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Green synthesis of colloidal silver using banana (*Musa balbisiana*) leaf extract

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Abstract
The area of nanotechnology is one of the liveliest areas of exploration in present-day material science. Metal nanoparticles especially silver nanoparticles have been extensively studied for their properties, which are quite distinct from the bulk material from which they are derived. A Number of methods like physical, chemical, photochemical, biological, green method etc. have been employed for the synthesis of silver nanoparticles. With increasing environmental concerns focus has been shifted on developing ecofriendly techniques for synthesis of silver nanoparticles. In present study silver nanoparticles were synthesized by green synthesis by using banana leaf extract. Nanoparticles thus obtained were characterized by UV-Vis spectrophotometry, transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD). Nanoparticles obtained by green synthesis method were quasi spherical, relatively larger in size in comparison to chemical method, unstable and showed marked degree of aggregation.

Keywords: Nanotechnology, silver nanoparticles, spectrophotometry, quasi spherical

Introduction
Nanotechnology is an evolving field of realistic science and leading edge technology that utilizes the physical and chemical attributes of nano-sized materials as an aid to control their shape, size and surface area in order to generate nano-sized materials of different characteristics. The potential of nanoparticles and nonmaterial are developing rapidly (Naiwa, 2000) [8].
Presently, commercially available Silver nanoparticles are synthesized, through both wet and dry synthesis procedures, and approved for use in consumer products at an exponential rate. Currently, many methods have been reported for the synthesis of Silver nanoparticles by using chemical (Solomon *et al*., 2007, Chen *et al*., 2007, Patil *et al*., 2012) [11, 3, 9], physical (Kim *et al*., 2005) [7], photochemical (Christy *et al*., 2012) [4], green and biological routes (Fayaz *et al*., 2010) [5]. Each method has advantages and disadvantages with common problems being costs, scalability, particle sizes and size distribution.
With ever increasing concern about our environment, there has been change in approach and focus has been shifted to green chemistry. The chemicals used in the chemical synthesis processes are very reactive and can have potential harmful effect both on handler as well as for the environment and high cost of production being another factor. This has led to increase in focus on green synthesis methods. India is rich is various plant species that can act as source of reducing agents e.g. leaves of banana (*Musa balbisiana*), black tulsi (*Ocimum tenuiflorum*) and neem (*Azadirachta indica*) have been successfully used for the synthesis of silver nanoparticles (Banerjee *et al*., 2014) [2]. Green synthesis methods are both ecofriendly and economical.
The potential of nanoparticles and nonmaterial are developing rapidly (Naiwa, 2000) [8]. Silver in nano-crystalline form has found amazing applications in the field of high sensitivity bio molecular detection, disease and chemical diagnostics, antimicrobial and therapeutic compounds, catalysis and micro-electronics.

Materials and methods
Green Synthesis
Fresh and green leaves of banana (*M. balbisiana*) were handpicked directly from banana trees. The leaves were washed thoroughly with distilled water, cut into small pieces and allowed to dry at room temperature. Nearly 20 grams of dried leaves were boiled in 200 ml distilled water for 30 minutes. The extract so obtained was allowed to cool and filtered first through muslin cloth and then through Whatman filter paper 01.

The process of filtration was repeated till a clear fluid without any suspended material was obtained and was stored at 4 ºC. In a 250 ml flask 50 ml filtrate was taken and pH was adjusted near around neutral using 1M NaOH. To the above flask 10 ml of 1mM silver nitrate was added and mixed well on magnetic stirrer. The mixture was allowed for bio reduction in a microwave at power of 600W for a total time of 5 minutes, giving a pause of 40 seconds after every minute. The change in color was observed (Banerjee *et al*., 2014) [2].

Characterization of silver nanoparticles
Characterization of silver nanoparticles is important to understand their properties. Characterization was done using a selection of different techniques such as UV–Vis spectroscopy, Transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR) and Thin Film X-ray diffractometry (XRD).

UV-VIS spectroscopy
Twenty-four hours after synthesis, 3 ml samples were collected in a cuvette from both the nanoparticle solutions. The absorbance of silver nanoparticle solution was observed between 300nm to 800nm using UV-VIS spectrophotometer (Thermo Scientific GENESYS 10S UV Vis Spectrophotometer) having a scan resolution of 3 nm.

Fourier transform infrared spectroscopy
Fourier transform infrared spectroscopy of silver nanoparticle solution was carried out in order to ascertain the purity and nature of the metal nanoparticles. FTIR analysis of dried silver nanoparticle powder was done (Thermo Scientific NICOLET 6700 FTIR) in the range of 500-4000 $cm^{-1,}$ using a KBR pellet (1:100) and absorbance at various wavenumbers was recorded.

Transmission Electron Microscopy (TEM)
The samples for TEM were prepared by partially drying a drop of the silver nanoparticle solution on a copper grid coated with a continuous carbon support film at room temperature. The grid was washed thoroughly with high purity water before the original sample was fully dried. The core size of Silver nanoparticles was computed by scrutinizing images captured by JEM 1011DV 300W (accelerating voltage 100 kV).

