

Green synthesis of *Embelia ribes* mediated silver nanoparticles and their characterization using UV-Spectroscopy, FESEM, XRD, and FTIR analysis: An in vitro study

Running Title: Biosynthesis and Characterization of *Embelia ribes* mediated AgNPs

Dr Anjali Rathi

Department of Conservative Dentistry and Endodontics,
Saveetha Dental College and Hospitals,
Saveetha Institute of Medical and Technical Sciences,
Saveetha University,
Chennai, India

Corresponding Author

Sindhu Ramesh

Professor,

Department of Conservative Dentistry and Endodontics,
Saveetha Dental College and Hospitals,
Saveetha Institute of Medical and Technical Sciences,
Saveetha University,
162, PH Road, Chennai 600077
TamilNadu, India

Received: Sep 15, 2025

Accepted: Oct 11, 2025

Published: Oct 14, 2025

Abstract

Introduction: *Embelia ribes* (Vidanga) is a medicinal plant recognized for its bioactive constituent embelin, which exhibits multiple therapeutic properties. The green synthesis of nanoparticles using plant-based extracts has emerged as an eco-friendly and economical alternative to chemical methods. In this study, silver nanoparticles (AgNPs) were synthesized using *E. ribes* seed extract and characterized to confirm their structural and functional properties.

Aim: This research focuses on synthesizing *E. ribes*-mediated AgNPs and characterizing them using UV–Vis spectroscopy, X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and field-emission scanning electron microscopy (FESEM).

Materials and Methods: Ethanolic seed extract of *E. ribes* was prepared and used as a natural reducing and capping agent. The formation of AgNPs was confirmed by UV–Vis analysis, while structural information was obtained via XRD. FESEM was employed to examine the morphology, and FTIR spectroscopy was used to identify the functional groups involved in nanoparticle stabilization.

Results: A distinct surface plasmon resonance peak at ~430 nm confirmed nanoparticle synthesis. XRD patterns indicated crystalline AgNPs with a face-centered cubic structure. FESEM revealed agglomerated particles with irregular, porous surfaces, while FTIR spectra highlighted the role of plant-derived phytochemicals in reducing and stabilizing the nanoparticles.

Conclusion: The study successfully demonstrates an eco-friendly approach to synthesizing silver nanoparticles using *E. ribes* extract. The obtained AgNPs show desirable crystalline and surface characteristics, suggesting potential biomedical and pharmaceutical applications.

Keywords: *Embelia ribes*, green synthesis, FTIR, FESEM, silver nanoparticles, UV–Vis, XRD

Introduction

The growing field of nanoscience and nanotechnology has increasingly focused on the development of nanoparticles with varied sizes and innovative shapes, which significantly influence their distinct physical and chemical properties.[1] Nanoparticles are attracting considerable interest due to their remarkable characteristics, largely determined by their size, shape, and structure. Among them, silver nanoparticles (AgNPs) have gained prominence for their exceptional antimicrobial, biosensing, superconducting, and electronic properties. Research indicates that AgNPs are highly effective against a wide range of bacteria, viruses, and eukaryotic microorganisms, demonstrating strong bioactivity at low concentrations with minimal side effects on human health (Afkhami et al, 2023) [2]. Nanoparticles of metal and metal oxide are created by several physical and chemical methods [3].

The increasing awareness of the potential side effects associated with conventional medications has led to a growing interest in traditional herbal medicines. However, conventional methods of synthesizing silver nanoparticles, such as physical or chemical approaches including sol-gel processes, micelle formation, chemical precipitation, hydrothermal methods, pyrolysis, and chemical vapor deposition, have raised concerns regarding the toxicity and environmental hazards. To overcome these issues, green synthesis of silver nanoparticles has emerged as a new area of research and medicine. [4,5]

Embelia ribes is a woody shrub commonly known as Vidanga or false black pepper and Vaibidang in Sanskrit, belonging to the family Myrsinaceae. Known for its array of pharmacological properties, it has been used to treat a range of conditions such as diabetes, bronchitis, jaundice, rheumatoid arthritis, and cure tumors and mental disorders [6]. Seeds are used as an antibiotic, anthelmintic, antituberculosis, alterative, and stimulant. Owing to its significant contribution in the field of medicine, the Medicinal Board of the Government of India, New Delhi, has recognized *Embelia ribes* as a crucial one out of 32 medicinal plants for its large-scale cultivation and is labelled as Agro-techniques of Selected Medicinal Plants. The significant chemical bioactive constituent, embelin, has therapeutic and medicinal ability to be converted to innovative drugs, for which it has gained cogitation recognition [7].

