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Biosynthesis of silver nanoparticles using leaf extract of *Terminalia catappa*

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ABSTRACT

The biosynthesis of nanocrystals in various size and shapes have become an area of significant interest due to their potential biomedical applications. Here, we report the synthesis of silver nanoparticles in aqueous medium using *Terminalia catappa* (Almond) leaf extract as the reducing and stabilizing agent. On treating silver nitrate solution with *Terminalia catappa* leaf extract, reduction of Ag^+ ions was observed leading to the formation of triangular, hexagonal, decahedral and spherical silver nanoparticles in the solution.

KEYWORDS

Biosynthesis,
Terminalia catappa,
Silver nanoparticles,
Nanotriangles,
Decahedral.

INTRODUCTION

Nanotechnology has acquired special place in cutting age technologies[1]. In this context silver nanoparticles can be exploited for purification of drinking water, degradation of pesticides, killing human pathogenic bacteria and useful in the field of bio-labeling, sensors, antimicrobial agents and filters[2]. Recently synthesis of Au and Ag nanoparticles using lactic acid bacteria[3], phyllanthin[4], edible mushroom[5] and *Emblica officinalis* fruit[6] extract have been reported. The elaborate process of maintaining cell cultures could be eliminated by using plants for synthesis of nanoparticles (NPs). It could also be suitably scaled up for large-scale synthesis at lower cost.

In our earlier reports, synthesis of gold NPs using *Cymbopogon flexuosus*[7]. *Terminalia catappa*[8] (TC) and silver NPs using *Citrus limonium*[9] leaf extracts have been demonstrated. Still wide scope is available in the improvement of bio-based nanoparticle synthesis methods, particularly in relation to modulating their size and shape, as well as in reducing the time required for nanoparticle synthesis. The selection of TC extract has been preferred due to its anticancer[10] antibacterial[11] and antioxidant activities[12-14]. This paper reports the biosynthesis of Ag nanoparticles by using $AgNO_3$ as a substrate and *Terminalia catappa* aqueous leaf extract as reducing and stabilizing agent.

EXPERIMENTAL

The broth used for the reduction of Ag^+ ions to Ag^0 was prepared by boiling 10 g of thoroughly washed and finely cut *Terminalia catappa* leaves in a 500 mL Erlenmeyer flasks with 40 mL of sterile distilled water for 15 min. In a typical experiment, 1.4 mL of broth was added to 10 mL of 1.112×10^{-3} M aqueous silver nitrate ($AgNO_3$) solution. After 24 h yellow solution was obtained.

For FTIR spectroscopy measurements, drop coated samples on Si (111) wafers were prepared. After complete reduction of Ag^+ ions by the TC leaf broth and formation of silver NPs was centrifuged at 4000 rpm for 10 min to isolate the silver NPs from free proteins or other compounds present in the solution. The silver NPs pellet obtained after centrifugation was redispersed in water prior to FTIR analysis centrifuged again at 9000 rpm for 10 min.

RESULTS AND DISCUSSION

The reduction of aqueous Ag^+ ions after reaction with the TC leaf extract was followed by UV-vis spectroscopy. Figure 1A shows the UV-vis absorption spectra recorded from the as-prepared aqueous silver NPs solution, a strong resonance at ca. 376 nm is clearly seen in the curve. In our earlier study[6] the SPR band for spherical silver NPs was observed at 400 nm and there are reports in the literature that the band at ~350 nm is due to transition involving higher multipoles of silver NPs[15, 16]. This multipole transition becomes prominent for particle having symmetry lower than that of a sphere and arises due to the excitation of surface plasmon vibrations in the Ag nanoparticles[15, 16]. The formation of triangular, hexagonal, decahedral along with spherical silver NPs in our study supported by earlier reports[15, 16].

The silver NPs in aqueous phase were extremely stable with no aggregation observed even after five months. The stability for such a long period seems to be due to antimicrobial[12], antioxidant[12-14] properties of TC leaf extract and antimicrobial properties of silver NPs[17] itself.