Thin film X-Ray Diffractometry
Thin film X-ray diffractometry (XRD) was done using PHILIPS PW 1729 X-Ray generator. Thin films of silver nanoparticles were prepared by coating grease free glass slide (75mm×25mm×1mm) with the Silver nanoparticles by placing few drops of Silver nanoparticles solution and spreading it to cover the whole surface. The Silver nanoparticles solution was allowed to evaporate at room temperature, leaving a thin film on glass slide.

Results and Discussion
Green method of synthesis resulted in production of yellow colored silver nanoparticle solution with a brownish tinge, characteristic of spherical nanoparticles of larger size and little aggregation similar to findings of Jin *et al*. (2001) [6]. Fig. 01 shows nanoparticle solutions 24 hours after synthesis.

Fig 1: Silver nanoparticle solution 24 hour after synthesis

UV-Vis Spectroscopy
The silver nanoparticles synthesized by green method exhibited an absorption maximum at 410 nm which falls in the range characteristic of silver nanoparticles. The graph had a wider base, which is characteristic of spherical silver nanoparticles with marked aggregation (Zielińska *et al*., 2009) [12].

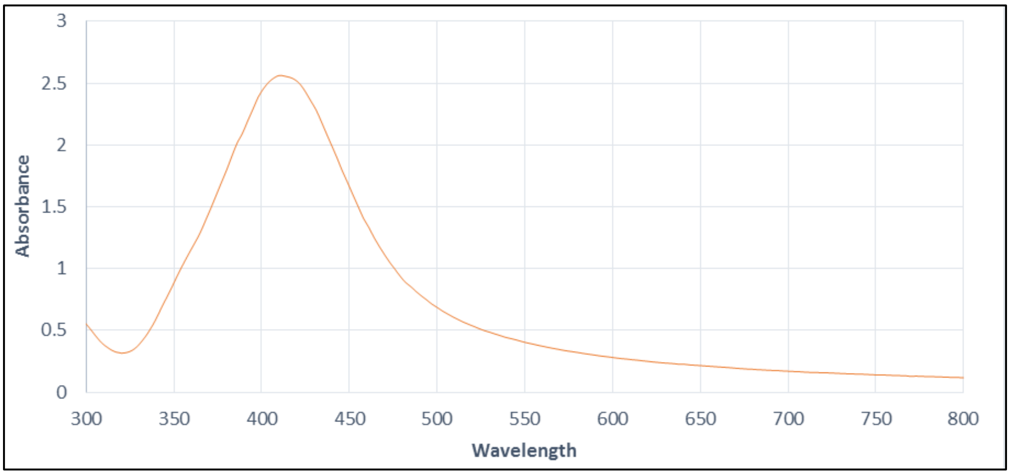

Fig 2: UV-VIS spectra of silver nanoparticles

Fourier transform infrared spectroscopy (FTIR)
Silver nanoparticles synthesized by green method manifest absorption peaks at 3382.53, 1646.91 and 694.25 cm^{-1}. The broad peak at 3382.53 cm^{-1} in the spectrum was assigned to O-H vibrational stretching of compounds present in the banana extract, confirmed by similar findings of Abdelghany *et al*. (2015) [1]. The peak at 1646.91 was assigned to C-C ring carbon stretching of mononuclear and polynuclear aromatic compounds (Reddy *et al*., 2014) [10]. The peaks at 694.25cm^{-1} was assigned to Ag−O vibration.

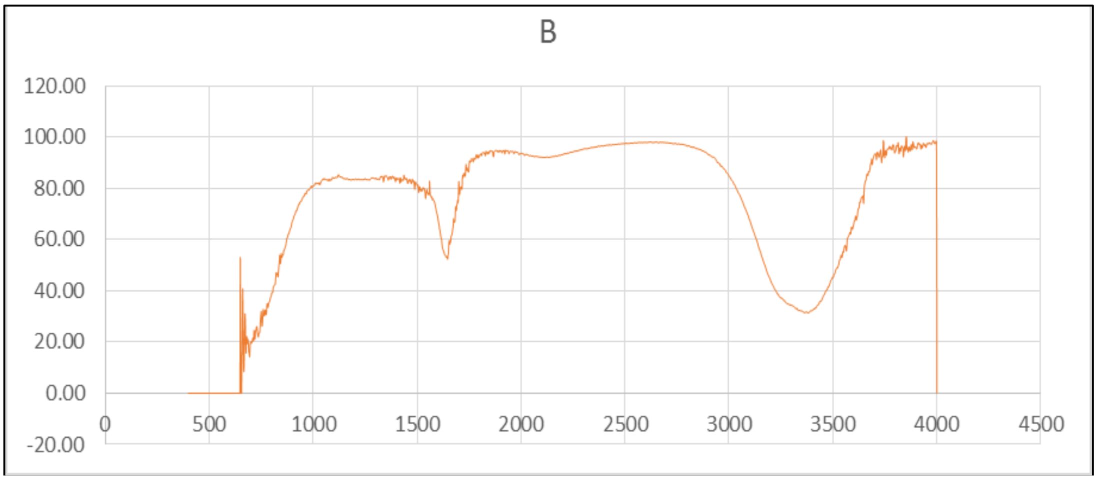

Fig 3: FTIR spectra of silver nanoparticles Synthesized by green synthesis method.