Embelin is a naturally occurring quinone extract, found in the seeds of *Embelia ribes*, showing anti-inflammatory, antibacterial, antioxidant, and antipyretic effects. The analgesic properties, along with other stated properties, have caused further scientific exploration for its medicinal usage. The gaining impetus in the use of nanoparticles is due to increased efficacy in reaching minute areas, which otherwise are inaccessible for conventional medication. However, further research is needed to explore the therapeutic benefits of *Embelia ribes* and to identify the functional groups that are present [8,9].

UV–Visible spectroscopy is utilized to evaluate the optical properties and confirm the presence of phytoconstituents. X-ray diffraction (XRD) analysis is a crucial technique for determining the crystalline structure, phase purity, and particle size of synthesized nanoparticles. It provides detailed information about the arrangement of atoms within the material, confirming the successful formation and crystallinity of nanoparticles [10]. A FESEM is used to visualize extremely fine topographic characteristics on the surface of whole or fractioned objects. It gives proper shape and heterogeneity or the homogenous pattern of the corresponding nanoparticles [11]. Fourier transform infrared (FTIR) spectrometry measures the vibrations of bonds within chemical functional groups and generates a spectrum that can be regarded as a biochemical or metabolic “fingerprint” of the sample [12]. Fourier Transform Infrared (FTIR) spectroscopy was employed to investigate the chemical interactions and functional groups present in the formulations containing *Embelia ribes*. The latter has been explained in detail below.

In the current study, green synthesis of silver nanoparticles was derived using *Embelia ribes* seed extract. The formation of *Embelia ribes*-mediated silver nanoparticles was confirmed using UV spectroscopy, XRD, and FESEM. FTIR analysis was performed to identify the functional groups present in seed extract of *Embelia ribes*.

Materials and Methods:

The dried seeds of *Embelia ribes*, a well-known medicinal plant traditionally used in Ayurvedic formulations, were obtained from the Indian Medical Practitioners Co-operative Pharmacy and Stores (IMPCOPS), located in Chennai, Tamil Nadu, India. The authenticated seeds were thoroughly cleaned to remove any debris or foreign material and then shade-dried to preserve their phytochemical constituents. The dried material was coarsely powdered using a mechanical grinder. The powdered sample was subjected to cold maceration in ethanol (or aqueous/ethanol mixture, depending on the study design) at room temperature for 72 hours with intermittent shaking to enhance extraction efficiency. After maceration, the extract was filtered using Whatman No. 1 filter paper and concentrated under reduced pressure using a rotary evaporator to obtain a thick, semi-solid crude extract. The final extract was stored at 4°C in airtight containers until further use for pharmacological or biochemical studies.

Silver Nanoparticles Synthesis-

A solution of 1 millimole (mM) of silver nitrate in 90 milliliters (ml) was utilized for the nanoparticle synthesis process. Subsequently, 10 ml of the filtered *E. ribes* extract was added to the solution, and the mixture was placed on an orbital shaker with a magnetic stirrer for 2 hours. Color changes were observed every 24 hours for a total of 3 days [13].

The analysis of the synthesized nanoparticles was conducted using UV-visible spectroscopy. In the last step, the formulated solution underwent centrifugation at 8000 rpm (as depicted in Fig. 1b-d) to isolate the nanoparticle, which was subsequently dried at 80 degrees Celsius in a hot air oven. The dried powder is sent for characterization. [14].

