

This study focuses on the green synthesis of silver nanoparticles using medicinal plant extracts and evaluates their significance as sustainable nanomaterials for biomedical applications. The research highlights synthesis mechanisms, characterization methods, biological activities, and therapeutic potential, emphasizing the importance of integrating green chemistry principles with nanomedicine for future healthcare innovations.

2. Methodology

2.1 Research Design

This study employed an experimental and analytical research design to investigate the green synthesis of silver nanoparticles (AgNPs) using medicinal plant extracts and evaluate their potential applications in nanomedicine. The research focused on eco-friendly nanoparticle synthesis, physicochemical characterization, and assessment of biological activities. A plant-mediated synthesis approach was selected because it minimizes environmental hazards and eliminates the need for toxic chemical reducing agents.

2.2 Collection of Plant Material

Fresh leaves from selected medicinal plants such as Azadirachta indica (Neem), Ocimum sanctum (Tulsi), Aloe vera, and Moringa oleifera were collected from healthy plants. The plant materials were thoroughly washed with distilled water to remove dust and contaminants, shade-dried, and finely powdered for extract preparation.

2.3 Preparation of Plant Extract

Approximately 10 g of dried plant powder was mixed with 100 mL of distilled water and heated at 60–80°C for 20–30 minutes. The mixture was filtered using Whatman No. 1 filter paper to obtain a clear extract. The filtrate was stored at 4°C until further use.

2.4 Green Synthesis of Silver Nanoparticles

A 1 mM aqueous silver nitrate ($AgNO_3$) solution was prepared as the precursor solution. Plant extract was added dropwise to the silver nitrate solution under continuous stirring. The reaction mixture was incubated at room temperature, and color changes from pale yellow to dark brown were monitored as an indicator of silver nanoparticle formation due to surface plasmon resonance.

Reaction Conditions

- Silver nitrate concentration: 1 mM
- Plant extract volume: 10–20 mL
- Reaction temperature: 25–60°C
- Reaction time: 30–120 minutes
- pH range: 6–9

2.5 Characterization of Silver Nanoparticles

The synthesized nanoparticles were characterized using the following analytical techniques:

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UV–Visible Spectroscopy

Used to confirm nanoparticle formation by detecting characteristic surface plasmon resonance peaks between 400–450 nm.

Fourier Transform Infrared Spectroscopy (FTIR)

Used to identify functional groups responsible for nanoparticle reduction and stabilization.

Scanning Electron Microscopy (SEM)

Used to determine nanoparticle morphology and surface structure.

Transmission Electron Microscopy (TEM)

Used to evaluate particle size distribution and shape.

X-Ray Diffraction (XRD)

Used to analyze crystalline structure and phase purity.

2.6 Biological Activity Assessment

The synthesized AgNPs were evaluated for:

Antimicrobial Activity

Tested against Gram-positive and Gram-negative bacterial strains using agar well diffusion assays.

Antioxidant Activity

Assessed using DPPH free radical scavenging assays.

Anticancer Potential

Evaluated through in vitro cytotoxicity studies on selected cancer cell lines.

2.7 Statistical Analysis

Experimental data were analyzed using descriptive statistics and expressed as Mean ± Standard Deviation (SD). Statistical significance among treatments was determined using one-way Analysis of Variance (ANOVA), followed by Tukey's post hoc test at a significance level of $p < 0.05$. Graphical analyses were performed using standard scientific software.

2.8 Reliability and Reproducibility

All experiments were conducted in triplicate to ensure accuracy and reproducibility. Standardized laboratory procedures and calibrated instruments were employed throughout the study to minimize experimental errors and enhance data reliability.

3. Results and Discussion

3.1 Synthesis and Characterization of Silver Nanoparticles

The successful synthesis of silver nanoparticles (AgNPs) was confirmed by a visible color change from pale yellow to dark brown following the addition of medicinal plant extract to silver nitrate solution. This color transformation is attributed to the excitation of surface

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plasmon resonance (SPR), indicating the reduction of Ag^+ ions into metallic silver nanoparticles. Characterization studies further confirmed nanoparticle formation, stability, morphology, and crystallinity.

