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ORIGINAL ARTICLE

A Simple Biogenic Method for the Synthesis of Silver Nanoparticles using *Syngonium podophyllum*, an Ornamental Plant

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ABSTRACT

The potential of ornamental plant *Syngonium podophyllum* leaf extract has been explored for the synthesis of silver nanoparticles, which was confirmed by appearance of absorption peak at 420 nm in ultraviolet–visible (UV–Vis) spectrum. Silver nanoparticles were predominantly spherical in shape and size observed under scanning electron microscopy (SEM) was in the range of 11 to 26 nm. A sharp signal recorded at 3 keV under energy-dispersive X-ray (EDX) spectrum indicated the presence of elemental silver nanoparticles. Zeta potential was measured as –26.77 mV, which indicated the presence of moderately stable silver nanoparticles in the solution. Under Fourier transform infrared (FTIR), two prominent bands were assigned, i.e., 3,454.89 cm^{-1} represents the O–H stretching vibration and 1,637.46 cm^{-1} represents the –NH stretching vibration of the amide group. It indicates that protein might be responsible for the synthesis.

Keywords: Characterization, Green synthesis, Silver nanoparticles, *Syngonium podophyllum.*

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INTRODUCTION

Silver nanoparticles are one of the most promising products in the nanotechnology industry. Silver nanoparticles are particularly in high demand due to their widespread use. They are also more increasingly known for their healing properties, offering treatment options for various illnesses that cannot be treated with traditional methods. The development of nanotechnology has given new possibilities of using the silver nanoparticles as an active biomedical factor. Therefore, the silver nanoparticle is one of the most used nanoparticles that have gained importance.[1] The most important application of silver nanoparticles is their antimicrobial activities.[2,3] Silver nanoparticles have long been recognized in biomedical applications mainly due to potent antimicrobial activity.[4,5] Advancements in nanotechnology display arena of methods for the synthesis of nanoparticles of various shapes and sizes depending on their specific requirements.[6,7] Presently, physical and chemical methods have their own limitations.[8] Biogenic processes have evolved as a simple and viable option for the synthesis of nanoparticles and have several advantages over the chemical and physical methods.[9,10] Biogenic synthesis of nanoparticles using microorganisms has many drawbacks associated with microbial culture and their maintenance.[11,12] To overcome these limitations, plant systems are potentially advantageous for the synthesis of nanoparticles.[13,14] The present study highlights the new source of plant material, i.e., aqueous extract of *Syngonium podophyllum* leaf, for biogenic synthesis of novel silver nanoparticles. To the best of our knowledge, this is the first report where ornamental plant *S. podophyllum* has been explored for the synthesis of silver nanoparticles.

MATERIALS AND METHODS

Preparation of Extract

Syngonium podophyllum leaves were obtained from the MGM Institute of Health Sciences, Navi Mumbai. Leaves were washed in running water and twice with sterile distilled water and allowed to dry in air for 2 weeks, to remove the moisture completely. The dried leaves were pulverized well with mortar and pestle to make powder. Leaf extract was prepared by taking 5 gm of powder in 100 mL of deionized water and the mixture was boiled for 10 minutes. The leaf broth was then cooled and filtered with Whatman filter paper No-1. Filtrate was stored in a refrigerator for further use.

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Synthesis of Silver Nanoparticles

Silver nitrate ($AgNO_3$) was obtained from Sigma-Aldrich; 3 mM aqueous solution of $AgNO_3$ was prepared; 5 mL of extract was added to 15 mL of 3 mM $AgNO_3$ and allowed to react at 90°C for 25 minutes. A visual color change of the mixture was observed after 20 minutes. The synthesis of the silver nanoparticles in the solution was confirmed by the results obtained from ultraviolet–visible (UV–Vis) spectral analysis.

Ultraviolet–visible Spectroscopic Analysis

The bioreduction of silver ions in aqueous solution was monitored by measuring UV–Vis spectra of the solution. The UV–Vis spectra of these aliquots were monitored as a function of time of reaction on Shimadzu UV–Vis spectrophotometer operated at a resolution of 1 nm. The periodic scan of the absorbance was performed between 200 and 1,100 nm wavelength by using UV–Vis spectrophotometer (Shimadzu).

Scanning Electron Microscopy Analysis

The scanning electron microscope (SEM) analysis was performed with field emission gun (FEG)-SEM, model JSM 7600F, instrument at the Sophisticated Analytical Instrument Facility, Indian Institute of Technology-Bombay, Mumbai.

Energy-dispersive X-ray Spectroscopy

Energy-dispersive X-ray (EDX) spectroscopic study was performed with nanoparticles containing system to determine the elemental composition of silver in the suspension.