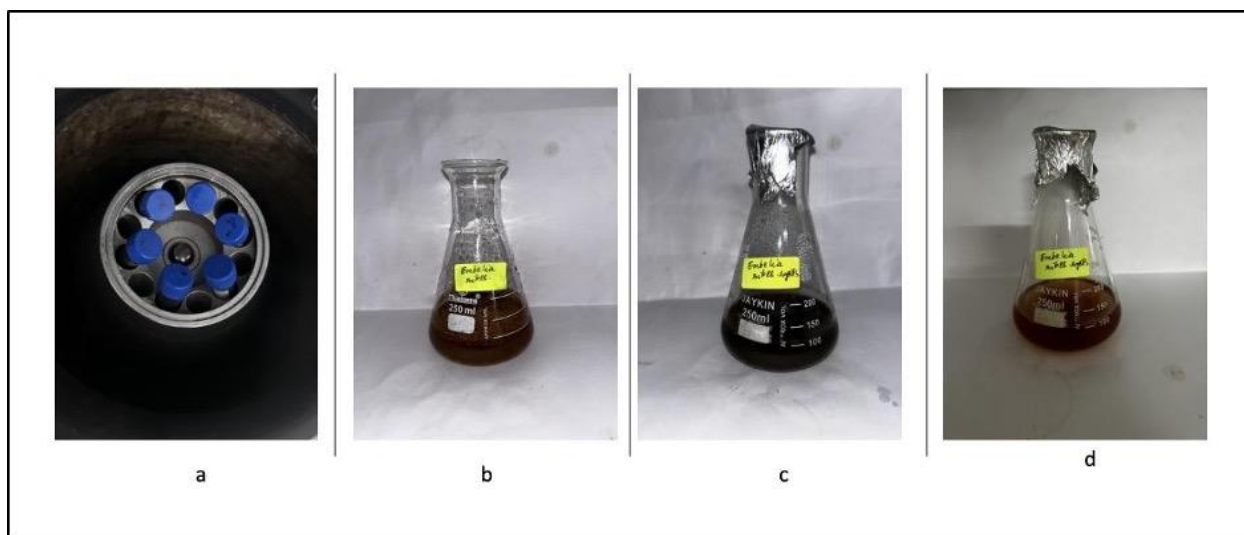


Fig 1a: Centrifugation for Nano Particle formation and Crude Extract of *Embelia Ribes* b: Seed extract of *Embelia Ribes* c: *Embelia ribes* mediated silver nanoparticles d: *Embelia Ribes* mediated Silver Nanoparticles and Change in Color after 3 days, confirming formation of SNPs using UV-Visible spectroscopy.

Characterization of Prepared Extract Using -

a. UV Spectroscopy

Peak in the UV spectroscopy analysis indicating formation of *Embelia ribes*. The analysis was performed using a UV–Vis spectrophotometer (e.g., Shimadzu UV-2600 or PerkinElmer Lambda 365) over a wavelength range of 200–800 nm. For the measurement, an accurately weighed amount of the dried silver incorporated sample was dispersed in a suitable solvent, that is, ethanol [15].

b. XRD Analysis

X-Ray Diffraction (XRD) analysis was carried out to determine the crystalline structure, phase purity, and lattice orientation of the *Embelia ribes*-mediated silver nanoparticles. In the case of silver nanoparticles (AgNPs), distinct diffraction peaks corresponding to specific lattice planes indicate the face-centered cubic (FCC) structure typically associated with metallic silver. The sharpness and intensity of the peaks reflect the degree of crystallinity, while the peak positions help in identifying the characteristic phases. [16].

C. FESEM Analysis

The morphology and shape of the AgNPs were examined using field emission electron microscopy (Icon Analytical, Quanta 250, FEI, United States). The AgNPs suspension was air-dried, loaded into the sample holder, and coated, and images were obtained at 20 kV with a different magnification [17].

D. FTIR Analysis

All spectra were obtained with the aid of an OMNI sampler attenuated total reflectance accessory on a JASCO FTIR spectrophotometer (FTIR-4600), followed by previous methods with some modifications.

A dry powder of the seed was used for FTIR analysis; samples were encapsulated in KBr pellets to prepare translucent discs suitable for spectral scanning. A small amount of each extract, obtained from different solvents and plant parts, was carefully placed on the germanium crystal of the infrared spectrometer, with constant pressure applied to ensure consistent contact. The infrared absorbance data were recorded across a wavenumber range of 4000 to 650 cm^{-1} . Before each sample measurement, reference spectra were obtained from the cleaned blank crystal to eliminate background interference. All spectra were collected at a resolution between 4.0 and 1.0 cm^{-1} , enhancing the signal-to-noise ratio. Each sample was analyzed in triplicate to ensure reproducibility. Characteristic absorption bands were analyzed to identify the presence of functional groups associated with the hydrogel matrix (e.g., $-\text{OH}$, $-\text{COOH}$, $-\text{NH}_2$) and bioactive components of *Embelia ribes* extract. Comparative FTIR spectra of the pure hydrogel, pure *Embelia ribes* extract, and the composite hydrogel were used to confirm the successful incorporation of the phytoconstituents and to evaluate any chemical modifications within the hydrogel matrix [18].

