Green synthesis of silver nanoparticles from waste peel of tuber vegetable [elephant foot yam (*Amorphophallus paeoniifolius*)]

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Abstract
This research study presents the biological method by using the extract from the waste part of a plant, tuber peel extract of Amorphophallus paeoniifolius. AgNPs were synthesized by mixing $AgNO_3$ and peel extract. The synthesized nanoparticles were separated from aqueous solution by centrifugation process followed by decantation. The time required to complete the synthesis of nanoparticles was 2 hrs.

Characterization of AgNPs were confirmed by applying UV-vis spectroscopy, X-ray diffraction (XRD) analysis, Fourier transform infrared spectroscopy (FTIR) and Energy dispersive X-ray spectroscopy (EDS). From UV-vis characterization absorption spectra were found at 400 nm for AgNPs. XRD data confirmed that both synthesized nanoparticles were face-cantered cubic in crystalline nature and the average crystallite size for the assign peaks was 16 nm. FTIR data evaluated the characteristic peaks of different phytochemical components of tuber peel extract which acted as the reducing agent and possibly as stabilizing agents. IR spectrum was recorded in the range of 4000-500 cm^{-1}. The absorption peak at 1296.16 cm^{-1} symbolized the bending band of adsorbed water of Ag.

Keywords: Silver nanoparticles, *Amorphophallus paeoniifolius*, biological synthesis, XRD, UV, SEM analysis

Introduction

Synthesis of silver nanoparticles (AgNPs) via plant extract is a facile, economical, rapid and flexible approach for production of AgNPs. In recent times, many researchers work on synthesis of AgNPs, because of their excellent physical and chemical properties at nanoscale and they also show significant biological properties. The superior properties of AgNPs have received more attraction in different fields such as catalysis[17,18], micro-electronics[14], sensor[19], antibacterial activity[6,20,24], antifungal[30], anticancer activity[8] etc.

The need for biosynthesis of nanoparticles arises from the fact that the physical and chemical processes became costly and the use of hazardous chemicals in various steps is enormous[5,16]. Phytochemical mediated metal nanoparticle synthesis is effective, economic and environmental friendly. Plants are considered as biosynthetic laboratories of wide spectrum of phytochemicals such as phenolics, alkaloids and flavonoids.

Phytochemicals are expected to self-assemble and cap the metal nanoparticles formed in their presence and thereby induces some shape control during metal ion reduction[4,7,13]. To avoid large-scale production costs and the use of hazardous chemicals, researchers have started transitioning towards green synthesis methods to produce nanoparticles. Green synthesis of AgNPs consists of using plant, fungi, virus and bacteria as a source of reducing and stabilizing agent[1,3,10,29].

From the literature survey, it was found that nanoparticles synthesized with plant-extracts show more biocompatibility. The plant extracts contain different types of phytochemical components, namely, alkaloids, steroids, carbohydrates, proteins etc.[22] The presence of these phytochemicals is responsible for the reduction of metal ions into metal nanoparticles and further colloidal stabilization[27].

Different plant extracts have been used in recent times to synthesise AgNPs, such as *Zingiber officinale*[26], *Ficus carica*[15] and *Polyalthia longifolia*[11]. There are many more reports where AgNPs were synthesized from plant extracts. *Amorphophallus paeoniifolius* is an herbaceous, perennial C3 crop that is categorized under the family Araceae; it has yellow flesh and is a rich source of starch[9,31]. This plant is also known as elephant foot yam and has the local name, “Suran”. This plant is widely available in Maharashtra at very low cost. This medicinal plant contains different phytochemical components such as steroids, flavonoids, carbohydrates, tannins, saponins and proteins[32]. Due to the presence of different bioactive molecules, this plant has many uses in medicinal purposes such as cough, vomiting, bronchitis, asthma and anorexia[28].

In this study, we have reported cost-effective, simple, rapid and eco-friendly synthesis of AgNPs at room temperature (Fig. 1). Tuber peel extract of *Amorphophallus paeoniifolius* was used as the source of reducing and stabilizing agents. Using this tuber peel extract as a reducing and stabilizing agent, instead of toxic chemicals, satisfies the main object of green chemistry. The formation of AgNPs was confirmed by using the UV-Vis spectrophotometric technique. Their crystalline nature was identified by using the X-ray diffraction method (XRD). Elemental compositions present in the synthesized nanoparticles were confirmed by energy dispersive spectra (EDS).

