



FORMULATION AND EVALUATION OF HERBAL PLANT CONTAINING SILVER NANOPARTICLE FORMULATION AND ITS ANTI-BACTERIAL ACTIVITY

Sunil Singh^{*1}, Hemant Agrawal², Naveen Gupta³

¹Student- Madhyanchal Professional University (MPU), Bhopal (M.P).

²Associate Professor - Madhyanchal Professional University (MPU), Bhopal (M.P).

³Dean - Madhyanchal Professional University (MPU), Bhopal (M.P).



***Corresponding Author: Sunil Singh**

Student- Madhyanchal Professional University (MPU), Bhopal (M.P).

DOI: <https://doi.org/10.5281/zenodo.23594814>



How to cite this Article: Sunil Singh^{*1}, Hemant Agrawal², Naveen Gupta³. (2026). Formulation and Evaluation of Herbal Plant Containing Silver Nanoparticle Formulation And Its Anti-Bacterial Activity. World Journal of Pharmaceutical and Life Sciences, 12(10), 242–249.

This work is licensed under Creative Commons Attribution 4.0 International license.

Article Received on 08/09/2026

Article Revised on 28/009/2026

Article Published on 01/10/2026

ABSTRACT

The present study focuses on the green synthesis, characterization, and antibacterial evaluation of silver nanoparticles (SNPs) mediated by *Acacia pennata* leaf extract. Fresh leaves of *Acacia pennata* were collected, shade dried, powdered, and extracted successively using petroleum ether and methanol through Soxhlet extraction. Preliminary phytochemical screening of the extracts confirmed the presence of important bioactive constituents such as alkaloids, flavonoids, glycosides, tannins, phenolic compounds, and steroids, which may contribute to the reduction and stabilization of silver ions during nanoparticle synthesis. Silver nanoparticles were biosynthesized using different concentrations of *Acacia pennata* extract with 1 mM silver nitrate solution under controlled conditions. Formation of nanoparticles was confirmed visually by a characteristic color change from yellow to brown and further validated by UV–Visible spectrophotometric analysis, which showed a surface plasmon resonance peak at 672 nm. The synthesized nanoparticles were characterized for particle size, zeta potential, and surface morphology. Among all formulations, SNPs F1 exhibited the smallest particle size (155.74 nm) and highest zeta potential (-27.8 mV), indicating good stability and uniform dispersion. SEM analysis revealed spherical and well-dispersed nanoparticles with minimal aggregation. The antibacterial activity of the synthesized silver nanoparticles was evaluated against *Escherichia coli* and *Staphylococcus aureus* using the agar well diffusion method. The findings demonstrated that the nanoparticles possessed antibacterial activity, although the crude extract showed comparatively larger zones of inhibition. The study confirms that *Acacia pennata* can serve as an effective natural reducing and stabilizing agent for eco-friendly synthesis of silver nanoparticles. The developed nanoparticle system exhibited promising physicochemical properties and antibacterial potential, supporting its future application in pharmaceutical and biomedical fields as a plant-based antimicrobial nanotherapeutic system.

KEYWORDS: *Acacia pennata*, Silver nanoparticles, Green synthesis, Antibacterial activity, Phytochemical screening, SEM analysis, UV–Visible spectroscopy.

1. INTRODUCTION

Targeted drug delivery systems are advanced therapeutic approaches designed to deliver drugs directly to the diseased site while minimizing side effects on healthy tissues. Unlike conventional drug delivery systems, targeted systems provide controlled and site-specific release of therapeutic agents, thereby improving drug efficacy and reducing toxicity (Rani et al., 2014; Singh et al., 2019). These systems are developed by considering factors such as drug properties, disease

conditions, route of administration, and target site. An ideal targeted drug delivery system should be biocompatible, non-toxic, stable, non-immunogenic, and capable of releasing drugs in a controlled and predictable manner (Dunuweera et al., 2019). Nanotechnology-based carriers, especially mesoporous silica nanoparticles and metallic nanoparticles, have emerged as promising systems due to their high surface area, improved drug loading capacity, enhanced stability, and imaging potential (Manzari et al., 2021; Cheng et al.,

2023).

