

Synthesis and characterization of silver nanoparticles using plant extract of *azadirachta indica* - Indian folk medicinal plant

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Abstract

Medicinal plants have been discovered and used in traditional medical practice since ancient times. Hundreds of plants have been reported to possess antimicrobial properties. Medicinal plants are used as folk medicines because they are readily available and inexpensive with no side effects. This study reports the biosynthesis of AgNPs using plant extracts of *Azadirachta indica*. After exposing metal salt (silver nitrate) with freshly prepared plant extract, reduction of metal salt occurs and colour change after incubation indicates the formation of metal nanoparticles. Characterization of the synthesized nanoparticles was carried out using UV-visible spectrophotometer, which showed a silver surface plasmon vibration band near 390-450nm for silver, the average size of the synthesized particles and zeta potential were studied using dynamic light scattering methods. Transmission electron microscopy provided information on the size of the synthesized particles. Scanning electron microscopy revealed the morphology and arrangement of the particles. Fourier transform infrared spectroscopy (FTIR) analysis showed the presence of various functional groups, which may be responsible for the stability of synthesized particles. This approach will help in eco-friendly synthesis of nanoparticles with higher stability and applicability in various fields.

Keywords: Silver, nanoparticles, characterization, green synthesis, environment friendly

Introduction

A green approach for the synthesis of metal nanoparticles is needed in the field of nanotechnology, which deals with the formation and design of particles which at least one-dimension ranges from 1 to 100 nm in size [1]. The interaction between inorganic materials and biological structures is an area of interest in the modern world [2]. Nanoparticles can be synthesized via physical, chemical, and biological methods. The biological method for

nanoparticle synthesis is called the green method because it is an ecofriendly approach and does not require any hazardous chemicals. Green synthesis can be performed using microorganisms or plants. Plants are considered strong candidates for fabricating different nanoparticles with different sizes and dimensions [3] For large-scale production of nanoparticles plants the most suitable because of their cost-effectiveness and eco-friendliness approach for nanoparticle synthesis [4, 6]

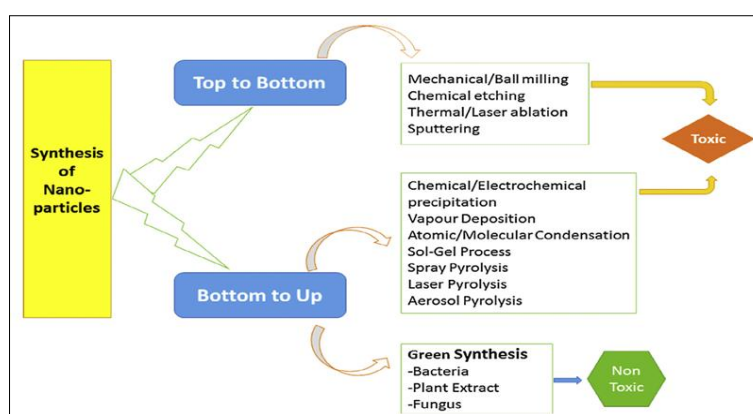


Fig 1: Different approach for synthesis of nanoparticles [5]

Medicinal plants such as *Indigofera aspalathoides* [7] *Ziziphora tenuior* [8] *Ocimum gratissimum* [9], and *Azadirachta indica* are used to treat various bacterial and fungal diseases and are commonly used in many household remedies, and are widely studied for their ability to synthesize nanoparticles. Leaf extract of *Azadirachta indica* is used for the synthesis of metal nanoparticles, without the addition of any physical or chemical agent [10] Throughout history, silver has been utilized as an antimicrobial agent in various forms or combinations with other technologies. Its antibacterial properties have been exploited in various applications, such

as incorporating silver nitrate or silver sulfadiazine into creams and dressings for treating burns and ulcers, preventing contamination in food packaging, and enhancing appliances such as refrigerators, and washing machines, and various industrial uses. Given the established antibacterial effectiveness of Ag, the advent of nanotechnology has led to the exploration of the potential of AgNPs as antibacterial agents. These nanoparticles have been applied in various fields, including medicine, textiles, and water treatment [11, 12]

Materials and Methodology

Silver nitrate and nutrient broth were purchased from Sigma Aldrich India. The plant samples were collected from the Shrimad Rajchandra Vidyapeeth campus garden.