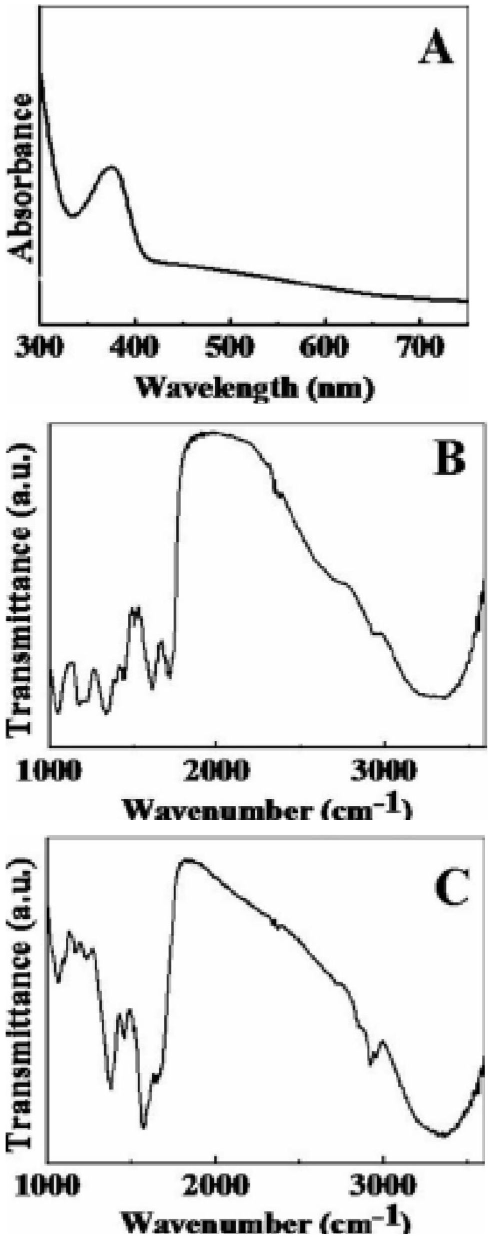

Figure 1 : A UV-vis absorption spectra recorded TC leaf extract-reduced silver nanoparticles; FTIR spectra recorded (B) from pure TC leaf extract and (C) from TC leaf extract-reduced silver nanoparticles.

FTIR measurements were carried out to identify the possible biomolecules in the TC leaf extract responsible for the reduction of Ag^+ ions and also the capping agents responsible for the stability of the biogenic nanoparticle solution. Chen *et al*.[18] reported that leaves of TC contains major tannin, punicalagin, whereas Rayudu and Rajdurai[19] analyzed the polyphenols and carboxylic compounds of TC. Figure 1B represents the FTIR spectrum of TC leaf extract which shows prominent absorption bands at 1717 cm^{-1}, 1441 cm^{-1} and 3355 cm^{-1}. The shoulder at 1717 cm^{-1} is characteristic of carbonyl stretch vibrations from carboxylic acid and phenols, while the stretch at 1441 arises due to the C-O stretching and O-H deformation possibly from the acid groups present in the TC leaf extract[20-21]. The broad stretching at 3355 cm^{-1} arises due to the free O-H groups present in the phenols. Figure 1C represents the FTIR spectrum of the TC leaf extract reduced silver nanoparticles with the absorption bands at 1377 cm^{-1}, 1644 cm^{-1} and 2956 cm^{-1}. The shift in the carbonyl stretch frequency (1717 cm^{-1}) to lower