Among various nanomaterials, silver nanoparticles (AgNPs) have gained considerable attention because of their unique physicochemical and biological properties. AgNPs are nanosized particles ranging from 1–1000 nm and possess remarkable antimicrobial, antioxidant, anticancer, and drug delivery capabilities (Burdusel et al., 2018). Their broad spectrum antimicrobial activity against Gram-positive and Gram-negative bacteria, including multidrug-resistant strains, has made them highly valuable in biomedical and pharmaceutical applications (Durán et al., 2016). The enhanced antimicrobial activity of AgNPs is mainly attributed to their large surface area, which promotes interaction with bacterial cell membranes, leading to membrane damage, DNA disruption, oxidative stress, and inhibition of protein synthesis (Ahamed et al., 2010).

The medicinal use of silver dates back to ancient times when silver vessels were used to preserve water and wine. Silver compounds such as silver nitrate and silver sulfadiazine were historically employed for the treatment of infections and burn wounds (Luoma, 2008). Although the use of silver declined after the discovery of antibiotics, interest in silver was revived due to the emergence of antibiotic-resistant bacterial strains and the development of nanotechnology. Silver nanoparticles exhibit multiple mechanisms of antimicrobial action, making microbial resistance comparatively difficult (Paramesh et al., 2024). Since the first synthesis of silver colloids in the nineteenth century, nanosilver has been widely investigated for various biomedical applications (Yu et al., 2013).

Silver nanoparticles can be synthesized by physical, chemical, and biological methods. Physical methods such as ball milling, laser ablation, and vapour condensation produce highly pure nanoparticles but require sophisticated equipment and high energy consumption (Gulbagca et al., 2019; Deepak et al., 2025, Edison et al., 2016). Chemical methods, including electrochemical synthesis, microwave-assisted synthesis, and microemulsion techniques, are widely used due to their better control over particle size and morphology (Bouafia et al., 2021; Kharat et al., 2016). However, these methods often involve toxic reducing agents and stabilizers. Recently, green synthesis approaches using plants, algae, and microorganisms have gained significant importance because they are eco-friendly, cost-effective, and safer alternatives (Nguyen et al., 2023). Plant-mediated synthesis is especially preferred due to the presence of phytochemicals such as flavonoids, polyphenols, proteins, and enzymes that act as reducing and stabilizing agents during nanoparticle formation (Dikshit et al., 2021).

Acacia pennata is a medicinal plant rich in bioactive compounds with reported antimicrobial and therapeutic properties. Encapsulation of *Acacia pennata* leaf extract

within silver nanoparticles may enhance its antibacterial efficacy through synergistic action. Green synthesized silver nanoparticles are expected to exhibit improved stability, biocompatibility, and enhanced biological activity compared with conventional formulations.

Silver nanoparticles have extensive biomedical and environmental applications. They are widely used as antimicrobial agents in wound dressings, coatings, food packaging, textiles, and medical devices (Abbasi et al., 2016). In cancer therapy, AgNPs can induce oxidative stress and apoptosis in cancer cells by generating reactive oxygen species and disrupting mitochondrial functions (Yeasmin et al., 2017). AgNPs also exhibit antioxidant and antidiabetic properties by scavenging free radicals and inhibiting carbohydrate hydrolyzing enzymes (Bedlovičová et al., 2020; Balan et al., 2016). Furthermore, environmental applications of AgNPs include air disinfection, water purification, and antimicrobial surface coatings due to their strong bactericidal activity (Jung et al., 2011; Kumar et al., 2008).

The present research aims to synthesize and characterize silver nanoparticles encapsulating *Acacia pennata* leaf extract and evaluate their antibacterial activity. The prepared nanoparticles will be characterized in terms of particle size, shape, stability, and entrapment efficiency. Their antibacterial efficacy will be evaluated against selected bacterial strains to determine their potential as an effective and eco-friendly antimicrobial formulation. This study may contribute to the development of novel nanoparticle-based antibacterial systems with significant biomedical applications.

2. MATERIALS AND METHODS

2.1 Collection of Plant Material

Fresh leaves of *Acacia pennata* were harvested and subjected to shade drying at ambient room temperature for a period of three days to preserve their phytochemical constituents. Once thoroughly dried, the plant material was transferred to clean, airtight glass containers and stored in a cool, dry place to avoid exposure to moisture and microbial contamination.

2.2 Process of Plant Material Extraction

A total of 300 grams of the powdered plant material was weighed and placed into a thimble for Soxhlet extraction. Sequential solvent extraction was performed, beginning with petroleum ether (500 ml) at 60°C to extract non-polar constituents. (Krakowska et al., 2022).