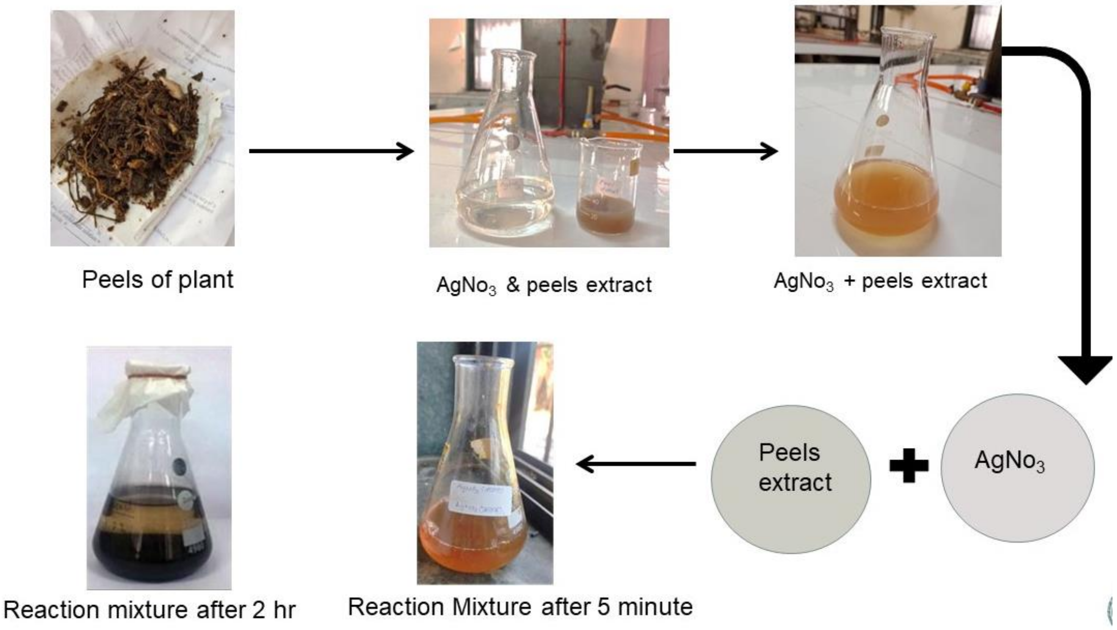

Fig. 1: Synthesis of silver nanoparticle from waste peel of tuber vegetable [elephant foot yam (*Amorphophallus paeoniifolius*)]

The functional groups present in the tuber peel extract and in synthesized nanoparticles were evaluated using Fourier transform infrared spectroscopy (FTIR). The antibacterial activity of these synthesized AgNPs was evaluated on Muller Hinton agar using the disc diffusion method against both Gram-positive and Gram-negative bacteria.

Material and Methods

Amorphophallus paeoniifolius is tuber vegetable commonly known by name elephant foot yam (Suran or Kand). The biomolecules present in the plants act as a reducing agent, they reduce silver nitrate and also, they act as a capping agent which favors the synthesis of size-controlled nanoparticles through the biological synthesis method as in fig. 1. The biomolecules like reducing sugars, phenolic compounds and protein molecules are reported to aid in reduction and proteins in capping that formed nanoparticles.

Materials: All the chemicals and reagents were of analytical grade. $AgNO_3$ (silver nitrate) was purchased from Sigma-Aldrich (Darmstadt, Germany). These chemicals were used without any further purification. Distilled water was used for the whole experiment. The glassware and falcon tube were primarily washed with tap water, then rinsed with distilled water and air-dried before use. Microbiological media were purchased from HI Media Laboratories Pvt. Ltd., Mumbai, India. *Amorphophallus paeoniifolius* plant was collected from local villages of the city Nagothane (Raigad).

Preparation of the Tuber Peel Extract: *Amorphophallus paeoniifolius* plant tuber was washed through tap water for removal of mud, dirt and foreign materials. Then, the tuber was peeled with knife and all the bark was removed from root and crushed in domestic blender to form powder. To get aqueous extract 10 g of powder was taken into a 250 mL reagent bottle with 50 mL distilled water and sonicated for about 90 min for crude extract formation. Then, the prepared crude extract was filtered by cellulose nitrate filter paper to avoid cellulose in the final extract. The extract was stored into a refrigerator at 4°C for nanoparticle synthesis.

Synthesis of AgNPs: The metal nanoparticles were synthesized from the plant extract following the previously mentioned reports[10,14]. For AgNPs synthesis, to the 100 ml of an aqueous solution of 0.01 M silver nitrate ($AgNO_3$), 10 ml of tuber peel extract was added, the mixture was then stirred on magnetic stirrer for about 2 hrs. AgNPs were visually observed through color change from yellowish to reddish-brown.