RESULTS

a. Ultraviolet- Visible Spectroscopy

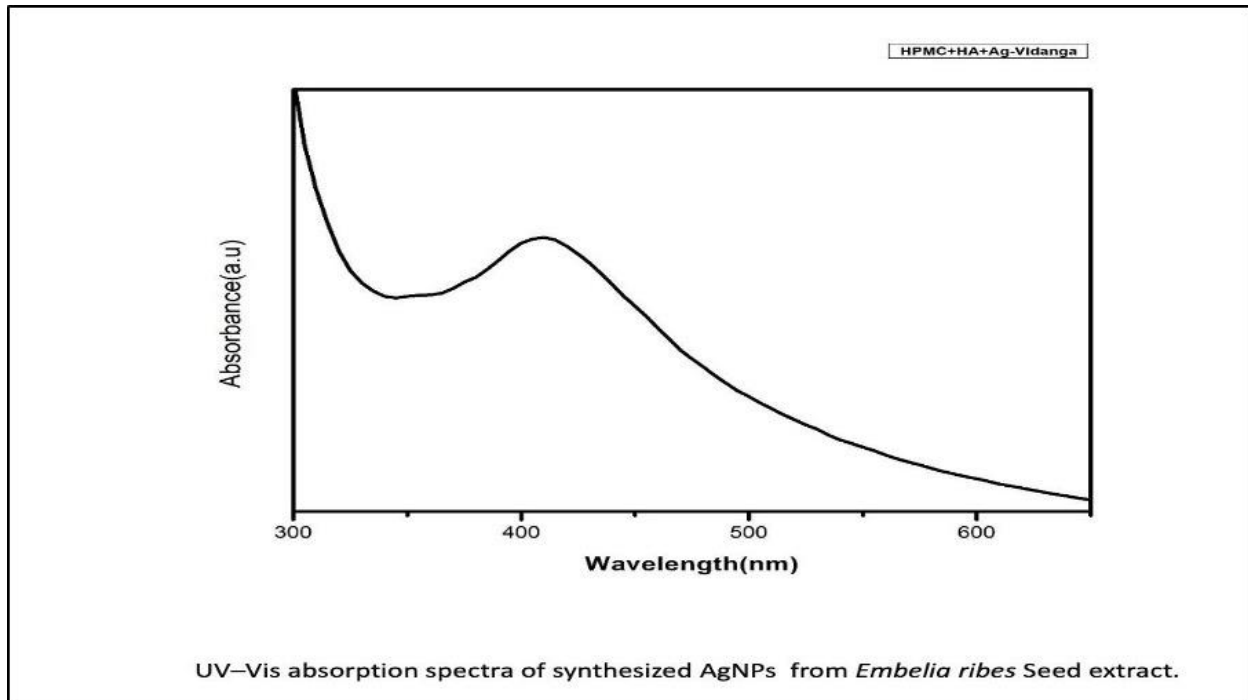


Fig 2: Demonstrating characterization peaks at 450nm range, suggesting formation of AgNPs.

The presence of a peak in the 400–450 nm range strongly suggests the successful formation of AgNPs. The UV–Vis absorption spectrum of the AgNP-loaded hydrogel formulation (HPMC + HA + Ag-Vidanga) exhibited a characteristic surface plasmon resonance (SPR) peak at approximately 430 nm. This confirms the successful synthesis and incorporation of silver nanoparticles derived from *Embelia ribes* seed extract within the hydrogel matrix.

b. X-Ray Diffraction Analysis

The X-ray Diffraction pattern of the plant-mediated silver nanoparticles (Ag-Vid) synthesized using *Embelia ribes* extract exhibited distinct diffraction peaks at 2θ values corresponding to 38.1° , 44.3° , 64.5° , and 77.3° , which are indexed to the (111), (200), (220), and (311) planes of the face-centered cubic (fcc) structure of metallic silver, according to the standard JCPDS file No. 04-0783.