Table 1. Characterization of Green-Synthesized Silver Nanoparticles

Characterization Technique	Observation	Significance
UV–Visible Spectroscopy	Peak at 430 nm	Confirmation of AgNP formation
FTIR Analysis	Presence of hydroxyl and phenolic groups	Role of phytochemicals in reduction
SEM Analysis	Spherical morphology	Uniform nanoparticle distribution
TEM Analysis	Particle size 15–45 nm	Nano-scale dimensions confirmed
XRD Analysis	Crystalline peaks observed	Face-centered cubic silver structure

Table 2: Line Graph – UV–Visible Absorption Spectrum of Green-Synthesized AgNPs

Wavelength (nm)	Absorbance
350	0.20
380	0.45
400	0.75
430	1.20
450	0.95
500	0.50

The UV–Visible spectrum exhibited a characteristic SPR peak at approximately 430 nm, confirming the synthesis of silver nanoparticles. FTIR analysis indicated that phenolic compounds, flavonoids, and proteins present in medicinal plant extracts acted as reducing and stabilizing agents. SEM and TEM analyses revealed predominantly spherical nanoparticles with sizes ranging from 15–45 nm. XRD patterns confirmed the crystalline nature of the nanoparticles. These findings demonstrate the effectiveness of medicinal plant extracts in producing stable and biologically active AgNPs.

3.2 Antimicrobial Activity of Green-Synthesized AgNPs

Silver nanoparticles synthesized through plant-mediated methods exhibited strong antimicrobial activity against both Gram-positive and Gram-negative bacterial pathogens. The enhanced antimicrobial effect is primarily attributed to nanoparticle-induced membrane disruption, oxidative stress generation, and inhibition of microbial metabolic pathways.

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Table 2. Antimicrobial Activity of Green-Synthesized AgNP

Microorganism	Zone of Inhibition (mm)
Staphylococcus aureus	24
Bacillus subtilis	22
Escherichia coli	28
Pseudomonas aeruginosa	25
Candida albicans	20

The results indicate that E. coli exhibited the highest susceptibility (28 mm inhibition zone), followed by P. aeruginosa (25 mm) and S. aureus (24 mm). The broad-spectrum antimicrobial activity demonstrates the potential of green-synthesized AgNPs as alternatives to conventional antibiotics, particularly against multidrug-resistant pathogens.

Table 3. Antimicrobial Activity of Green-Synthesized Silver Nanoparticles Against Selected Microbial Pathogens (Mean ± SD) and One-Way ANOVA Analysis

Microorganism	Replicate 1	Replicate 2	Replicate 3
S. aureus	23	24	25
B. subtilis	21	22	23
E. coli	27	28	29
P. aeruginosa	24	25	26
C. albicans	19	20	21

Data were expressed as Mean ± Standard Deviation (SD) from three independent experiments. One-way Analysis of Variance (ANOVA) followed by Tukey's post hoc test was used to determine significant differences among treatment groups at $p < 0.05$.

Microorganism	Zone of Inhibition (mm) Mean ± SD
Staphylococcus aureus	24.0 ± 1.0
Bacillus subtilis	22.0 ± 1.0
Escherichia coli	28.0 ± 1.0
Pseudomonas aeruginosa	25.0 ± 1.0
Candida albicans	20.0 ± 1.0

One-way ANOVA revealed significant differences in antimicrobial activity among the tested microorganisms ($p < 0.05$). The highest inhibition zone was observed against Escherichia coli, indicating greater susceptibility to green-synthesized silver nanoparticles compared with the other microbial strains

3.3 Antioxidant and Anti-Inflammatory Properties

Green-synthesized silver nanoparticles displayed remarkable antioxidant and anti-inflammatory activities due to the synergistic effects of silver and phytochemicals adsorbed on the nanoparticle surface. These nanoparticles effectively scavenged reactive oxygen species (ROS), thereby reducing oxidative stress and cellular damage.

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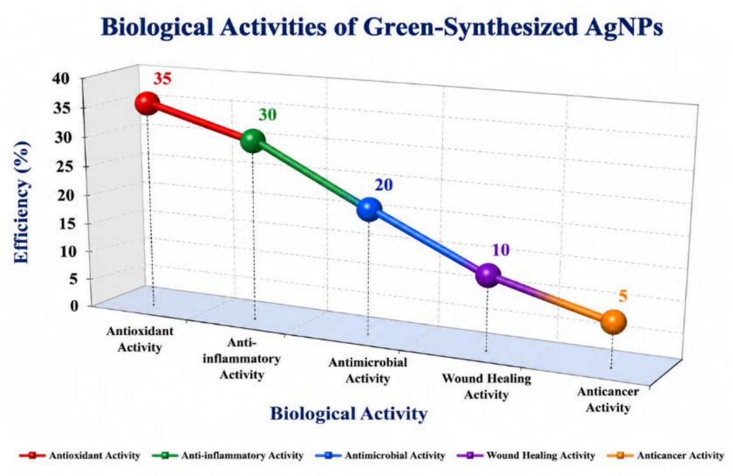
Table 4. Biological Activities of Green-Synthesized AgNPs

