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Phytofabrication of silver nanoparticles using leaves of Polygala javana DC

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***Abstract*— In this study, we report the phytofabrication of silver nanoparticles using the leaf broth of *Polygala javana* DC. (Family: Polygalaceae). We collected the leaves of *Polygala javana* from the campus of Ayya Nadar Janaki Ammal College, Sivakasi, Tamil Nadu. The leaf broth was added to aqueous solution of silver nitrate and it is known as reaction medium. This reaction medium was kept in an incubator cum shaker with 250rpm at 27^0c for 24 hours to reduce the silver nitrate into silver nanoparticles. The reaction medium changed its colour from pale yellow to dark brown during the incubation period. UV-visible spectroscopic analysis reveals the Surface Plasmon Resonance (SPR) with λ max at 470nm which has the raised absorbance up to 0.45a.u. It indicates the formation of silver nanoparticles. The synthesized silver nanoparticles were characterized by X-ray diffraction patterns (XRD), Fourier Transform Infrared Spectroscopy (FT-IR) and Scanning Electron Microscopy (SEM) with Energy Dispersive X-ray (EDX) patterns. The The FTIR analysis explains that the biomolecules in the leaf broth are responsible for the stability of silver nanoparticles. The XRD analysis gives the structural information of nanoparticles. The SEM and EDAX analyses confirm the significant presence of silver nanoparticles. The size of the particle ranged from 30 to 50 nm. Thus, we achieved the synthesis of silver nanoparticles with various sizes using the leaf broth of *Polygala javana.* This protocol brings the cost effective, eco-friendly route and an alternative to conventional physical and chemical methods in the synthesis of silver nanoparticles.**

Keywords*— *Polygala javana, Leaf broth, Silver nanoparticles, SPR, FTIR analysis, SEM analysis.

I. INTRODUCTION

In recent years, most researchers have focused the fabrication of metal nanoparticles due to their unique properties that are different from those of bulk materials [1,2]. Usually the metal nanoparticles can be synthesized using physical and chemical methods which needed high pressure, energy, temperature and toxic substances [3] for synthesizing metal nanoparticles and become hazard to the environment [4]. This problem has been overcome by the biological methods. These methods suggested as possible eco-friendly approaches and alternatives to physical and chemical methods [5]. In biological synthesis, the reduction of metal ions to metal nanoparticles has been done by plant biomolecules like proteins, alkaloids, flavonoids, triterpenes, lectins *etc*. (Hajra and Mondal, 2015). Now-a-days metal nanoparticles such as silver [6], Gold [7], Palladium [8] have been synthesized using plant extracts and they have a essential role in the production of good quality and quantity of nanoparticles within few hours [9,10]. At present, many researchers achieved the green synthesis of stable silver nanoparticles using various plants. For instance, some of them are using various natural products like green tea (*Camellia sinensis*) [11], neem leaf broth (*Azadirachta indica*) [12], *Aleo vera* plant extract [13] and latex of *Jatropha curcas* [14]. Recently, we demonstrated the eco-friendly synthesis of silver nanoparticles using leaves of *Merremia tridentata* [15]; *Odina wodier* [16]; *Hyptis suaveolens* [17]; *Tecoma stans* [18]; *Eucalyptus globulus* [19]; *Crinum asiaticum* [20]; Manilkara *zapota* and *Mimusops elengi* [21]. Hence, the present study is aimed to exploit one more plant, *Polygala javana* for the synthesis of silver nanoparticles.

II. MATERIALS AND METHODS

All the reagents used in the present study were obtained from Himedia Laboratories Pvt. Ltd., (Mumbai, India). Polygala javana DC. is herbaceous plant (Fig. 1) which belongs to the family Polygalaceae [22].

Fig. 1 Polygala javana plant

We collected the leveas of Polygala javana and thoroughly washed with tap water followed by distilled water to remove the surface contaminants and dried for 48 hours under shade. The dried leaves were ground to make fine powder using mortar and pestle and sieved using 20 mesh sieve to get uniform size range. For the preparation of leaf broth, the sieved leaf powder of Polygala javana (10g) was added to 100ml of distilled water and boiled at 70^0C for ten minutes. The freshly prepared leaf broth (10 ml) was re-suspended in 190 ml of aqueous solution of silver nitrate and this mixture is used as reaction medium. This reaction medium was kept it in an Incubator cum shaker (ORBITEK-MODEL) with 250 rpm at 27^0C for 24 hrs. From these reaction media a small aliquot of the samples was collected separately to characterize the silver nanoparticles that were synthesized during the above reaction. The characterization was performed through the following analyses: UV-Visible spectroscopy (UV-Vis), Fourier Transform Infra-Red Spectroscopy (FTIR), X-ray diffraction (XRD) analysis, Scanning Electron Microscopy (SEM), Energy Dispersive X- ray analysis (EDX) and Transmission Electron Microscopy (TEM).