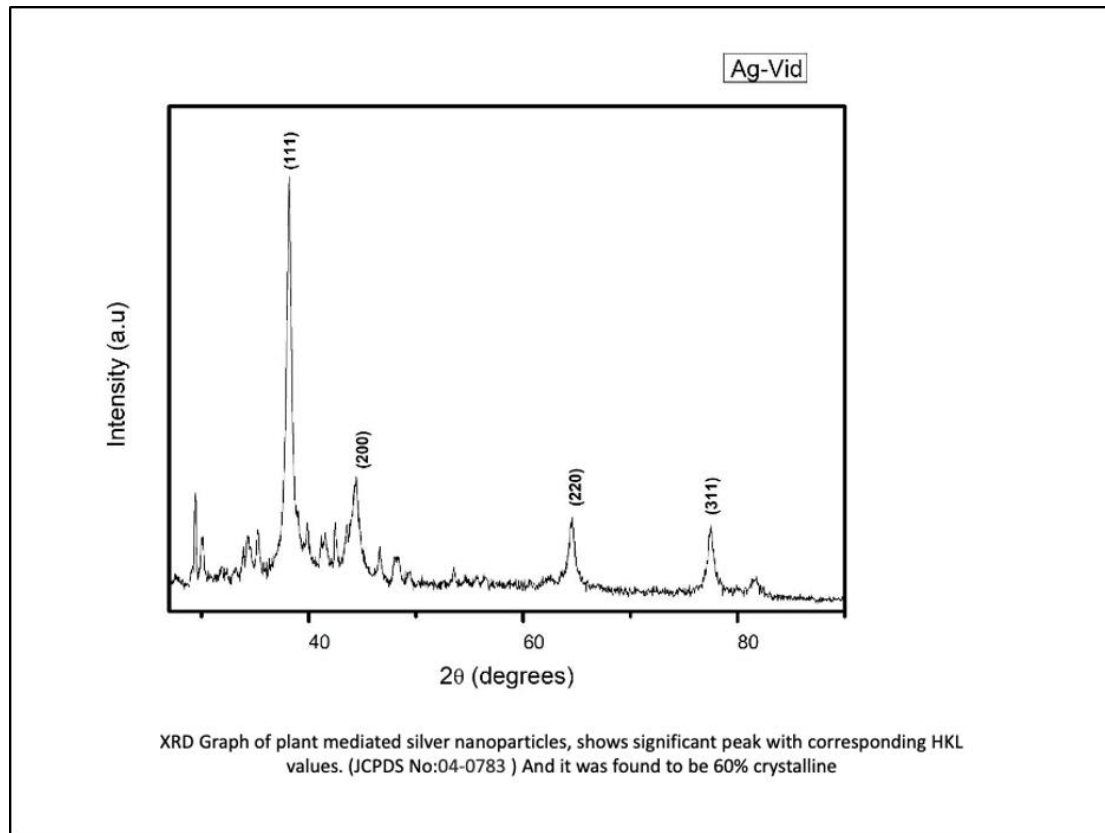
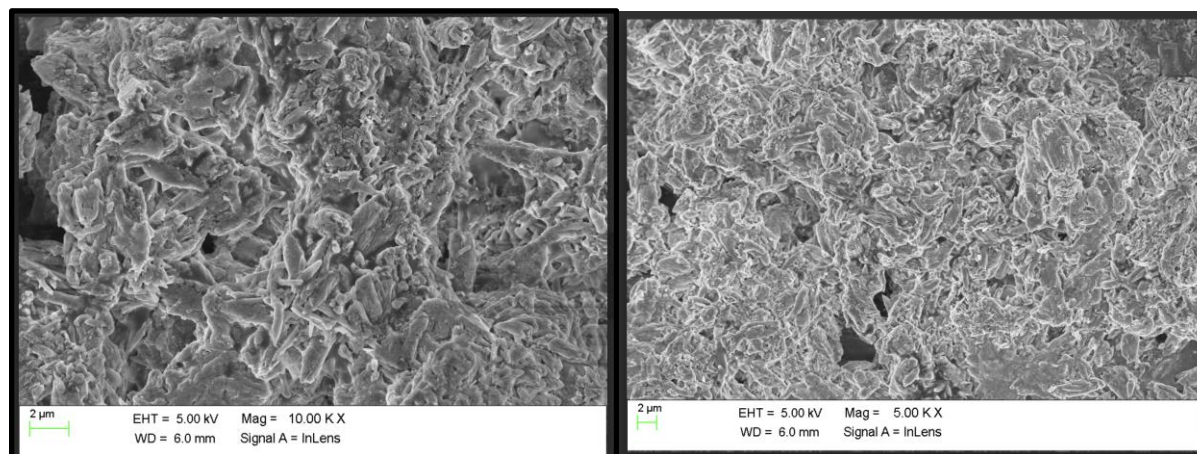


Fig 3: XRD pattern of plant-mediated silver nanoparticles (Ag-VID), showing distinct peaks at 2θ values corresponding to the (111), (200), (220), and (311) planes of face-centered cubic silver, in agreement with JCPDS No. 04-0783. The prominent (111) peak indicates high crystallinity, with the sample exhibiting approximately 60% crystallinity.

The intense peak at 38.1° (111) indicates that the (111) plane is the predominant orientation, suggesting high crystallinity. Minor background signals suggest the presence of some amorphous organic residues from the plant extract. The crystallinity of the synthesized AgNPs was calculated to be approximately 60%, confirming the successful formation of crystalline silver nanoparticles through the green synthesis method, as noted in Figure 3 [19].

C. Field Emission Scanning Electron Microscopy (FESEM)



Fig

4: FESEM images of *Embelia ribes*-mediated silver nanoparticles at 5,000 $\times$ and 10,000 $\times$ magnifications, showing agglomerated clusters of irregularly shaped particles with a rough and porous surface morphology, likely stabilized by phytochemical capping from the plant extract.

The FESEM images of *Embelia ribes*-derived silver nanoparticles, captured at 5,000 $\times$ and 10,000 $\times$ magnifications (Fig. 4 left and right), reveal a heterogeneous and densely packed surface morphology. The nanoparticles appear as agglomerated clusters, with irregular and plate-like structures intertwined within a rough matrix. The porous texture and overlapping layers suggest the presence of organic capping agents from *E. ribes* extract, which stabilize the nanoparticles and prevent excessive growth [20]. The nanoscale features are visible, with particles embedded in a web-like network of phytochemical residues, indicating strong plant-mediated reduction and stabilization. The surface roughness and increased surface area, evident from the morphology, could contribute to enhanced biological interactions, including antimicrobial activity [21].

