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Synthesis of silver nanoparticles through green approach using *Dioscorea alata* and their characterization on antibacterial activities and optical limiting behavior

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ABSTRACT

In this work, we have successfully synthesized highly biocompatible and functionalized *Dioscorea alata* (*D. alata*) mediated silver nanoparticles with different quantities of its extract for the evaluation of proficient bactericidal activity and optical limiting behavior. The crystalline nature of the synthesized silver nanoparticles was confirmed by powder X-ray powder diffraction (XRD) analysis and furthermore confirmed from SAED pattern of HRTEM Analysis. The Surface Plasmon Resonance band was measured and monitored by UV–Visible spectral studies. The functional groups present in the extract for the reduction and stabilization of the nanoparticles were analyzed by Fourier transform infrared spectroscopy (FTIR) technique. Surface morphology and size of particles were determined by high-resolution transmission electron microscopy analysis (HRTEM). The elemental analysis was made by Energy Dispersive X-ray Spectroscopy (EDX). The synthesized silver nanoparticles (AgNPs) in colloidal form were found to exhibit third order optical nonlinearity as studied by closed aperture *Z*-scan technique and open aperture technique using 532 nm Nd:YAG (SHG) CW laser beam (COHERENT—Compass 215 M-50 diode-pumped) output as source. The negative nonlinearity observed was well utilized for the study of optical limiting behavior of the silver nanoparticles. *D. alata* mediated silver nanoparticles possess very good antimicrobial activity which was confirmed by agar well diffusion assay method.

1. Introduction

Silver (Ag) nanoparticles are considered as important in the area of research mainly due to their distinct size and shape tunable properties. The distinct properties of the silver nanoparticles are used in a broad range of applications [1–7]. Controlling the size, and shape of metal nanoparticles are significant because many of their inherent properties are determined by shape and size. The importance has been recently placed on the control the size and shape of the nanoparticles. It is only within the past few decades that it has become possible to control the shape and size of particles synthesized and various methods have been developed for this [8]. Size control during synthesis of nanoparticles is a significant procedure for biosynthesis of silver nanoparticle. Depending on the size and shape of the nanoparticles, their applications branch out. With the rapid development of new chemical and physical methods, concern for environmental contaminations has increased as the chemical procedures convoluted in the preparation of nanomaterials give large amount of hazardous by-products. Thus there is a need for 'green chemistry' techniques and these greener environmental friendly processes in the synthesis of nanoparticles are becoming increasingly popular.

The green synthesis techniques for nanoparticles preparation are advantageous over the physical and chemical methods as they are much simpler, cost- effective, ecofriendly and relatively reproducible and often results in more stable particles. Various green methodologies have come up for the synthesis of Ag nanoparticles using microbes such as Bacillus [9], *Bacillus licheniformis* [10], and *Acetobacter xylinum* [11]. Other green reducing agents are also used to synthesize and stabilize Ag nanoparticles [12,13]. The plant extracts have potential advantages over the microorganisms owing to the ease of improvement, the less biohazard and extravagant process of conserving cell cultures. And it is the best platform for syntheses of nanoparticles; being free from toxic chemicals as well as providing natural capping agents for the stabilization of silver nanoparticles [14,15]. The optical nonlinearity of a material system can be expressed more precisely as a function of the dipole moment or polarization of the material system which depends on the strength of the applied field. In the case of linear optics, the induced polarization depends linearly upon the electric field strength. Third-order nonlinear optical effects are now essential for many advanced applications in nanophotonics. Nonlinear optics enhances the light–matter interactions in nanoparticles and is the basics of photonic

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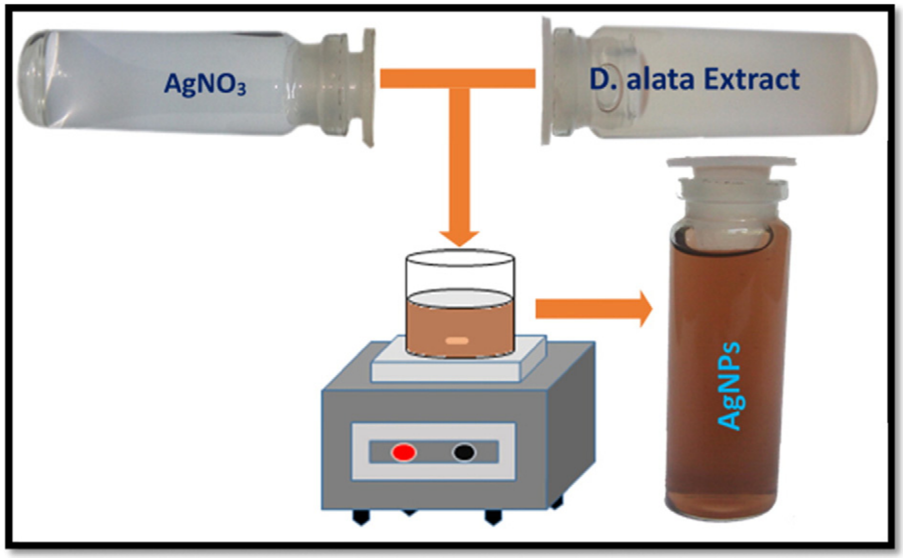