III. Results and Discussion

A. UV-Visible spectrum of silver nanoparticles

UV-Visible spectral analysis was carried out on a Labomed (Model UV-D3200) UV- Visible spectrophotometer. The formation of silver nanoparticles was monitored by UV-Visible spectroscopy in the 300-700nm range. When the leaf broth was added to silver nitrate solution, the reaction medium color was changed from transparent yellow to brown (Fig. 2), which is due to the excitations of surface plasmon vibrations with a λ max at 470nm and the absorbance was raised to 0.45a.u (Fig. 2). It indicates the synthesis of silver nanoparticles. Similarly, the λ max of silver nanoparticles synthesized using *Euphorbia hirta* was 430nm [23]; *Odina wodier* was 450nm [16]; *Merremia tridentata* was 440nm [15]; *Crinum asiaticum* was 465nm [20], while it was 380nm in case of silver nanoparticles synthesized by *Nerium idicum* [24].

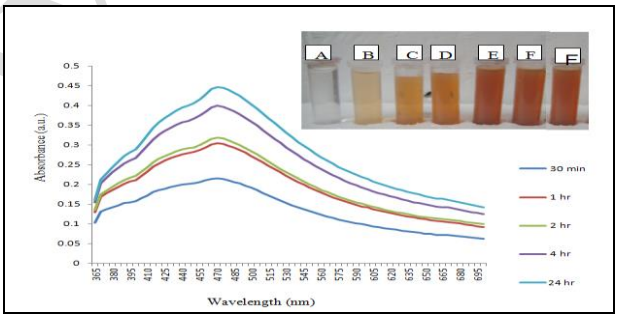

Fig. 2 SPR of Reaction medium. Inset shows the colour change of the reaction medium at different time intervals (left to right). A- Silver nitrate; B- leaf broth alone; C- 30min, D- 1hr; E- 2hrs; F- 4hrs and G- 24hrs).

B. FT-IR Spectroscopic Analysis

FT-IR measurements (using Shimadzu FT-IR spectrophotometer through KBR pellet method) identified the biomolecules in the leaf broth of *Polygala javana*, which are responsible for reduction and providing stability to the silver nanoparticles as capping agents. Fig. 3 shows the FT-IR spectrum of synthesized silver nanoparticles and it reveals the presence

of different functional groups. The absorption bands were observed in the region of 400-4000cm^{-1}are 3402.07cm^{-1} corresponds to hydroxyl group, H- banded OH stretch, 2924.09cm^{-1}, 2854.65cm^{-1} and 1458.18 cm^{-1} correspond to C-H stretch of alkanes, 2276.00 cm^{-1} corresponds to –SCN stretch of thiocyanate, 1874.81 cm^{-1} corresponds to C=O stretch of five membered ring anhydride, 1797.66 cm^{-1} corresponds to C=O stretch of esters, 1774.51 cm^{-1} corresponds to C=O stretch of ketones, 1735.93 cm^{-1} corresponds to C=O stretch of aldehydes, 1620.21 cm^{-1} corresponds to N-H bend of primary amines, 1543.05 cm^{-1} corresponds to N-O asymmetric stretch of nitrocompounds, 1381.03 cm^{-1} corresponds to C=O stretch of corboxylate, 1072.42 cm^{-1} corresponds to C-N stretch of aliphatic amines, 671.23 cm^{-1} and 655.80 cm^{-1} correspond to C-Br stretch of alkyl halides. The strong absorbance band at 1386 cm-1 was associated with the stretch of functional groups such as –C-O-C-, -C=O-, -C=C, -C=O- [25]. The absorbance bands are known to be associated with the stretching vibrations for -C-C-O, -C-C-, -C=C-, C=O (esters, ethers) and C-O (polyols) respectively [26]. Jain *et al.* (2009) [27] reported that polyols were mainly responsible for the reduction of Ag ions, whereby they themself got oxidized to unsaturated carbonyl groups leading to a broad peak at 1650 cm^{-1} (for reduction of Ag). The polyphenols may be involved as reducing agents and reduced Ag+ ions to silver nanoparticles [28].