D. Fourier Transform Infrared Spectroscopy Analysis of *Embelia ribes*

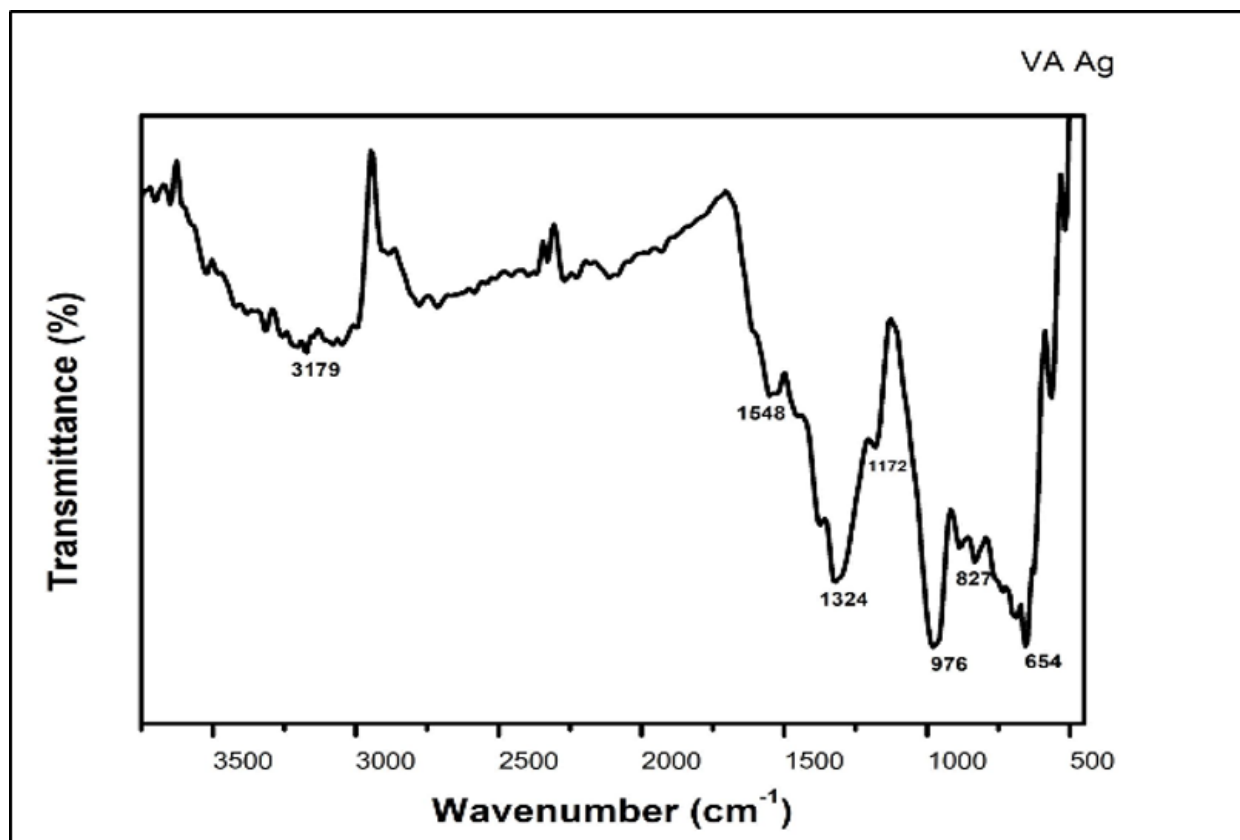


Fig. 5: FTIR spectrum of biosynthesized AgNPs.

The FTIR spectrum of the silver nanoparticles (VA Ag) synthesized using *Embelia ribes* seed extract exhibited several prominent absorption bands, confirming the presence of various functional groups involved in nanoparticle formation and stabilization. A broad peak at 3179 cm^{-1} was assigned to O–H stretching vibrations of carboxylic acid groups, indicating the involvement of phenolic compounds. The band observed at 1548 cm^{-1} corresponded to N–O stretching of nitro compounds, suggesting the presence of nitrogen-containing phytoconstituents [22].

The peak at 1324 cm^{-1} was attributed to C–O stretching vibrations of aromatic esters, while the strong band at 1172 cm^{-1} confirmed C–O stretching typical of ester functionalities. Additionally, peaks at 976 cm^{-1} and 827 cm^{-1} were assigned to C=C bending of disubstituted and trisubstituted alkenes, respectively. A further band at 654 cm^{-1} was indicative of C=C bending vibrations. These functional groups collectively suggest the participation of flavonoids, phenolic acids, and esters in

the reduction and capping of silver nanoparticles, highlighting the bioactive nature of the *Embelia ribes* extract [23].

DISCUSSION

This study confirms the eco-friendly synthesis of silver nanoparticles (AgNPs) using *Embelia ribes* seed extract as both a reducing and capping agent. The observed color transition during the reaction, along with the surface plasmon resonance (SPR) band at approximately 430 nm in the UV–Vis spectrum, strongly indicates the successful reduction of silver ions. Previous studies on plant-mediated nanoparticle synthesis have reported similar SPR peaks, supporting the involvement of phytoconstituents such as flavonoids, phenols, and terpenoids in the reduction process.