Preparation of Plant Extract

Azadirachta indica leaf extract was prepared and used for the synthesis of AgNPs. Fresh plants were collected from the Shrimad Rajchandra Vidyapeeth Campus garden. The collected plants were washed with running tap water to remove dirt and pollutants from the leaf surface and dried at room temperature. 10gm of finely cut leaves were added to 100 ml of distilled water and placed on a hot plate magnetic stirrer for 30 min. After 30 min, the extract was filtered using Whatman no.1 filter papers and stored in refrigerator [13].

Biosynthesis of AgNPs

The prepared plant extract (10 mL) was added into 100 ml of a 1Mm silver nitrate solution and incubated. The reaction between the plant extract and silver nitrate was performed under dark conditions. A change in color from pale yellow to brown indicated the synthesis of the AgNPs. Further characterization was carried out using UV- vis spectroscopy.

Characterization of AgNPs

UV – visible spectral analysis

UV – visible spectral analysis Synthesis of nanoparticles is easily detected easily by spectroscopy because the synthesized silver nanoparticles show absorbance near 400 nm due to surface plasmon resonance and this SPR peak is typical for other particles [14]. Because of the surface plasmon resonance, which causes the synthesized nanoparticles to exhibit absorbance near 400 nm, it was easy to identify the particles using UV-visible spectrum analysis. However, it should be noted that this SPR peak is also characteristic of other particles.

Particle size distribution

The particle size distribution of the synthesized AgNPs was checked using the dynamic light scattering method. Using

dynamic light scattering, we can investigate the average size distribution of the synthesized particles in solution [15].

Zeta potential

Zeta potential analysis provided the charge on the surface of the synthesized nanoparticles. If the charge is more negative or positive, this indicates the stability of the synthesized particles in solution. In addition, we provide information regarding the dispersion of the particles in the solution.

The surface charge of the produced nanoparticle was revealed through a zeta potential investigation. The stability of artificial particles in a solution is indicated by whether the charge is positive or negative. and provides details regarding how the particles are dispersed in the solution.

Transmission electron microscopy (TEM)

Transmission electron microscopy was used to determine the size and shape of the AgNPs, and TEM images were obtained using a Hitachi H-71001 electron microscope [16]

Scanning electron microscopy (SEM)

The nanoparticles surface topology, composition, and electric conductivity were studied by the interaction of electrons with the nanoparticles, which produces an SEM image that provides information about the morphology of the synthesized particles [17]

FTIR

FTIR analysis for the identification of functional group Fourier transform infrared spectroscopy was used to identify the functional group. The chemical groups responsible for the synthesis of the particle and for stability was investigated using FTIR analysis [18].

Result and discussion

Plant collection and Synthesis of particles

Fresh plants were collected, and extracts were prepared from the collected plants. The color change after the reaction of plant extract with an aqueous solution of silver nitrate from light green to brown indicates the synthesis of AgNPs.

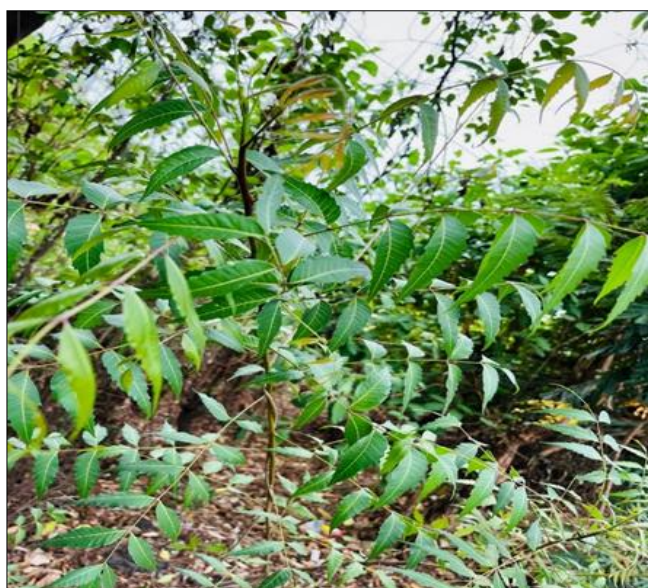


Fig 2: A) collected plant B) Plant extract before and after reacting with metal salt.

UV – visible spectral analysis

The synthesized nanoparticles were characterized by UV-vis spectrophotometry. UV-vis spectra of synthesized nanoparticles were recorded after 24 h of incubation. The strongest peak was obtained at 430 nm due to surface plasmon resonance which is the typical absorbance peak of AgNPs.

Particle size distribution

Particle size distribution of synthesized AgNPs was determined using dynamic light scattering (DLS). Figure shows the particle size distribution of silver nanoparticles synthesized with a Z-average (d. nm) of to be 139nm. PDI is a polydispersity index of 0.3, it should be less than 0.5.