The percentage yield of the extracts was calculated using the standard formula:

$$\% \text{ Yield} = (\text{Weight of dried extract} / \text{Weight of plant material used}) \times 100$$

2.3 The Organoleptic Studies of *Acacia pennata* Extract

The organoleptic properties of the *Acacia pennata*

extract were evaluated by a trained sensory panel to assess key visual attributes, including odor, and texture.

2.4 Solubility study of *Acacia pennata* extract

A measured quantity of the extract was transferred into individual test tubes, each containing 1 ml of different solvents methanol, dichloromethane (DCM), distilled water, chloroform, and acetone.

2.5 Preliminary phytochemical investigations

Qualitative screening of *Acacia pennata* extract revealed the presence of key phytochemical classes including alkaloids, flavonoids, phenolics, saponins, steroids, terpenoids, and coumarins across various solvent extracts. These findings support its rich bioactive profile and potential applications in antioxidant, anti-inflammatory, and antimicrobial contexts (Roy et al., 2010).

1. Tests for Alkaloids
2. Test for Glycosides
3. Test for Carbohydrates
4. Test for Flavonoids
5. Tannin and Phenolic Compound Test
6. Test for Saponin
7. Test for Triterpenoids and Steroids

2.6 Biosynthesis of Silver Nanoparticles

➤ Preparation of 1mM AgNO₃ solution

The biosynthesis of silver nanoparticles (SNPs) using *Acacia pennata* extract was initiated by preparing a 1

mM silver nitrate (AgNO₃) solution. This was accomplished by dissolving 0.016 g of AgNO₃ in 100 mL of purified water, followed by continuous stirring to ensure complete dissolution, according to the method described by Mishra and Singh (2015).

Five different concentrations of the plant extract 100 mg/mL, 75 mg/mL, 50 mg/mL, 25 mg/mL, and 12.5 mg/mL were prepared for nanoparticle synthesis. Subsequently, 1 mL of each extract concentration was separately added to 15 mL of the prepared 1 mM AgNO₃ solution in individual beakers. The reaction mixtures were continuously stirred for 20 minutes to facilitate effective interaction between the phytochemicals present in the extract and the silver ions.

To avoid photo-degradation of silver ions, all reaction mixtures were incubated in a dark chamber. A gradual color change from yellow to brown was observed, indicating the reduction of Ag⁺ ions and the formation of silver nanoparticles. The synthesis process was further monitored at regular intervals using a UV-Visible spectrophotometer. The appearance of characteristic surface plasmon resonance (SPR) peaks in the absorbance spectrum confirmed the successful biosynthesis of silver nanoparticles, as reported by Mishra and Singh (2015).

Table 1: Composition of silver nanoparticle formulation.

S. No	Formulations	<i>Acacia pennata</i> (mg/ml) (Each 1 ml)	Methyl paraben (%)	Silver nitrate solution (ml) 1mM	Stirring time(min.) 300 rpm
1	F1	100	0.02	15	20
2	F2	75	0.02	15	20
3	F3	50	0.02	15	20
4	F4	25	0.02	15	20
5	F5	12.5	0.02	15	20

2.7.1 Visual Observation of the Biosynthesized Silver Nanoparticles

The reaction mixture was observed visually at specific time intervals 30 minutes, 1 hour, 2 hours, and 3 hours following the addition of *Acacia pennata* extract to the 1 mM silver nitrate solution. (Zaki et al., 2011).

2.7.2 Particle size of the Biosynthesized Silver Nanoparticles

In this analysis, the size of the biosynthesized silver nanoparticles was measured using a Malvern Zetasizer, which operates based on dynamic light scattering (DLS) principles. (Akbari et al., 2011).

2.7.3 Zeta potential of the Biosynthesized Silver Nanoparticles

The measurements were carried out using a Malvern Zetasizer after diluting the nanoparticle samples tenfold with distilled water. Prior to testing, the samples were sonicated for 5 to 15 minutes to break up any

agglomerates and ensure a uniform suspension (Bhattacharjee, 2016).

2.7.4 Scanning Electron Microscopic (SEM) of the Biosynthesized Silver Nanoparticles

The surface morphology of the biosynthesized silver nanoparticles was examined using a scanning electron microscope (SEM). (Mohammed and Abdullah, 2018).