Results and Discussion

Measurement of optical density: Optical density of the reaction mixture was measured after each ½ hour. It was observed that optical density increases continuously which then remained constant after 3 hours confirming the formation of Ag nanoparticles as in fig. 2 and table 1.

UV-Vis Spectroscopy: UV-Vis spectroscopy is a technique that can confirm the formation of metal nanoparticles in aqueous solution. Fig. 3 displayed the UV-Vis spectrum of AgNPs colloidal solution. A broad band at 400 nm indicated the formation of AgNPs[2,12].

XRD Analysis: The XRD pattern of AgNPs is shown in fig. 4, which shows that a broad pattern has been attributed to an amorphous compound and bio-capped AgNPs[21]. All the diffraction peaks were detected at 2θ values of 18.2°, 26.8°, 30.2°, 31.8°, 38.4°, 40.2°, 42.6°, 43.8°, 46.0°, 47.3°, 50.3° and 60.0°. The average size of Ag NPs was quantitatively measured employing Debye–Scherrer equation where d =

kλ/β cos θ, k =Debye–Scherrer constant (0.89), λ =X-ray wavelength (0.154 nm), β = width of the peak with the maximum intensity in half height and θ = diffraction angle.

The results obtained from the analyses of the XRD pattern displayed that the average size of Ag NPs was about 16 nm.

IR Analysis: Strong absorption band at 3273 cm^{-1} was due to the O-H stretching vibration of alcohol or phenolic compounds. A weak peal at 2922 cm^{-1} was due to the asymmetric stretching vibration of the C-H bond of alkane. Bands at 1635 cm^{-1} and 1535 cm^{-1} could be assigned due to the characteristic band of $–NH_2$ groups containing amino acids of protein and C=O groups of flavonoids and tannins. Due to the angular deformation of the C-H bond[23,25], a sharp intense peak was obtained at 1296 $cm^{−1}$. For ether linkages and C-O or C-O-C groups, peaks appeared at 999, 810, 763, 520 $cm^{−1}$ and 775 $cm^{−1}$which could be attributed to the deformation vibration of C-H bonds of the phenolic ring (Fig. 5).

Fig. 2: Variation in colour change of extract

Table 1
Measurement of optical density of resulting $AgNO_3$ solution

Optical density of reaction mixture at time interval	Optical density
Just after addition of tuber peel extract	0.28
30 min	0.35
60 min	0.40
90 min	0.42
120 min	0.52
120 min	0.52