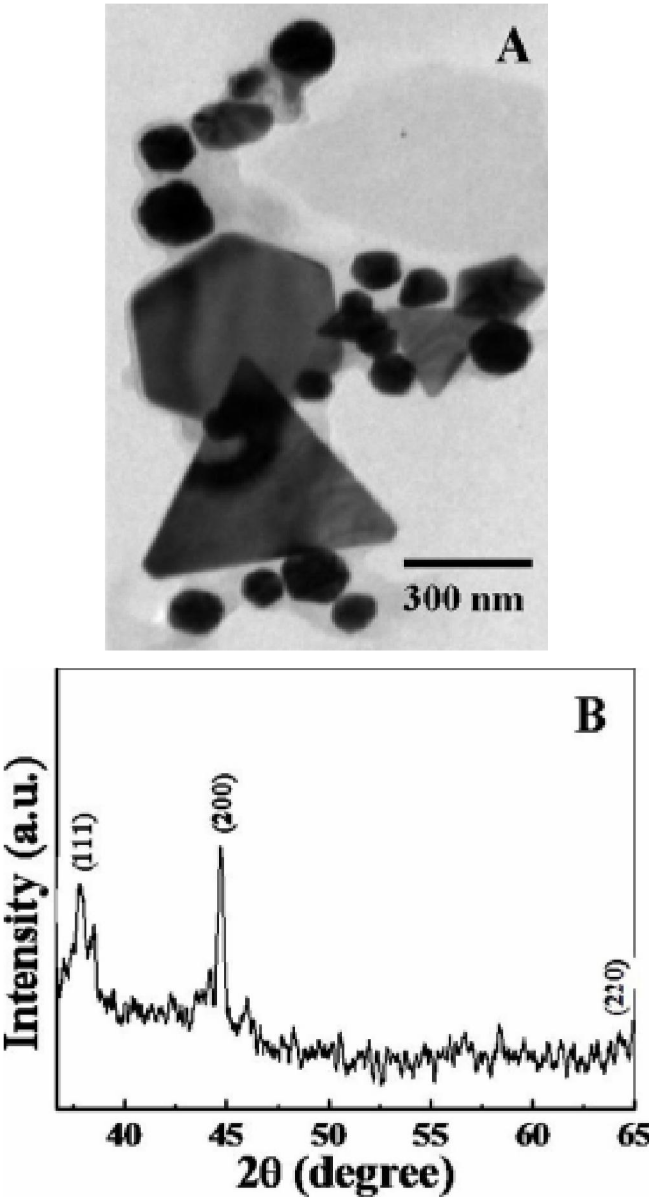

Figure 2 : Representative TEM image of TC leaf extract-reduced silver nanoparticles (A). (B) XRD pattern of a solution-cast film of the TC leaf extract-reduced silver nanotriangles deposited on a glass substrate. The Bragg reflections are identified in the XRD pattern.

wavenumbers (1644 cm^{-1}) followed by the disappearance of the 1717 cm^{-1} resonance may be due to its binding with the Ag nanoparticle surface. The shift in the C-O stretching and O-H deformation frequency (1441 cm^{-1}) to lower wavenumbers (1377 cm^{-1}) followed by the disappearance of the 1441 cm^{-1} resonance indicate the facilitation of the binding of O-H group of phenols with the Ag nanoparticle surface. In addition to above supportive evidence the 3355 cm^{-1} feature shifts to 2956 cm^{-1} due to the binding of the hydroxyl group with Ag nanoparticle surface[20]

Figure 2A shows a TEM image recorded from the biologically synthesized silver NPs at the end of the reaction with TC leaf extract. TEM reveals the formation of triangular, hexagonal, decahedral and spherical silver nanoparticles.

The formation of silver NPs synthesized using TC leaf extract was further supported by X-ray diffraction (XRD) measurements (Figure 2B). The Bragg reflections corresponding to the (111), (200), (220) sets of lattice planes are observed that may be indexed on the basis of the fcc structure of silver. In consideration of the wavelength of the light source CuKα_1 (λ = 1.54056Å) our 2θ values are almost a match with JCPDF file no. 04-0783 for silver.

The antibacterial[11] and antioxidant[12-14] properties of biomolecules present in the TC leaf extract and antibacterial properties of silver NPs[17] have facilitated excellent stability of the NPs and could have important application in packaging materials, surgical equipments, and is currently being pursued.

CONCLUSION

The synthesis of stable silver NPs using TC leaf extract has been demonstrated. The reduction of the metal ions and the stabilization of the silver NPs is believed to occur by the various acids and hydrolysable tannins present in the TC leaf. The antibacterial, antioxidant properties of TC leaf extract, antibacterial properties and extreme stability of silver NPs could be exploited in packaging materials, surgical equipments etc.

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