2.8 Anti-microbial activity of the Biosynthesized Silver Nanoparticles by Well diffusion assay (Pratap et al., 2012)

1. Preparation of Nutrient Agar Media

The following procedure was used to prepare nutrient agar for microbial culture:

- **Media Preparation:** 2.8 grams of nutrient media powder were accurately weighed and dissolved in 100 milliliters of purified water with continuous stirring to ensure complete dissolution. (Pratap et al., 2012).

3. RESULTS AND DISCUSSION

3.1 Plant Collection

Table 2: Plant collection.

S. No.	Plant name	Plant part used	Weight
1.	<i>Acacia pennata</i>	Leaves	300 gm

3.2 Percentage Yield determination

Assessing the percentage yield plays a crucial role in phytochemical extraction, as it serves as a measure of how effective the extraction process is. It allows for comparisons across various plant species, different plant parts, or when using different extraction solvents. Table 5 presents the results showing the extractive yield obtained from *Acacia pennata*.

Table 3: Percentage Yield of crude extracts of *Acacia pennata* extract.

Plant name	Solvent	Color of extract	Theoretical weight	Yield(gm)	% yield
<i>Acacia pennata</i>	Pet ether	Greenish Yellow	300	4.51	1.50%
	Methanol	Dark brownish	288	5.43	1.88%

3.3 Organoleptic properties

Table 4: The Organoleptic Studies of *Acacia pennata* leaves extract.

S. No	<i>Acacia pennata</i>	Study
1	Colour	Dark brownish
2	Odour	Characteristic herbal smell
3	Appearance	Thick, sticky extract

3.4 Solubility study

Table 5: Solubility study of *Acacia pennata*.

Extract	Solvents	Observation/Inference
<i>Acacia pennata</i>	Methanol	Completely disperses
	Distilled Water	Partially disperses
	DMSO	Fully dissolves
	Chloroform	Slightly disperses
	Acetone	Fully dissolve

3.5 Preliminary Phytochemical study

The preliminary phytochemical screening of *Acacia pennata* extracts confirmed the presence of several important bioactive compounds. Both petroleum ether and methanolic extracts showed positive results for alkaloids, glycosides, flavonoids, tannins, and phenolic compounds, indicating their potential antimicrobial and antioxidant properties. Carbohydrates and triterpenoids/steroids were detected only in the methanolic extract, suggesting that methanol is more effective in extracting polar and semi-polar phytoconstituents. Saponins were absent in both extracts. Overall, the methanolic extract exhibited a broader phytochemical profile compared to the petroleum ether extract, highlighting its suitability for further nanoparticle synthesis and pharmacological studies.

3.6 Evaluation parameter of the Biosynthesized Silver Nanoparticles

3.6.1 Color Observation

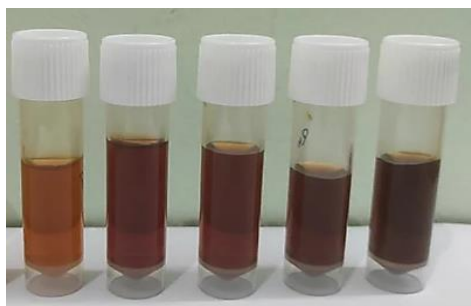


Figure 1: synthesized silver nanoparticle After 30 min.

3.6.2 UV-Visible spectrophotometric analysis

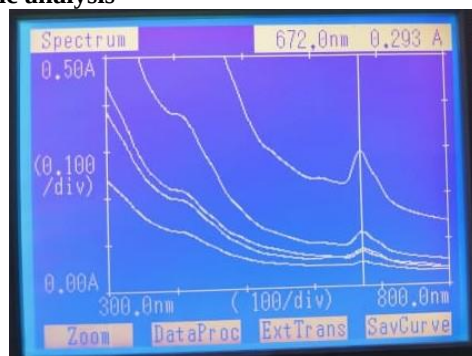


Figure 2: UV Graph of F1 Formulation.

Table 6: UV peak detection.