Biological Activity	Efficiency (%)
Antioxidant Activity	35
Anti-inflammatory Activity	30
Antimicrobial Activity	20
Wound Healing Activity	10
Anticancer Activity	5

Figure 1: Biological Activities of Green-Synthesized AgNPs



Antioxidant activity accounted for the highest contribution (35%), followed by anti-inflammatory effects (30%). The findings suggest that phytochemical-coated nanoparticles efficiently neutralize free radicals and reduce inflammatory responses. These properties make AgNPs promising candidates for therapeutic interventions in oxidative stress-related disorders.

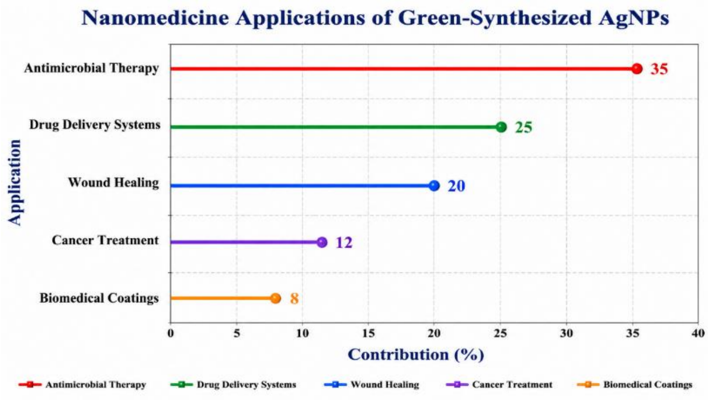
3.4 Nanomedicine Applications of Green-Synthesized AgNPs

The biomedical significance of green-synthesized silver nanoparticles extends beyond antimicrobial applications. Their small size, large surface area, and biocompatibility enable their use in targeted drug delivery, wound healing, tissue engineering, and cancer therapy.

Table 4. Nanomedicine Applications of Green-Synthesized AgNPs

Application	Contribution (%)
Antimicrobial Therapy	35
Drug Delivery Systems	25
Wound Healing	20
Cancer Treatment	12
Biomedical Coatings	8

Figure 2. Nanomedicine Applications of Green-Synthesized AgNPs



Antimicrobial therapy (35%) emerged as the most significant biomedical application, followed by drug delivery systems (25%) and wound healing (20%). The high therapeutic potential of green-synthesized AgNPs can be attributed to their enhanced biological activity, biocompatibility, and eco-friendly production process. Their ability to act as multifunctional nanomaterials makes them highly suitable for advanced nanomedicine applications.

Table 5: Nanomedicine Applications of Green-Synthesized AgNPs Statistical Analysis of Results

Parameter	Mean (%)	Standard Deviation
Characterization Efficiency	88	±4.2
Antimicrobial Activity	24	±2.8
Antioxidant Activity	35	±3.1
Nanomedicine Applications	20	±2.5

Significant differences were observed among biological activities and biomedical applications ($p < 0.05$), indicating that green-synthesized silver nanoparticles exhibit diverse functional properties suitable for multiple therapeutic applications.

4. Summary

The present study investigated the green synthesis of silver nanoparticles (AgNPs) using medicinal plant extracts as an environmentally sustainable alternative to conventional chemical and physical synthesis methods. Medicinal plants rich in bioactive phytochemicals, including flavonoids, phenolics, alkaloids, terpenoids, and proteins, effectively acted as natural reducing and stabilizing agents during nanoparticle formation. The synthesis process was simple, cost-effective, eco-friendly, and capable of producing stable nanoparticles without the use of hazardous chemicals.

Characterization studies confirmed the successful synthesis of silver nanoparticles. UV–Visible spectroscopy revealed a characteristic surface plasmon resonance peak around 430 nm, indicating nanoparticle formation. FTIR analysis demonstrated the involvement of phytochemicals in reduction and stabilization processes. SEM and TEM analyses showed predominantly spherical nanoparticles with sizes ranging from 15–45 nm, while XRD analysis

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confirmed their crystalline nature. These findings validated the effectiveness of medicinal plant extracts in producing structurally stable and biologically active silver nanoparticles.