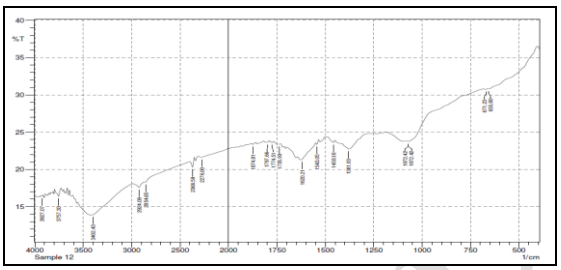

Fig. 3 FTIR spectrum of Reaction medium

C. XRD analysis

Crystalline nature of silver nanoparticles was examined by X-ray diffractometer Shimadzu (XRD 6000). Fig. 4 shows the X-ray diffraction pattern obtained for the synthesized silver nanoparticles using *Polygala javana* leaf extract. XRD pattern showed five distinct diffraction peaks at $2\Theta = 27.46^0$, 31.88^0, 37.80^0, 45.74^0 and 54.42^0 which indexed planes 226, 264, 111, 200 and 311 of the face - centered cubic structure of silver. These sets of lattice planes had been indexed on the basis of the face centered cubic structures (fcc) of standard silver JCPDS No- 04-0783. They were used to calculate the size of nanoparticles using the Debye-Scherrer's equation. The average size of the silver nanoparticles obtained is 30nm. The XRD pattern showed that the silver nanoparticles formed are crystalline in nature [29]. This also suggested that the crystallization of bio-organic phase occurred on the surface of silver nanoparticles [30].

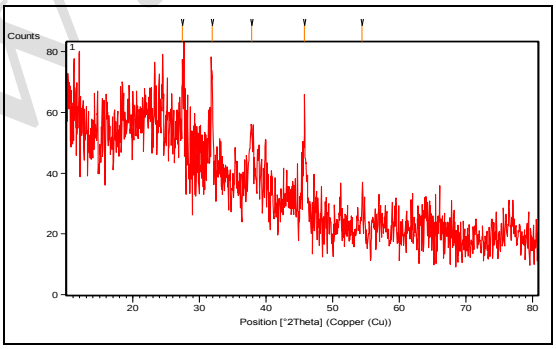

Fig. 4 XRD patterns of Reaction medium

D. SEM and EDX analysis

SEM images provided the information about the morphology and size of the biologically synthesized silver nanoparticles. The obtained silver nanoparticles with different shapes such as relatively spherical, hexagonal and cubic with a diameter range of ~30-50nm (Fig. 5). Similarly, the spherical shaped silver nanoparticles with a diameter ranging from 30 to

40nm were synthesized using *Boswellia ovalifoliolata* [31]; ~ 5-30nm using the leaf broth of *Odina wodier* [16]*;* 30-50 nm using the bark of *Eucalyptus globulus* [19] and 30-50nm using *Merremia tridendata* [15].

The EDX result shows a large peak of silver that confirms its presence in the suspension (Fig. 6). The EDX results provide chemical analysis of field of view and as well as the spot analysis of minute particles and confirms the presence of specific elements [32].