S. No	Silver nanoparticle Formulations	Peak detection
1	SNPs (F1)	672.0

3.6.3 Particle size

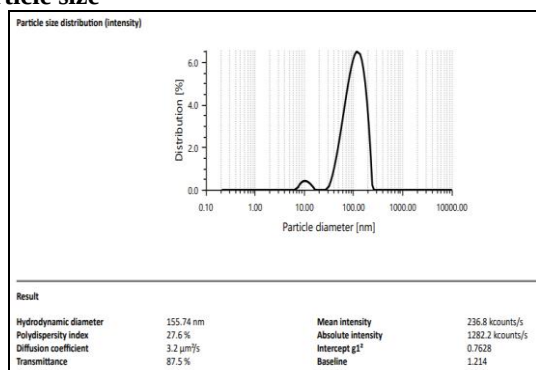


Figure 3: Particle size (F1)

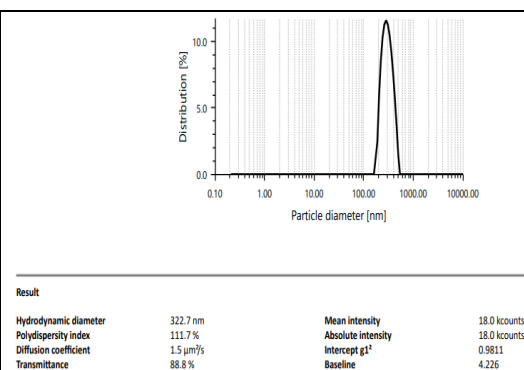


Figure 4: Particle size (F2)

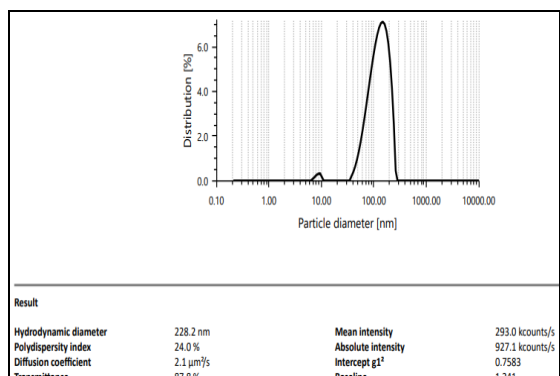


Figure 5: Particle size (F4)

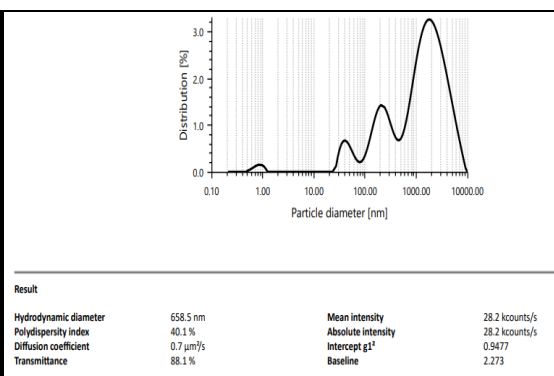


Figure 6: Particle size (F3)

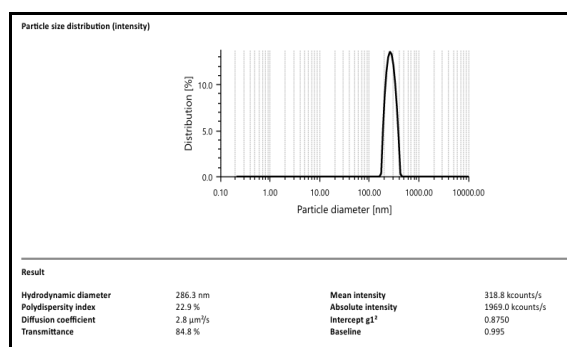


Figure 7: Particle size (F5)

3.6.4 Zeta potential

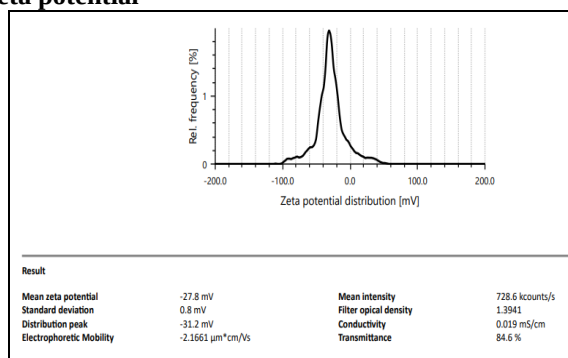


Figure 8: Zeta potential (F1)

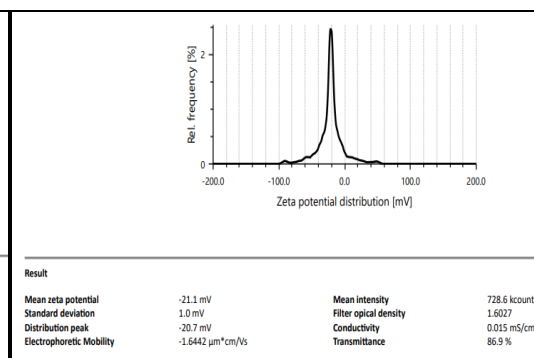


Figure 9: Zeta potential (F2)