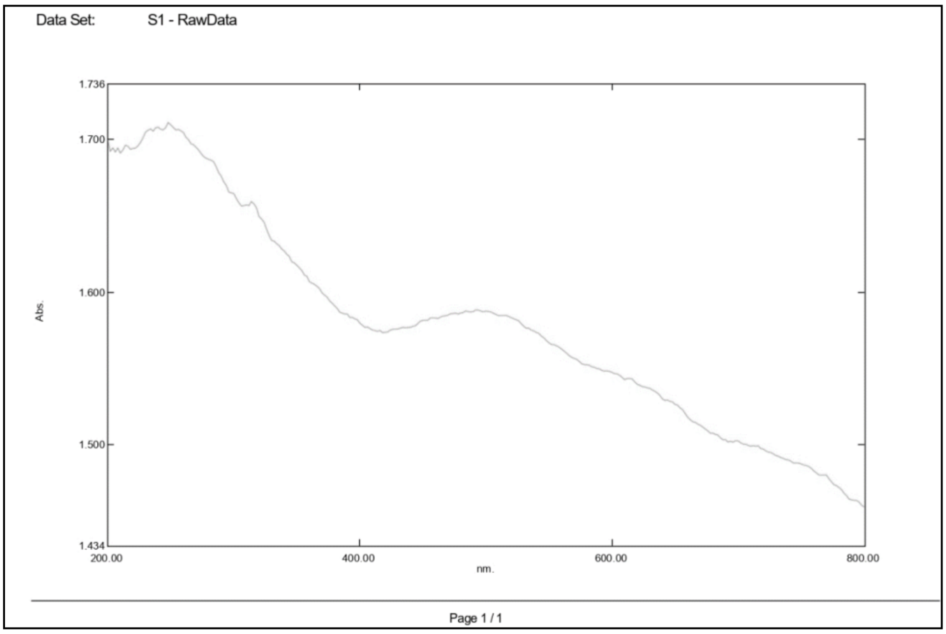

Fig. 3: UV analysis of AgNPs

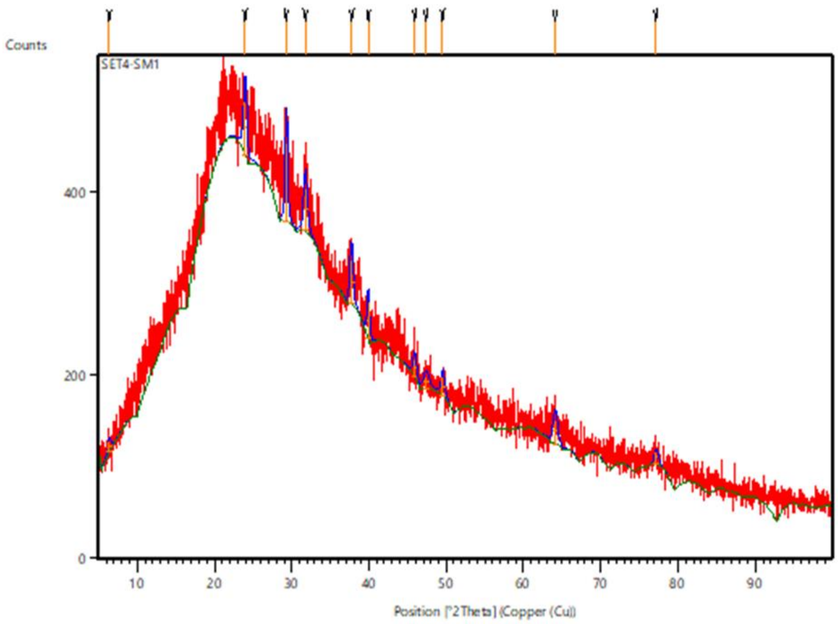

Fig. 4: XRD analysis of AgNPs

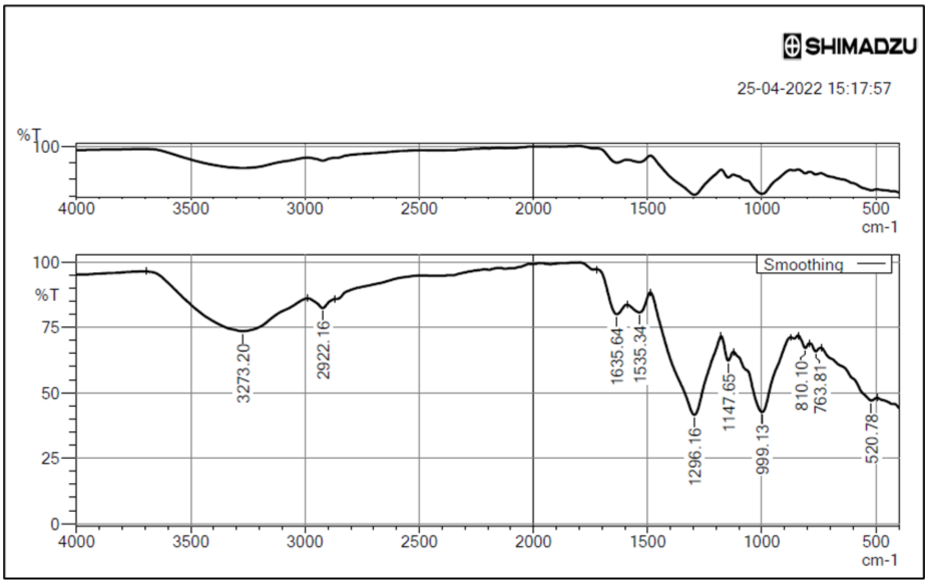

Fig. 5: FTIR analysis of AgNPs

Conclusion

We have demonstrated that use of a natural, low-cost biological reducing agent and peels of elephant foot (*Amorphophallus paeoniifolius*) extract can produce metal nanostructures, through efficient green nano chemistry methodology, avoiding the presence of toxic solvents and waste. Tuber peel extract of *Amorphophallus paeoniifolius* was used as reducing and stabilizing agent in this synthesis pathway. The nanoparticles separated from aqueous solution by centrifugation process were followed by decantation.

FTIR synthesis of silver nanoparticles showed absorption peaks in the range 4000-500 cm^{-1}. The absorption peak at 1296.16 cm^{-1} symbolized the bending band of adsorbed water of Ag. FTIR spectra indicated the presence of phytochemicals that were responsible for the reduction and possible stabilization processes. UV-visible spectra showed a characteristic band of 400 nm. XRD data evaluated the crystallinity of these synthesized nanoparticles; it was seen that AgNPs were face-centered cubic and the average crystallite sizes for the assign peaks were 16 nm.

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