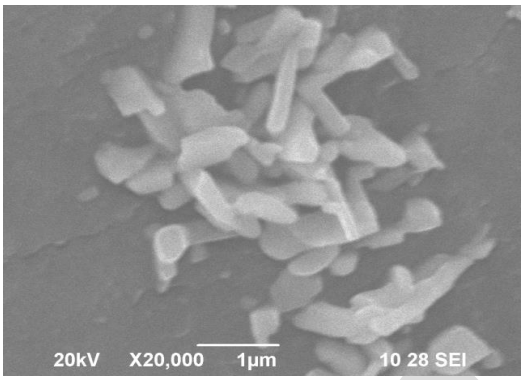

Fig. 5 SEM image of silver nanoparticles

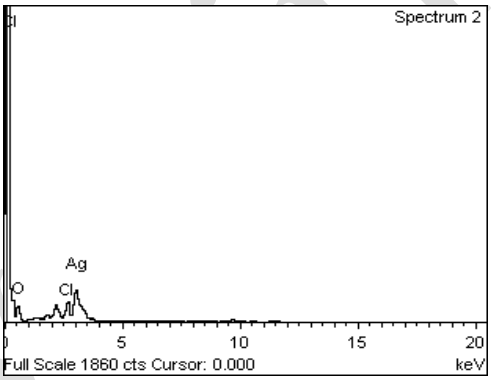

Fig. 6 EDX spectrum of reaction medium

E. TEM analysis

Transmission electron microscopy (TEM) analysis of the sample was carried out using Philips-Techno 10 instrument operated at an acceleration voltage of 200KV with resolution of 0.3nm. TEM images of the synthesized silver nanoparticles suggest that the particles are spherical and their dimensions ranging from 10 to 56nm with an average size of 35nm (Fig. 7). However, the size of the silver nanoparticles synthesized using the leaf broth of *Tecoma stans* was found to range 5 to 30 nm (~) with the mean 15 nm [18] and the mean size of the silver nanoparticles synthesized using the bark of *Eucalyptus globulus* was 30.5nm [19]. The leaves of *Eucalyptus hybrida* (Safeda) produced silver nanoparticles of 50nm size [29] and the leaves of *Pongamia pinnata* were employed to synthesize silver nanoparticles of 20nm size [33].

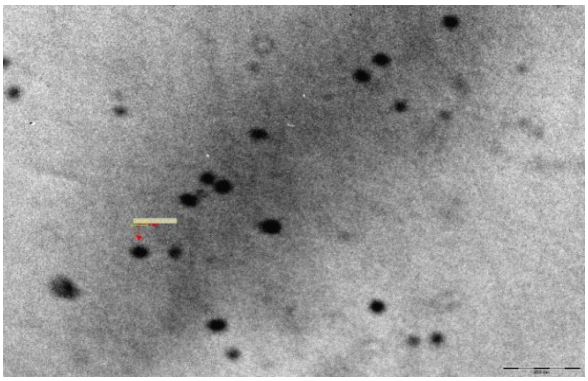

Fig. 7 TEM image of silver nanoparticles

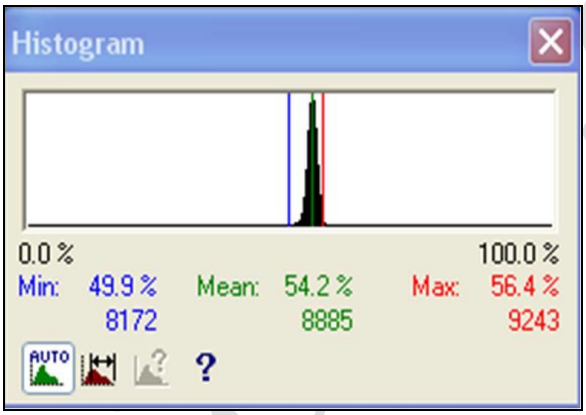

Fig. 7a Size-wise distribution of silver nanoparticles

IV. CONCLUSION

We achieved the rapid reduction of silver nitrate into silver nanoparticles through leaf broth. The reaction medium changed its color from pale yellow to dark brown within 24 hours of incubation period. The UV-Visible spectrum of the reaction medium has λ max at 470nm. The FT-IR spectrum showed the bands at 3402.07cm^{-1}, 2924.09cm^{-1}, 2854.65cm^{-1}, 2368.59 cm^{-1}, 2276.00 cm^{-1}, 1874.81 cm^{-1}, 1797.66 cm^{-1}, 1774.51 cm^{-1}, 1735.93 cm^{-1}, 1620.21 cm^{-1}, 1543.05 cm^{-1}, 1458.18 cm^{-1}, 1381.03 cm^{-1}, 1072.42 cm^{-1}, 671.23 cm^{-1} and 655.80 cm^{-1} it may be ascribed to the reduction of silver nitrate into silver nanoparticles. The SEM image shows the synthesized particles with different shapes such as relatively spherical, hexagonal and cubic with a diameter range of ~30-50nm. The strong silver peak obtained from the EDX spectrum confirms the significant presence of elemental silver. The XRD and TEM analyses determine the average size of the nanoparticles is 30 and 35nm respectively. The rapid, eco-friendly and biological synthesis of silver nanoparticles using leaf broth of *Polygala javana* provides a good quality and quantity of silver nanoparticles. It also alternate to conventional physical and chemical methods.

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