Zeta Potential Measurement

To understand the possible charge present on the nanoparticle surface, zeta potential was measured on Zetasizer (Zeta meter Delsa NanoC, Beckman Coulter, Japan).

Fourier Transform Infrared Spectroscopy Measurement

Fourier Transform infrared (FTIR) spectroscopy measurement of sample was performed using Bruker, Germany, Model-3000 Hyperion Microscope with Vertex 80 FTIR System, range: 7,500–450 cm^{-1}. Sample was prepared on KBr pellet and it was allowed to dry. This was then used for characterization.

RESULTS AND DISCUSSION

Visual Observation

Change in color on mixing of plant extract with $AgNO_3$ solution is generally observed by that system which is able to synthesize nanoparticles.[15] The ornamental plant *S. podophyllum* (Fig. 1) is established for the silver nanoparticle synthesis by using a simple process. A distinct change from light turbid yellow color to a brownish color was observed by mixing of aqueous leaf extract of *S. podophyllum* with 3 mM $AgNO_3$ solution at 90°C (Figs 2A and B). The change in color of reaction mixture was very fast and it was recorded within 25 minutes, which indicates the formation of silver nanoparticles. This might be a result of $AgNO_3$ reduction and stimulation of surface plasmon resonance. No precipitation was observed and color change was stable even after completion of the reaction. Dubey et al[16] also demonstrated the use of leaf extract of ornamental plant *Rosa rugosa* for the synthesis of silver nanoparticles.

Fig. 1: Picture of *S podophyllum* plant

Figs 2A and B: Visual observation: (A) Leaf extract of *S. podophyllum;* (B) reaction mixture of $AgNO_3$ solution and leaf extract with silver nanoparticles

Ultraviolet–visible Spectroscopic Analysis

The color change exhibited by the reaction sample during synthesis of silver nanoparticles is due to the excitation of electrons of the transition metal, which affects the absorbance in the UV region. Therefore, the silver nanoparticles synthesized by aqueous leaf extract of *S. podophyllum* were characterized by UV–Vis spectrophotometer. Optical properties of nanoparticles are sensitive to size, shape, concentration, agglomeration state, and refractive index, thus making UV–Vis spectroscopy a valuable tool for nanoparticle identification and characterization.[17] The peak was observed at 420 nm, which corresponds to the absorbance of silver nanoparticles (Fig. 3). Silver nanoparticles generally display unique optical properties in relation to their surface plasmon resonance.

Scanning Electron Microscopy

The morphology and size of the generated silver nanoparticles were analyzed by SEM (FEG-SEM, Model- JSM 7600F). Silver nanoparticles were observed with varied size ranging from 11 to 26 nm (Fig. 4). A number of researchers have analyzed biologically synthesized silver nanoparticles with the help of SEM. Geethalakshmi and Sarada[18] have also used SEM for the characterization of silver nanoparticles synthesized from *Trianthema decandra* extract. The analysis showed that the particles were cubic shaped and the size existed in the range from 25 to 50 nm. Kumar et al[19] have synthesized nanoparticles from silver using *Morus nigra* leaf extract. Scanning electron microscope analysis has indicated that size of generated silver nanoparticles was of 200 nm and appears to be spherical in morphology. Jancy and Inbathamizh[20] have also analyzed $AgNO_3$ solution in its reduced form by using SEM where they have clearly indicated the distinguishable $AgNO_3$ particles (1000 nm size) and silver particles in the bioreduced colloidal suspensions (15–20 nm in size) owing to their size difference.

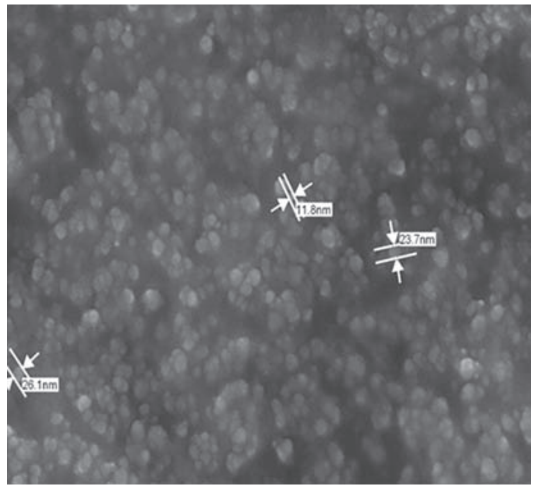

Fig. 4: Scanning electron microscope image of generated silver nanoparticles (scale – 100 nm magnification) by aqueous leaf extract of *S. podophyllum*

Scanning electron microscopic image of silver nanoparticles synthesized by aqueous leaf extract of *S. podophyllum* revealed that these silver nanoparticles are predominantly spherical in shape embedded in matrix.