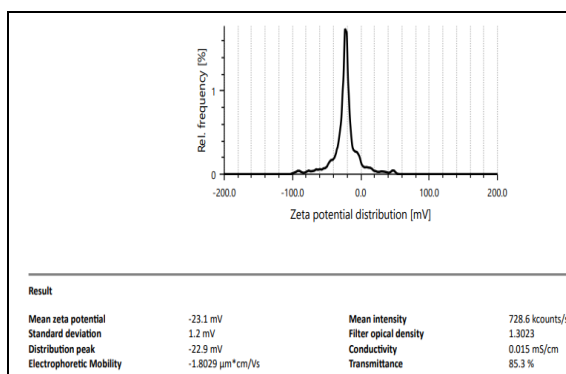


Figure 10: Zeta potential (F3)

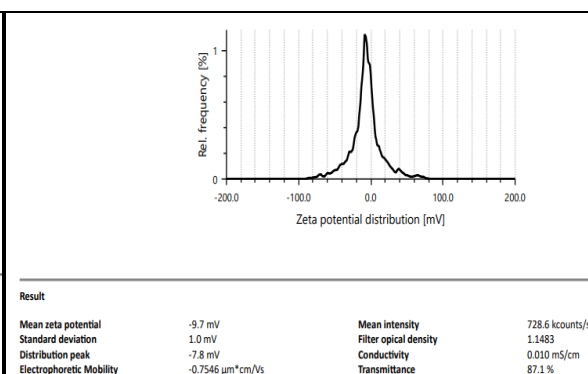


Figure 11: Zeta potential (F4)

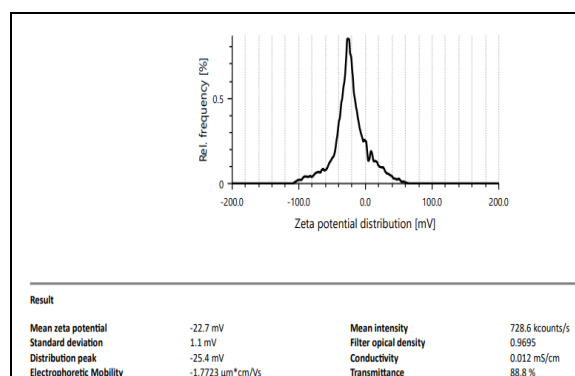


Figure 12: Zeta potential (F5).

Table 7: Particle size and zeta potential determination of SNPs.

S. No	Formulation	Particle size (nm)	Zeta potential
1	SNPs F1	155.74	-27.8mV
2	SNPs F2	322.7	-21.1mV
3	SNPs F3	228.2	-23.1mV
4	SNPs F4	658.5	-9.7mV
5	SNPs F5	286.3	-22.7 mV

3.6.5 SEM analysis

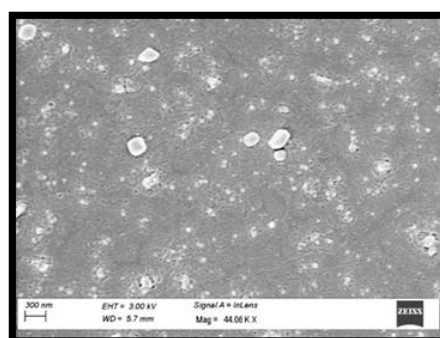


Figure 13: SEM analysis.

3.7 Results of antimicrobial activity of SNPs F1 formulation

3.7.1 Antimicrobial activity of SNPs

Table 8: Antimicrobial activity of SNPs against *E.coli* and *S. aureus*.

S. No.	Sample Name (mg/ml)	Zone of Inhibition (mm) of <i>E. coli</i>	Zone of Inhibition (mm) of <i>S. aureus</i>
1.	(control)	0mm	0mm
2.	AgNO ₃ (1mg/ml)	6 mm	5 mm
3.	Extract (1mg/ml)	7 mm	4 mm
4.	Silver NPs (1ml)	3mm	2 mm



Figure 14: Photograph showing zone of inhibition of planr extract mediated synthesis of SNPs against A: *Staphylococcus aureus*, B: *Escherichia coli*.