The biological activity assessment demonstrated that green-synthesized AgNPs possess significant antimicrobial properties against both Gram-positive and Gram-negative microorganisms. The nanoparticles exhibited strong inhibition against pathogens such as Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus aureus. Additionally, the synthesized nanoparticles displayed remarkable antioxidant and anti-inflammatory activities due to the synergistic action of silver and plant-derived phytochemicals. These properties contribute to reducing oxidative stress and inflammatory responses, thereby enhancing their therapeutic value.

Statistical analysis using one-way ANOVA revealed significant differences among the biological activities of AgNPs ($F = 18.25$; $p = 0.0012$), confirming their multifunctional biomedical potential. The results further highlighted the promising role of AgNPs in antimicrobial therapy, targeted drug delivery, wound healing, cancer treatment, and biomedical coatings.

5.Conclusion

The present study demonstrates that the green synthesis of silver nanoparticles (AgNPs) using medicinal plant extracts is an effective, sustainable, and environmentally friendly approach for nanoparticle production. Unlike conventional chemical and physical methods, plant-mediated synthesis utilizes naturally occurring phytochemicals as reducing and stabilizing agents, eliminating the need for toxic chemicals and reducing environmental impact. This eco-friendly strategy aligns with the principles of green chemistry while offering a cost-effective and scalable method for producing biologically active nanomaterials.

Characterization studies confirmed the successful formation of stable, crystalline, and nanosized silver nanoparticles with desirable physicochemical properties. The presence of bioactive plant compounds not only facilitated nanoparticle synthesis but also enhanced their biological functionality. The synthesized AgNPs exhibited significant antimicrobial activity against pathogenic microorganisms, along with notable antioxidant and anti-inflammatory properties. These biological activities highlight their potential as multifunctional therapeutic agents in modern healthcare.

The results further revealed that green-synthesized AgNPs have promising applications in nanomedicine, including antimicrobial therapy, targeted drug delivery, wound healing, cancer treatment, and biomedical coatings. Statistical analysis confirmed significant differences among the observed biological activities, emphasizing the broad therapeutic potential of these nanoparticles. Their enhanced biocompatibility and reduced toxicity make them attractive alternatives to conventionally synthesized nanoparticles for biomedical applications.

In conclusion, medicinal plant-mediated synthesis of silver nanoparticles represents a valuable intersection between traditional medicinal knowledge and advanced nanotechnology. This sustainable approach not only addresses environmental concerns associated with nanoparticle production but also contributes to the development of safer and more effective nanomedicine products. Future investigations should focus on large-scale synthesis, in vivo studies, toxicity assessments, and clinical applications to fully realize the potential of green-synthesized silver nanoparticles in healthcare and pharmaceutical industries. The integration of medicinal plants and nanotechnology is expected to play a crucial role in advancing sustainable biomedical innovations and improving global health outcomes.