Energy-dispersive X-ray Spectroscopy

Silver nanoparticles synthesized by aqueous leaf extract of *S. podophyllum* were further characterized by EDX for confirmation of elemental silver nanoparticles in the suspension. A sharp signal was observed at 3 keV of silver nanoparticles along with other peaks in EDX spectrum of 0–10 keV, which indicates the presence of elemental silver nanoparticles in the suspension (Fig. 5). Gajbhiye et al[21] have also used EDX spectroscopy to confirm the presence of elemental silver extracellularly in biologically synthesized silver nanoparticles by common fungus, *Alternaria alternata.* It was confirmed that the presence of elemental silver by the sharp signals with optical absorption band peak in the range of 3 to 4 keV is typical for the absorption

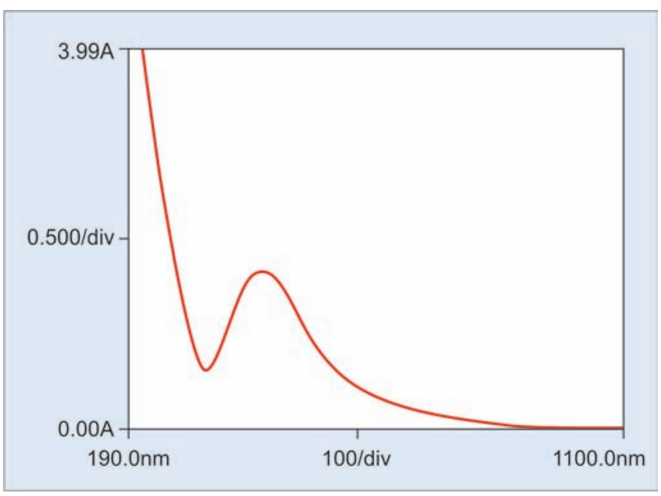

Fig. 3: Ultraviolet–visible absorption spectra of silver nanoparticles synthesized by aqueous leaf extract of *S. podophyllum*

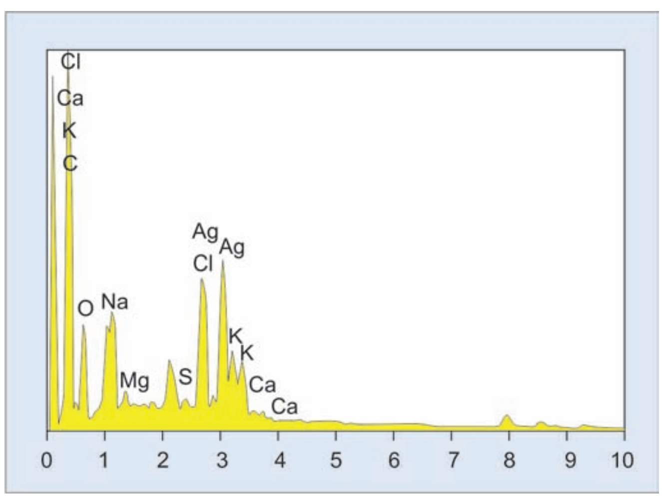

Fig. 5: Energy-dispersive X-ray curve with Ag peak in silver nanoparticle containing system

of metallic silver nanocrystallites. Foroughi and Khalil[22] investigated the synthesis of stable silver nanoparticles by bioreduction method using aqueous extracts of the manna of hedysarum plant and the soaproot (*Acanthe phylum bracteatum*). They have also confirmed the existence of an elemental silver signal in the solution containing silver nanoparticles in EDX spectrum.

Zeta Potential Measurement

In view to know the surface charge of nanoparticles synthesized by aqueous leaf extract of *S. podophyllum* for understanding the parameter, i.e., related to nanoparticle aggregation in dispersion, zeta potential was measured. Electrophoretic mobility of generated silver nanoparticles in the sample was measured as a value of –26.77 mV (Fig. 6). The result clearly showed that silver nanoparticles generated by leaf extract of *S. podophyllum* are moderately stable in the reaction system due to electrostatic repulsion. Plant-based generation of nanoparticles is generally advantageous over others where stable silver nanoparticles can be achieved without adding a different physical or chemical capping agent. Heydari and Rashidipour[23] have also demonstrated a green synthetic approach for the synthesis of silver nanoparticles by utilizing extract of oak fruit hull (Jaft) and characterized the generated nanoparticles using zeta potential for understanding the surface of synthesized nanoparticles and predicting the long-term stability of dispersion. In the absence of any electrolyte in deionized water, the zeta potential value of dispersed synthesized Ag nanoparticles was −25.3 mV.