The XRD pattern demonstrated well-defined diffraction peaks indexed to the (111), (200), (220), and (311) planes, confirming the face-centered cubic crystalline structure typical of metallic silver. The prominent intensity of the (111) reflection suggests a preferential crystal growth direction and high structural order. A crystallinity level of around 60% further verifies the formation of highly crystalline nanoparticles, which is advantageous for enhanced stability and functionality in biomedical applications [24].

The FESEM analysis revealed irregular, agglomerated clusters with a rough and porous surface. Such morphology is often attributed to the presence of plant-derived organic molecules, which act as stabilizers while inducing partial aggregation. This surface topography could potentially increase the reactive surface area, enhancing biological interactions and antimicrobial properties.

FTIR spectroscopy indicated the presence of functional groups such as hydroxyl (O–H), carbonyl (C=O), and aromatic C–O vibrations, which can be linked to bioactive compounds in *E. ribes*. These groups play a dual role in reducing silver ions and forming a protective capping layer around the nanoparticles, contributing to their stability [25].

Overall, the combined findings validate that *E. ribes* extract can effectively synthesize silver nanoparticles with desirable crystalline and surface characteristics. This green synthesis route is not only cost-effective and environmentally friendly but also adds biological value to the nanoparticles due to the intrinsic phytochemical coating.

CONCLUSION

The present study successfully demonstrated the green synthesis of silver nanoparticles using *Embelia ribes* seed extract as a natural reducing and stabilizing agent. Characterization through UV–Vis spectroscopy confirmed nanoparticle formation with a distinct SPR peak around 430 nm. XRD analysis verified the crystalline nature of the particles, with prominent peaks corresponding to the face-centered cubic structure of metallic silver. FESEM imaging revealed agglomerated nanoparticles with irregular and porous surface morphology, while FTIR analysis confirmed the presence of bioactive phytochemicals that facilitated both reduction and capping of the nanoparticles.

The combination of structural and surface properties suggests that *E. ribes*-mediated AgNPs possess significant potential for biomedical and pharmaceutical applications, particularly due to the synergistic effects of silver and plant-derived phytoconstituents. This eco-friendly synthesis method provides a sustainable alternative to conventional chemical routes, ensuring minimal environmental impact while enhancing the bioactivity of the nanoparticles.

FUTURE SCOPE: Further studies on the antimicrobial and biocompatible properties of *Embelia ribes*-based silver nanoparticles are essential to explore their potential in dental, pharmaceutical, and wound-healing applications.

Acknowledgments

The author is grateful to Saveetha Dental College for the platform provided to conduct the study.

Conflicts of Interest

The author declares no conflict of Interest.

REFERENCES

1. Beydoun, D., Amal, R., Low, G. and McEvoy, S., 1999. Role of nanoparticles in photocatalysis. *Journal of nanoparticle Research*, 1(4), pp.439-458.
2. Zhang, L., Gu, F.X., Chan, J.M., Wang, A.Z., Langer, R.S. and Farokhzad, O.C., 2008. Nanoparticles in medicine: therapeutic applications and developments. *Clinical pharmacology & therapeutics*, 83(5), pp.761-769.
3. Lin, W., 2015. Introduction: nanoparticles in medicine. *Chemical reviews*, 115(19), pp.10407-10409.
4. Dilipan, E., Sivaperumal, P., Kamala, K., Ramachandran, M. and Vivekanandhan, P., 2023. Green synthesis of silver nanoparticles using seagrass *Cymodocea serrulata* (R. Br.) Asch. & Magnus, characterization, and evaluation of anticancer, antioxidant, and antiglycemic index. *Biotechnology and Applied Biochemistry*, 70(3), pp.1346-1356.
5. Parkavi Arumugam, Tanmay Agarwal, Saheb Ali, Shiva Shankar Gummaluri, Boyapati Ramanarayana. Evaluation of antibacterial, antioxidant, and cytotoxic properties of green synthesized zinc oxide nanoparticles from *Santalum Album*: An in vitro study. *Bulletin of Stomatology and Maxillofacial Surgery*. 2025;21(4). 191-203. doi: 10.58240/1829006X-2025.4-19
6. Sharma, V., Gautam, D.N.S., Radu, A.F., Behl, T., Bungau, S.G. and Vesa, C.M., 2022. Reviewing the traditional/modern uses, phytochemistry, essential oils/extracts and pharmacology of *Embelia ribes* Burm. *Antioxidants*, 11(7), p.1359.
7. Rathi, A. and Ramesh, S., 2024. Antioxidant Activity of *Embelia ribes* Mediated Silver Nanoparticles: An In-vitro Study. *Research Journal of Pharmacy and Technology*, 17(9), pp.4199-4202.
8. Lal, B. and Mishra, N., 2013. Importance of *Embelia ribes*: An update. *International Journal of Pharmaceutical Sciences and Research*, 4(10), p.3823.