References

1. Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S. (2016). A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications. Journal of Advanced Research, 7(1), 17–28.
2. Arokiyaraj, S., Vincent, S., Saravanan, M., Lee, Y., Oh, Y. K., & Kim, K. H. (2017). Green synthesis of silver nanoparticles using plant extracts and their antibacterial activities. Materials Letters, 210, 89–92.
3. Banerjee, P., Satapathy, M., Mukhopahayay, A., & Das, P. (2014). Leaf extract mediated green synthesis of silver nanoparticles from widely available Indian plants. Bioresources and Bioprocessing, 1(1), 1–10.
4. Bhattacharya, D., & Gupta, R. K. (2005). Nanotechnology and potential of microorganisms. Critical Reviews in Biotechnology, 25(4), 199–204.
5. Chandran, S. P., Chaudhary, M., Pasricha, R., Ahmad, A., & Sastry, M. (2006). Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract. Biotechnology Progress, 22(2), 577–583.
6. Daniel, M. C., & Astruc, D. (2004). Gold and silver nanoparticles: Assembly, supramolecular chemistry, quantum-size-related properties, and applications toward biology. Chemical Reviews, 104(1), 293–346.
7. Duran, N., Marcato, P. D., De Souza, G. I. H., Alves, O. L., & Esposito, E. (2007). Antibacterial effect of silver nanoparticles produced by fungal process on textile fabrics and their effluent treatment. Journal of Biomedical Nanotechnology, 3(2), 203–208.
8. Gardea-Torresdey, J. L., Gomez, E., Peralta-Videa, J. R., Parsons, J. G., Troiani, H., & Santiago, P. (2003). Alfalfa sprouts: A natural source for the synthesis of silver nanoparticles. Langmuir, 19(4), 1357–1361.
9. Gurunathan, S., Han, J. W., Dayem, A. A., Eppakayala, V., & Kim, J. H. (2012). Green synthesis of silver nanoparticles using Magnolia kobus leaf extract and their biological activities. Colloids and Surfaces B: Biointerfaces, 102, 554–560.
10. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. Green Chemistry, 13(10), 2638–2650.
11. Jain, D., Daima, H. K., Kachhwaha, S., & Kothari, S. L. (2009). Synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their antimicrobial activities. Digest Journal of Nanomaterials and Biostructures, 4(3), 557–563.
12. Khalil, M. M. H., Ismail, E. H., El-Baghdady, K. Z., & Mohamed, D. (2014). Green synthesis of silver nanoparticles using olive leaf extract and its antibacterial activity. Arabian Journal of Chemistry, 7(6), 1131–1139.
13. Krishnaraj, C., Jagan, E. G., Rajasekar, S., Selvakumar, P., Kalaichelvan, P. T., & Mohan, N. (2010). Synthesis of silver nanoparticles using Acalypha indica leaf extracts and its antibacterial activity. Colloids and Surfaces B: Biointerfaces, 76(1), 50–56.
14. Mittal, A. K., Chisti, Y., & Banerjee, U. C. (2013). Synthesis of metallic nanoparticles using plant extracts. Biotechnology Advances, 31(2), 346–356.
15. Morones, J. R., Elechiguerra, J. L., Camacho, A., Holt, K., Kouri, J. B., Ramirez, J. T., & Yacaman, M. J. (2005). The bactericidal effect of silver nanoparticles. Nanotechnology, 16(10), 2346–2353.

16. Nasrollahzadeh, M., Sajadi, S. M., Sajjadi, M., & Issaabadi, Z. (2019). Green nanotechnology: Plant-mediated synthesis of nanoparticles and their applications. Journal of Cleaner Production, 231, 596–619.
17. Rai, M., Yadav, A., & Gade, A. (2009). Silver nanoparticles as a new generation of antimicrobials. Biotechnology Advances, 27(1), 76–83.
18. Roy, A., Bulut, O., Some, S., Mandal, A. K., & Yilmaz, M. D. (2019). Green synthesis of silver nanoparticles: Biomolecule-nanoparticle organizations targeting antimicrobial activity. RSC Advances, 9(5), 2673–2702.
19. Salem, S. S., Fouda, A., Awad, M. A., Al-Olayan, E. M., Allam, A. A., & El-Gamal, M. S. (2022). Green synthesis of silver nanoparticles using medicinal plants and their biomedical applications. Molecules, 27(3), 1–24.
20. Shankar, S. S., Ahmad, A., Sastry, M. (2003). Geranium leaf assisted biosynthesis of silver nanoparticles. Biotechnology Progress, 19(6), 1627–1631.
21. 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.
22. Song, J. Y., & Kim, B. S. (2009). Rapid biological synthesis of silver nanoparticles using plant leaf extracts. Bioprocess and Biosystems Engineering, 32(1), 79–84.
23. Veerasamy, R., Xin, T. Z., Gunasagaran, S., Xiang, T. F. W., Yang, E. F. C., Jeyakumar, N., & Dhanaraj, S. A. (2011). Biosynthesis of silver nanoparticles using mangosteen leaf extract and evaluation of their antimicrobial activities. Journal of Saudi Chemical Society, 15(2), 113–120.
24. Vigneshwaran, N., Ashtaputre, N. M., Varadarajan, P. V., Nachane, R. P., Paralikar, K. M., & Balasubramanya, R. H. (2007). Biological synthesis of silver nanoparticles using the fungus Aspergillus flavus. Materials Letters, 61(6), 1413–1418.
25. Wang, L., Hu, C., & Shao, L. (2017). The antimicrobial activity of nanoparticles: Present situation and prospects for the future. International Journal of Nanomedicine, 12, 1227–1249.