Fig 3: DLS analysis of Synthesized Particles

Zeta Potential analysis

The Zeta potential of the synthesized AgNPs is -24.7 mV. These results indicate that the AgNPs exhibit a favourable range for maintaining stability and preventing agglomeration. Because highly negative or highly positively charged particles ripple with each other's we can say that these particles are very stable in nature.

Transmission Electron Microscopy (TEM)

TEM analysis revealed that silver nanoparticles in both samples, as mentioned in the study, exhibited a face-centered cubic (fcc) metallic silver crystal structure. The synthesized particles displayed a size distribution within the 50 nm scale, indicating that the synthesized particles were Ultra fine in nature.

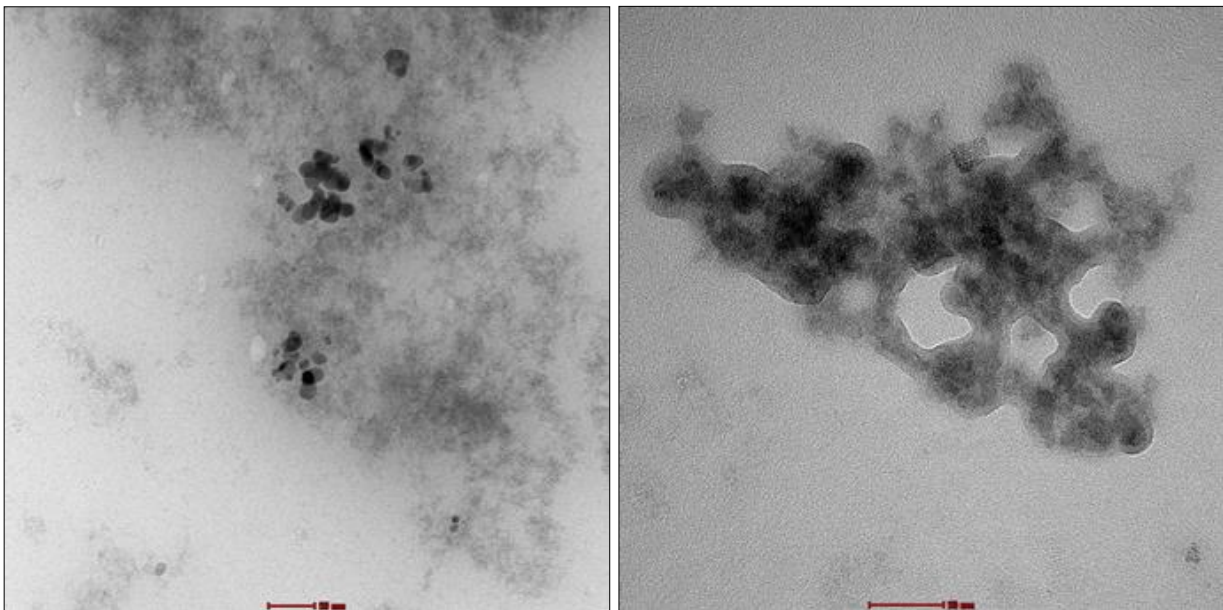


Fig 4: Transmission Electron analysis of Synthesized Particles

Scanning electron microscopy (SEM) The morphology and grain size of synthesized of the synthesized nanoparticles were analyzed using Scanning electron microscope. The SEM micrograph shows that the

synthesized AgNPs were spherical in shape and joined with each other forming a cluster like structure, the morphology and boundary of the synthesized particles were also clearly observed.