9. Wankhade, P.R., Gupta, R.D., Das, R.J., Awandekar, N.B. and Umekar, M.J., 2021. Review on pharmacological and phytochemistry of Embelia ribes plant. *Int. J. Pharmacogn. Life Sci*, 2, pp.34-43.
10. Epp, J., 2016. X-ray diffraction (XRD) techniques for materials characterization. In *Materials characterization using nondestructive evaluation (NDE) methods* (pp. 81-124). Woodhead Publishing.
11. Alyamani, A.M.O.L. and Lemine, O.M., 2012. FE-SEM characterization of some nanomaterial. In *Scanning electron microscopy*. IntechOpen.
12. Hameed, M.S., Antony, S.D.P., Shanmugam, R. and Raghu, S., 2024. Synthesis and Characterization of Nanosilica-Coated Antibiotics, TAP: A Comprehensive Study Utilizing XRD, EDS, FTIR, SEM, and TEM–Invitro Study. *Journal of International Oral Health*, 16(5), pp.386-393.
13. Arumugam, P., 2025. Emerging role of natural product-derived phytochemicals in the green synthesis of metal nanoparticles: a paradigm shift in sustainable nanotechnology. *Natural product research*, pp.1-2.
14. Shanmugam, G., 2024. Enhancing natural therapies: nanoparticles' impact on drug delivery. *Natural Product Research*, pp.1-2. 16(4).
15. Ganesan, B., Perumal, P., Manickam, V., Gotteti, S.D., Srikakolapu, S.R. and Thirumurthy, L.S., 2010. Optimization of extraction conditions for embelin in Embelia ribes by UV spectrophotometry. *Arch Appl Sci Res*, 2(2), pp.49-53.
16. Mahakal, M., Kutumbale, A., Mehta, D. and Mehta, B.K., 2018. Green synthesis of ZnO nanoparticles from the methanolic extract of Embelia ribes and their characterization by uv-visible, FTIR, XRD and SEM analysis. *Int J Pharm Biol Sci*, 8, pp.402-409.
17. Jagtap, R.R., Garud, A., Puranik, S.S., Rudrapal, M., Ansari, M.A., Alomary, M.N., Alshamrani, M., Salawi, A., Almoshari, Y., Khan, J. and Warude, B., 2022. Biofabrication of silver nanoparticles (AgNPs) using embelin for effective therapeutic management of lung cancer. *Frontiers in Nutrition*, 9, p.960674.

- 18.Kamble, V. and Gaikwad, N., 2016. Fourier Transform infrared spectroscopy spectroscopic studies in embelia ribes burm. F.: a vulnerable medicinal plant. *Asian J Pharm Clin Res*, 9(3), pp.41-47
- 19.Boini, T., Maurya, R., Misro, L. and Radhakrishnan, T., 2023. Extraction and identification of bioactive compound embelin from embelia ribes fruits. *J Med Pharma Allied Sci*, 12, pp.5571-5581.
20. Hameed, M.S., Antony, S.D.P., Shanmugam, R. and Raghu, S., 2024. Synthesis and Characterization of Nanosilica-Coated Antibiotics, TAP: A Comprehensive Study Utilizing XRD, EDS, FTIR, SEM, and TEM–Invitro Study. *Journal of International Oral Health*, 16(5), pp.386-393.
21. Krishna, G., Sivalingam, A.M., Brahma, N. and Alex, A., 2024. Phytochemical analysis of silver nanoparticles of Zingiber officinale and evaluation for its antibacterial property. *Journal of Pharmacy and Bioallied Sciences*, 16(Suppl 2), pp.S1226-S1232.
- 22.Manikandan, D., Prakash, D.G., Arun, J., Gandhi, N.N., Mani, U. and Kathirvan, K., 2019. Antibacterial and anticancer activities of silver nanoparticles biosynthesized using Embelia ribes Burm. f. berries extract. *Indian Journal of Experimental Biology*, 57(3).
23. Viswanathan, S., Palaniyandi, T., Shanmugam, R., Karunakaran, S., Pandi, M., Wahab, M.R.A., Baskar, G., Rajendran, B.K., Sivaji, A. and Moovendhan, M., 2024. Synthesis, characterization, cytotoxicity, and antimicrobial studies of green synthesized silver nanoparticles using red seaweed Champia parvula. *Biomass Conversion and Biorefinery*, 14(6), pp.7387-740024.
- 25.Boini T, Maurya R, Misro L, Radhakrishnan T. Extraction and identification of bioactive compound embelin from embelia ribes fruits. *J Med Pharma Allied Sci*. 2023;12:5571-81.