4. DISCUSSIONS

The present study successfully demonstrated the green synthesis of silver nanoparticles using *Acacia pennata* leaf extract. Methanolic extraction produced a higher percentage yield (1.88%) compared to petroleum ether extraction (1.50%), indicating the efficient extraction of polar phytoconstituents. Organoleptic and solubility studies revealed that the extract possessed characteristic herbal properties and showed good solubility in polar solvents such as methanol and DMSO.

Preliminary phytochemical screening confirmed the presence of alkaloids, glycosides, flavonoids, tannins, and phenolic compounds in both extracts, while carbohydrates and triterpenoids/steroids were detected only in the methanolic extract. These phytochemicals may act as reducing and stabilizing agents during nanoparticle synthesis and contribute to the biological activity of the formulation.

The successful formation of silver nanoparticles was confirmed by a visible color change from yellow to brown and the appearance of a characteristic UV–Visible absorption peak at 672 nm. Among all formulations, F1 exhibited the smallest particle size (155.74 nm) and highest zeta potential (-27.8 mV), indicating better nanoparticle stability and dispersion. SEM analysis further confirmed the spherical morphology and uniform distribution of the nanoparticles.

The antimicrobial study demonstrated that the synthesized silver nanoparticles exhibited antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*. Although the crude plant extract showed comparatively higher zones of inhibition, the synthesized nanoparticles also displayed inhibitory effects, suggesting their potential as antimicrobial agents. Overall, the study highlights the potential of *Acacia pennata*-mediated silver nanoparticles for future biomedical and pharmaceutical applications.

5. CONCLUSION

The present study successfully demonstrated the green

synthesis of silver nanoparticles using *Acacia pennata* leaf extract through an eco-friendly and cost-effective approach. Preliminary phytochemical screening confirmed the presence of important bioactive compounds such as alkaloids, flavonoids, glycosides, tannins, phenolics, and triterpenoids, which may play a significant role in the reduction and stabilization of silver nanoparticles. Among the different formulations prepared, formulation F1 showed the most favorable characteristics, including smaller particle size, better dispersion, and higher zeta potential, indicating good nanoparticle stability.

The formation of silver nanoparticles was confirmed by visual color change, UV–Visible spectrophotometric analysis, particle size analysis, zeta potential measurement, and SEM studies. The synthesized nanoparticles exhibited antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*, demonstrating their potential as antimicrobial agents. Overall, the findings suggest that *Acacia pennata*-mediated silver nanoparticles possess promising physicochemical and biological properties and may serve as potential candidates for future pharmaceutical, biomedical, and antimicrobial applications.

6. REFERENCES

1. Mohamed Ahamed, Mohamed S. Alsalihi, & Mohammad Javed Siddiqui. Silver nanoparticle applications and human health. *Clinica Chimica Acta*, 2010; 411(23–24): 1841–1848.
2. Elham Abbasi, et al. Silver nanoparticles: Synthesis methods and biomedical applications. *Critical Reviews in Microbiology*, 2016; 42(2): 173–180.
3. Mohammad Alam, et al. Microwave-assisted synthesis of silver nanoparticles and their biomedical applications. *Materials Today Chemistry*, 2023; 29: 101450.
4. K. Balan, et al. Antidiabetic activity of silver nanoparticles synthesized using plant extracts. *Journal of Applied Pharmaceutical Science*, 2016; 6(07): 139–146.