Fig. 1. Schematic representation of the synthesis process.

applications. The Z-scan technique was used to understand the nonlinear optical properties of Ag nanoparticles and the concept of different nanophotonic applications of the synthesized nanoparticles. In biomedical arena Bacterial infections involving the surface of the medical devices (e.g. subcutaneous implants, artificial prosthetics and catheters) and more generally infections spread by materials used in the environment are a solemn challenge for bio-medical scientists. In this regard silver nanoparticles are well known for their bactericidal properties. In the past decades a significant effort was made to obtain antibacterial coatings on different surfaces, such as apparels and medical devices. The antibacterial activity of the silver nanoparticles has been one of the utmost studied nanotechnology [16–18]. Therefore the aim of the present work is a complete green synthesis of Ag nanoparticles using *Dioscorea alata* tuber extract as reducing as well as stabilizing agent, study the nonlinear optical property of synthesized Ag nanoparticles and evaluate their antibacterial activity.

The Yams (*D. alata*) belonging to the *Dioscorea* genus are cultivated for their edible corms. Yams are one of the major foods in various tropical countries. The *D. alata* yam tubers consist mainly of starch, sugars, protein and fiber. The tuber of *D. alata* is a dietary supplement in Asia [19]. It is also used as a medicine in China as antiosteoporotic [20], hepatoprotective [21], antidiabetic [22], and antioxidant [23], and control of the neurodegenerative disease activities of *D. alata* was reported [24]. The influence of *D. alata* tuber mucilage on the stimulation of antibody production and splenocyte-mediated cytotoxicity was studied by Shang et al. [25] and the tuber extract has excellent pro-inflammatory and mitogenic activity upon consumption [26].

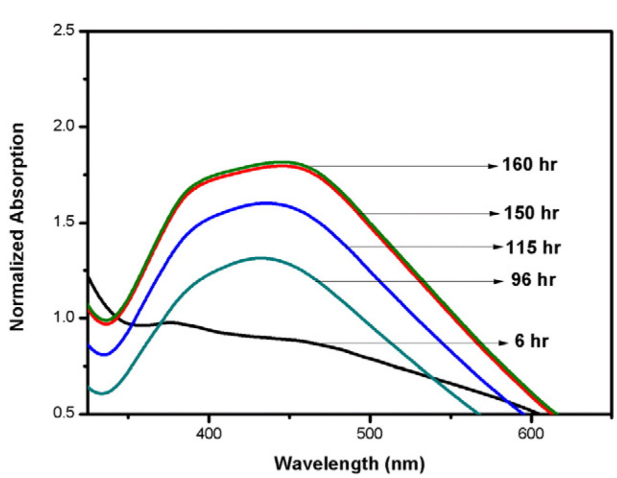

Fig. 2. Time dependent UV–Vis absorption spectra of prepared silver nanoparticles.

2. Materials and Methods

The commercial grade silver nitrate ($AgNO_3$) was purchased from Sigma-Aldrich chemical company, Chennai agency and used as such. *D. alata* tuber was collected from southern Asia cultivate land Koovanur, Tamilnadu, India.

D. alata extract was used as a reducing as well as stabilizing agent for the synthesis of silver nanoparticles. The collected *D. alata* tuber was washed five times using deionized water to remove dust then sliced into very small size pieces and dried for three days in shadow and

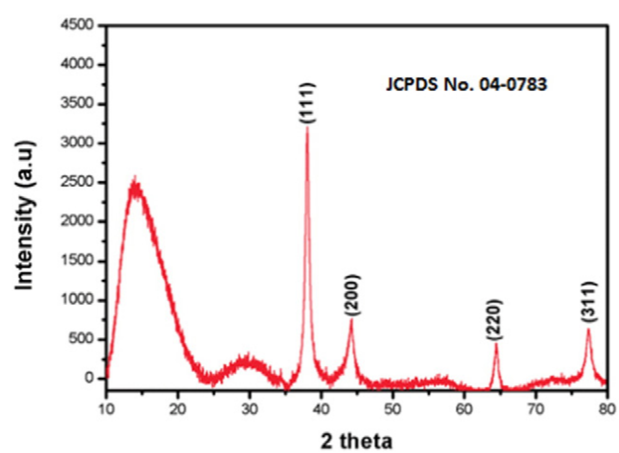

Fig. 3. Powder XRD pattern of the synthesized silver nanoparticles.

Table 1
Particle size calculation from XRD pattern.

Lattice plane	Peak position (degree)	FWHM (degree)	Particle size (nm)
(111)	38.05	0.6	14.63
(200)	44.11	0.7	12.63
(220)	64.43	0.5	16.77
(311)	77.36	0.7	14.17