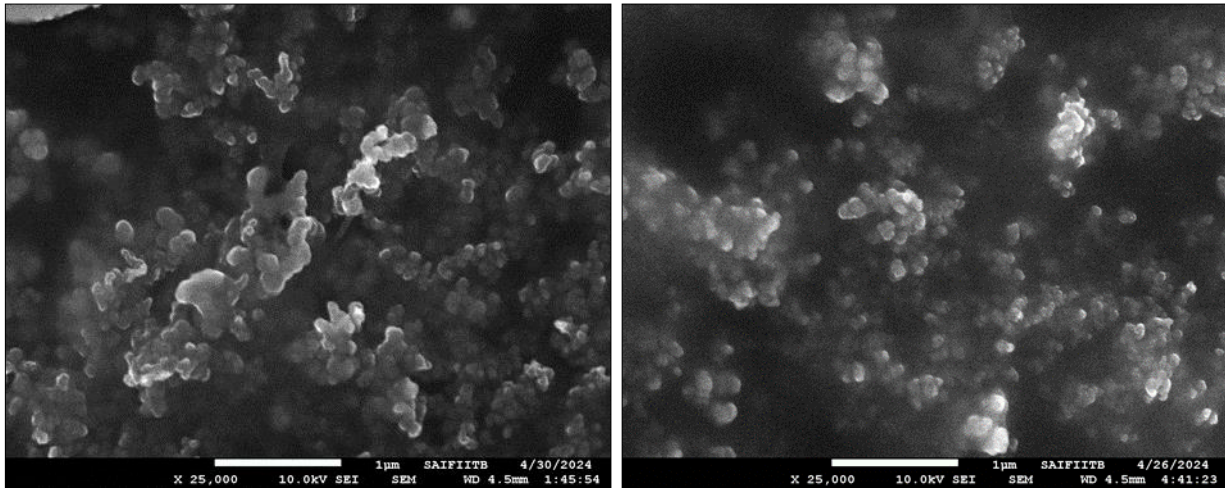


Fig 5: Scanning Electron analysis of Synthesized Particles

Fourier-transform infrared spectroscopy (FTIR)

The FTIR spectra of AgNPs synthesized by *Azadirachta indica*, as depicted in the figure, provide valuable insights into the functional groups: the peak at 3417 is due to OH stretching, 2105 is due to C≡C And 1643 is C=O involved in synthesis and stabilization process of the nanoparticles.

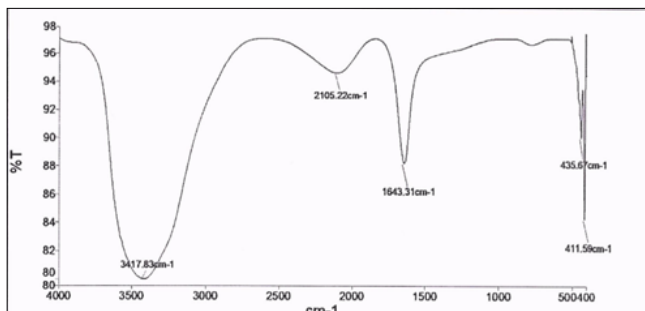


Fig 6: FTIR analysis of Synthesized Particles

Conclusion

Green synthesis of synthesized using plant extracts was successfully demonstrated in this study. The observed color change from light green to brown indicated the formation of nanoparticles, which was further confirmed by UV-visible spectral analysis, showing a distinct peak at 430 nm, characteristic of the silver nanoparticles' surface plasmon resonance. Particle size analysis using DLS showed that the nanoparticles had an average size of 139 nm with a polydispersity index of 0.3, suggesting a well-distributed and stable synthesis process. Additionally, the Zeta potential measurement of -24.7 mV highlighted the excellent stability of the nanoparticle, preventing aggregation due to strong electrostatic repulsion.

Further structural characterization using TEM revealed that the synthesized silver nanoparticles had a face-centered cubic (fcc) structure with an ultra-fine size of approximately 50 nm. SEM analysis showed that the nanoparticles were spherical and tended to form cluster-like structures. FTIR analysis also provided valuable insights into the functional groups involved in the synthesis and stabilization of the nanoparticles, with prominent peaks corresponding to OH, C≡C, and C=O groups. Overall, these findings indicate that plant-based methods are a promising and environmentally

friendly approach for synthesizing stable synthesized with favourable properties for potential applications.

In conclusion, plant-mediated synthesis of AgNPs, as demonstrated in this study, presents a viable alternative to chemical and physical methods. The stability, uniformity, and biocompatibility of nanoparticles produced through green synthesis hold promise for a wide range of applications, including antimicrobial agents, drug delivery systems, and environmental remediation. Future studies should focus on optimizing the synthesis parameters to control the size and shape of the nanoparticles more precisely and further explore their potential applications in various fields.

Future Prospects

Research on plant-mediated silver nanoparticle production for diverse applications has the potential for future developments in this field. Studies should concentrate on maximizing the conditions for synthesis, investigating various plant species, and customizing the size and form of nanoparticles for applications. These environmentally friendly nanoparticles have great potential for medicinal applications such as wound healing, medication delivery, and antibacterial therapies, owing to their biocompatibility. Additionally, their potential for environmental applications such as water purification, biosensing, and catalysis can be further explored. Overall, this green synthesis approach offers a sustainable, scalable, and versatile method for producing nanoparticles with broad industrial and scientific applications

Acknowledgment

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