5. Zuzana Bedlovičová, et al. Antioxidant activity and biocompatibility of silver nanoparticles. *Molecules*, 2020; 25(14): 3199.
6. Abdelkrim Bouafia, et al. Electrochemical synthesis of silver nanoparticles and their applications. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 2021; 614: 126178.
7. Alina Cristina Burduşel, et al. Biomedical applications of silver nanoparticles: An up-to-date overview. *Nanomaterials*, 2018; 8(9): 681.
8. Yuan Cheng, et al. Mesoporous silica nanoparticles in targeted drug delivery systems. *Drug Delivery*, 2023; 30(1): 2165420.
9. Pramod Kumar Dikshit, et al. Green synthesis of metallic nanoparticles using plant extracts and their applications. *Environmental Chemistry Letters*, 2021; 19: 355–374.
10. Sanjeewa P. Dunuweera, et al. Targeted drug delivery systems: Recent advances and future perspectives. *International Journal of Pharmaceutical Sciences and Research*, 2019; 10(9): 4086–4098.
11. Nelson Durán, et al. Mechanistic aspects and applications of silver nanoparticles in medicine. *International Journal of Nanomedicine*, 2016; 11: 103–113.
12. T. J. I. Edison, et al. Vapour condensation methods for nanoparticle synthesis: A review. *Materials Research Express*, 2016; 3(10): 102001.
13. Funda Gulbagca, et al. Ball milling synthesis of silver nanoparticles and characterization studies. *Powder Technology*, 2019; 343: 104–110.
14. Jung Hoon Jung, et al. Antimicrobial air filtration using airborne silver nanoparticles. *Science of the Total Environment*, 2011; 409(13): 2481–2487.
15. Shilpa Kakkar, et al. Design criteria for targeted drug delivery systems. *Journal of Controlled Release*, 2017; 253: 62–73.
16. S. N. Kharat, et al. Microwave-assisted synthesis of nanoparticles: A review. *Nano-Structures & Nano-Objects*, 2016; 6: 1–11.
17. Ashwani Kumar, et al. Silver nanoparticle embedded antimicrobial paints based on vegetable oil. *Progress in Organic Coatings*, 2008; 62(4): 393–397.
18. Samuel N. Luoma (2008). *Silver Nanotechnologies and the Environment: Old Problems or New Challenges?* Washington, DC: Project on Emerging Nanotechnologies.
19. Mahsa T. Manzari, et al. Mesoporous silica nanoparticles for targeted drug delivery applications. *International Journal of Molecular Sciences*, 2021; 22(2): 715.
20. Dung H. Nguyen, et al. Plant-mediated green synthesis of silver nanoparticles and biomedical applications. *Biomolecules*, 2023; 13(3): 512.
21. K. Paramesh, et al. Antibacterial mechanisms of silver nanoparticles against multidrug-resistant bacteria. *Frontiers in Microbiology*, 2024; 15: 1345621.
22. Kiran Rani, et al. Targeted drug delivery systems: A review. *International Journal of Pharmaceutical Sciences Review and Research*, 2014; 24(2): 310–320.
23. Virender K. Sharma, et al. Algae-mediated synthesis of silver nanoparticles and their applications. *Biotechnology Reports*, 2016; 12: 90–95.
24. Ravindra Singh, et al. Targeted drug delivery approaches and therapeutic applications. *Current Drug Delivery*, 2019; 16(5): 394–406.
25. Deepak, Gokhe, S., & Khan, A. (2025). Development and characterization of β -cyclodextrin-based nanosponge gel containing herbal extract using a quality by design (QbD) approach and its antimicrobial activity.
26. Sung Jae Yu, et al. (2013). History, properties, and applications of nanosilver. *Journal of Nanomaterials*, 2013; 256747.
27. Sharmin Yeasmin, et al. Anticancer activity of biosynthesized silver nanoparticles: A review. *International Journal of Molecular Sciences*, 2017; 18(5): 940.
28. Akbari, B., Tavandashti, M.P., & Zandrahimi, M. Particle size characterization of nanoparticles by dynamic light scattering method. *Acta Physica Polonica A*, 2011; 119(1): 34–35.
29. Bhattacharjee, S. DLS and zeta potential – What they are and what they are not? *Journal of Controlled Release*, 2016; 235: 337–351.
30. Krakowska, A., et al. Soxhlet extraction and phytochemical evaluation of medicinal plants. *Molecules*, 2022; 27(3): 1–15.
31. Mishra, P., & Singh, P. Green synthesis of silver nanoparticles using plant extracts and their characterization. *Journal of Nanoscience and Nanotechnology*, 2015; 15(3): 1–8.
32. Mohammed, A.E., & Abdullah, A. Scanning electron microscopy analysis of biosynthesized nanoparticles. *Materials Science Forum*, 2018; 929: 123–128.
33. Pratap, C.R., et al. Agar well diffusion method for antimicrobial activity screening of plant extracts and nanoparticles. *International Journal of Pharmaceutical Sciences Review and Research*, 2012; 17(2): 45–49.
34. Roy, S., Uddin, M.G., & Hassan, M.M. Phytochemical screening and biological evaluation of *Acacia pennata*. *International Journal of Pharmaceutical Sciences and Research*, 2010; 1(5): 102–106.
35. Zaki, S., El Kady, M.F., & Abd-El-Haleem, D. Biosynthesis and characterization of silver nanoparticles using plant extracts. *Journal of Nanobiotechnology*, 2011; 9(1): 1–10.