Transmission Electron Microscopy (TEM)
Micrographs of nanoparticles indicated spherical silver nanoparticles with a size range of 20 to 300nm. The particles showed a marked degree of aggregation.

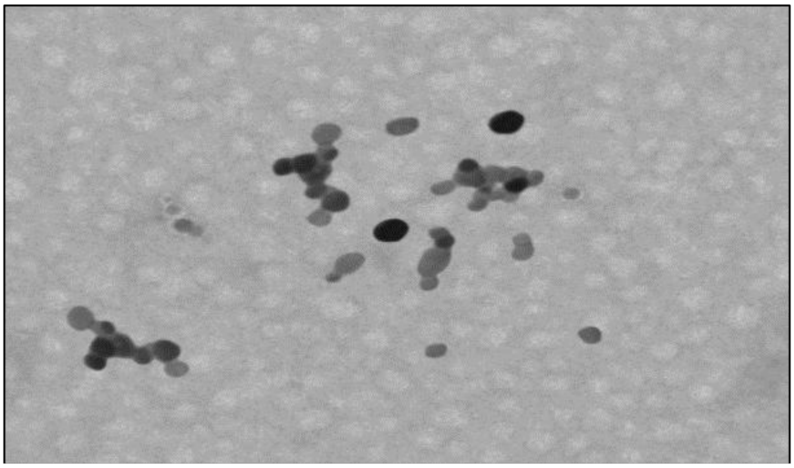

Fig 4: TEM micrographs of silver nanoparticles synthesized by green synthesis method

X-Ray Diffractometry (XRD)
Silver nanoparticles synthesized by green method displayed four sharp peaks; 2θ= 36.3, 46.4, 65.7, 76.0 which were indexed to (111), (200), (220) and (311) planes of face centered cubic (FCC) structure as per literature and findings of Jeeva *et al*. (2014).

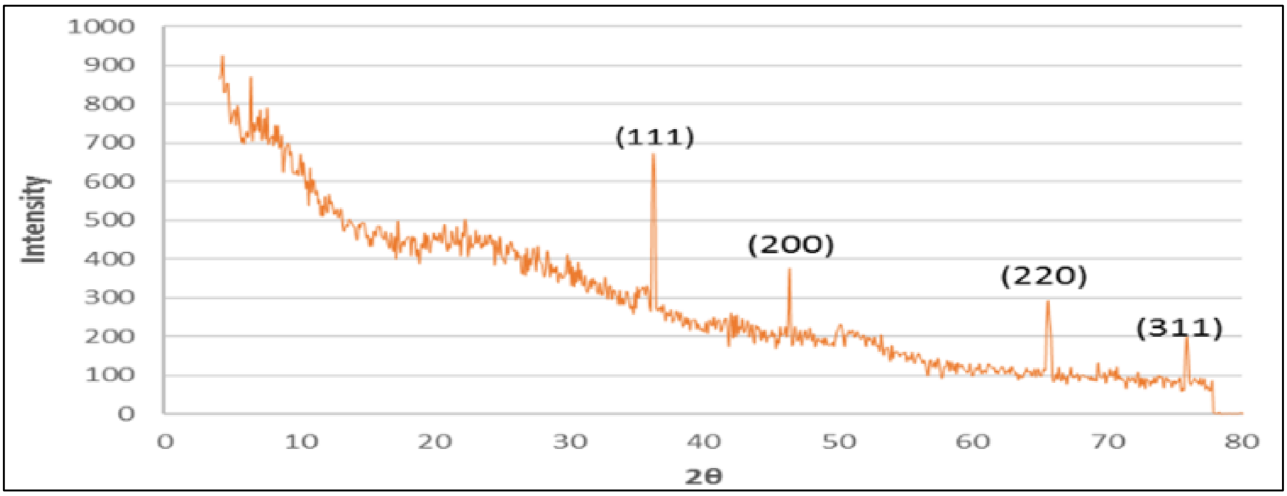

Fig 5: XRD pattern of silver nanoparticles synthesized by green synthesis method

Conclusion

The silver nanoparticles were synthesized by a green method using banana leaf extract. The nanoparticles were characterized using UV-Vis spectroscopy, FTIR, TEM and XRD. Nanoparticles exhibited a UV-Vis peak at 410nm. FTIR and XRD confirmed crystalline FCC structure. TEM micrographs indicated spherical nanoparticles with a degree of aggregation.

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