Fourier Transform Infrared Spectroscopy Analysis

Fourier transform infrared has been widely used to know the nature of surface adsorbents in nanoparticles. Fourier transform infrared spectroscopic studies were carried out to identify possible groups/molecules responsible for the reduction of $AgNO_3$ to silver nanoparticles by aqueous leaf extract of *S. podophyllum*. Representative spectra of generated nanoparticles manifest the various absorption peaks (Fig. 7). The two prominent bands seen at 3454.89 and 1637.46 cm−1 were assigned to the stretching vibrations. The band at 3454 cm−1 represents the O–H stretching vibration. The band at 1637.46 cm−1 represents the –NH stretching vibration of the amide group. The short stretch peaks were also observed at 1458.84, 1383.59 and 1231.43 cm^{-1}. The FTIR results indicate that the protein might be responsible for the formation, capping, and stabilization of silver nanoparticles. Sathyavathi et al[24] also demonstrated FTIR spectra of aqueous silver nanoparticle preparation synthesized from *Coriandrum sativum* leaf extract. It has been confirmed by infrared spectroscopic study that the carbonyl group has the ability to form amino acid residues and proteins that strongly binds to metals, which suggests that proteins prevent agglomeration of metallic nanoparticles possibly by forming an outer layer of covering (i.e., capping of silver nanoparticles). Kalishwaralala et al[25] have demonstrated biosynthetic approach of silver and gold nanoparticle synthesis using *Brevibacterium casei* and characterized using FTIR analysis to identify the possible (protein) biomolecule responsible for capping and efficient stabilization of the synthesized metallic nanoparticles from *B. casei.*

CONCLUSION

Although number of plant-based biological processes have already been established for the synthesis of silver nanoparticles, still a search for new source for the synthesis of silver nanoparticles is fascinating aspect of research. We have reported the synthesis of silver nanoparticles using new source of plant material, i.e., aqueous leaf

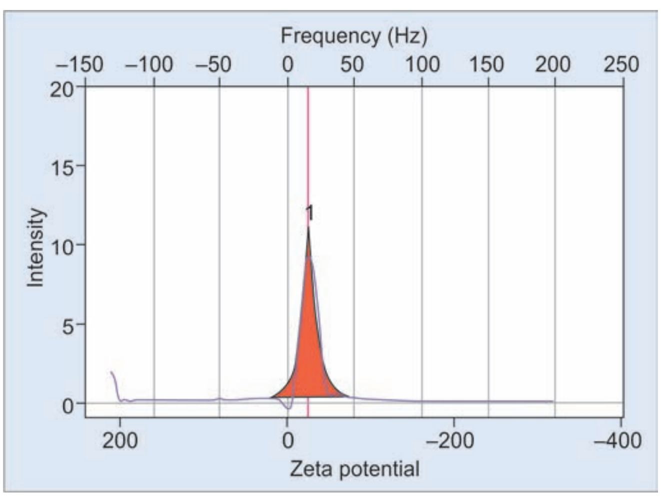

Fig. 6: Zeta potential of silver nanoparticles generated by leaf extract of *S. podophyllum*

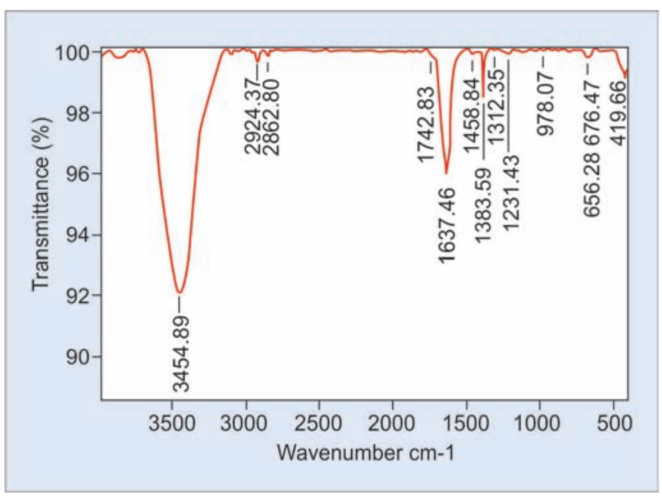

Fig. 7: Fourier transform infrared spectra of silver nanoparticles generated by aqueous leaf extract of *S. podophyllum*

extracts of ornamental plant *S. podophyllum*. This biogenic process provides a simple, fast, and efficient way for the generation of silver nanoparticles. These silver nanoparticles are moderately stable at room temperature. The FTIR study suggests that the protein might play an important role in the synthesis and stabilization of silver nanoparticles. The work carried out in the current article can pave the way toward the new prospective acceleration to fulfill demands of newer ecological, green chemistry-based method for the synthesis of silver nanoparticles.

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