

Phytofabrication of silver nanoparticles by using aquatic plant *Hydrilla verticillata*

NEILESH SABLE, SWAPNIL GAIKWAD, SHITAL BONDE, ANIKET GADE, MAHENDRA RAI*

¹Department of Biotechnology, Sant Gadge Baba Amravati University, Amravati-444602, Maharashtra India. Tel: +91-721-2662206 to 8, Fax: +91-721-2662135, 2660949, *email: mkrai123@rediffmail.com

Manuscript received: 20 June 2012. Revision accepted: 21 July 2012.

Abstract. Sable N, Gaikwad S, Bonde S, Gade A, Rai M. 2012. *Phytofabrication of silver nanoparticles by using aquatic plant Hydrilla verticillata*. *Nusantara Bioscience* 4: 45-49. In the context of current drive to developed new green technology in nanomaterials, synthesis of nanoparticles is of considerable importance. There has been considerable work done in the field of nanoscience and Nanotechnology during the last decade due to the introduction of various protocols for the synthesis of nanoparticles by using plants and microorganisms. Here we firstly report the extracellular phytosynthesis of silver nanoparticles (Ag-NPs) using aquatic plants *Hydrilla verticillata*. The characterization of the phytosynthesized Ag-NPs was done with the help of UV-Vis spectroscopy, FTIR, Nanoparticle Tracking Analysis (NTA), Zeta potential and SEM. The SEM micrograph revealed the synthesis of polydispersed spherical nanoparticles, with an average size of 65.55 nm. The phytofabricated Ag-NPs can be used in the field of medicine and agriculture, due to their antimicrobial potential.

Key words: phytofabrication, *Hydrilla*, Ag-NPs, SEM, FTIR

Abstrak. Sable N, Gaikwad S, Bonde S, Gade A, Rai M. 2012. *Fitofabrikasi nanopartikel perak menggunakan tumbuhan akuatik Hydrilla verticillata*. *Nusantara Bioscience* 4: 45-49. Dalam konteks mendorong pengembangan teknologi hijau yang baru pada nanomaterial, sintesis nanopartikel sangat penting. Selama dekade terakhir terjadi perkembangan yang cukup pesat dalam bidang nanosains dan nanoteknologi karena diperkenalkannya berbagai protokol untuk mensintesis nanopartikel menggunakan tumbuhan dan mikroorganisme. Dalam penelitian ini, dilaporkan fitosintesis ekstraseluler nanopartikel perak (Ag-NP) menggunakan tumbuhan akuatik *Hydrilla verticillata* untuk pertamakalinya. Karakterisasi Ag-NP yang difitosintesis dilakukan dengan bantuan spektroskopi UV-Vis, FTIR, Analisis Pelacakan Nanopartikel (NTA), potensial Zeta dan SEM. Mikrograf SEM menunjukkan hasil sintesis nanopartikel berbentuk bulat yang tersebar, dengan ukuran rata-rata 65,55 nm. Fitofabrikasi Ag-NP dapat dimanfaatkan dalam bidang kedokteran dan pertanian, karena memiliki potensi antimikroba.

Kata kunci: fitofabrikasi, *Hydrilla*, Ag-NPs, SEM, FTIR

INTRODUCTION

Nanotechnology is a relatively recent development in scientific research, the development of its central concepts happened over last decades. The development of experimental procedures for the synthesis of nanoparticles of different chemical compositions, sizes, shapes, and controlled polydispersity is vital for its advancement. Currently, there is an ever-increasing need to develop environmentally benign processes in the field of nanoparticle synthesis, therefore focusing attention on biological systems. Nanobiotechnology is combination between nanotechnology and biology and which refers to the ability to create and manipulate biological and biochemical materials, devices, and systems at nano level (Kholoud et al. 2010).

Different microorganisms such as bacteria, fungi, and yeasts can be used as nanofactories for the biosynthesis of nanoparticles. It has been shown that fungi are good candidates for synthesis of metal and metal sulfides nanoparticles, near about 20 different fungi has been

investigated for the synthesis of metal nanoparticles. *Verticillium* sp. reduces metal ions into Au and Ag nanoparticles (Mukherjee et al. 2002). *Fusarium oxysporum* produces high stable gold, silver and platinum nanoparticles (Mukherjee et al. 2002, Riddin et al. 2006). Other reports of nanoparticles synthesis by fungi includes by *Aspergillus niger* (Gade et al. 2008), *Fusarium acuminatum* (Ingle et al. 2008).

But, plants as a system for synthesis of nanoparticles are rapid and eco-friendly biosynthesis process. Plants are used to synthesize Nanoparticles either intracellularly or extracellularly (Bonde et al. 2012). Living plants (Gardea-Torresdey et al. 2002, 2003) are used for synthesis of gold and silver nanoparticles, part of a plant like from geranium leaf broth (Shivshankar et al. 2003, 2004, 2005) or by fruits (Li et al. 2006) or even by sundried leaves (Huang et al. 2007). The rapid synthesis of silver nanoparticles by using different plant extracts of *Pinus*, *Persimmon*, *Ginkgo*, *Magnolia*, and *Platanus* were used and compared for their extracellular metallic Ag-NPS synthesis (Song et al. 2008) and the other reports of utilization of plant for the synthesis

of metal nanoparticle includes; *Azadirachta indica* (neem) (Shankar et al. 2004), *Aloe vera* (Chandran et al. 2006), *Emblica officinalis* (amla). (Amkamwar et al. 2005), *Capsicum annuum* (Li et al. 2007), *Cinnamomum camphora* (Huang et al. 2007), *Gliricidia sepium* Jacq. (Raut et al. 2009), *Carica papaya* (Mude et al. 2009), *Opuntia ficus-indica* (Gade et al. 2010), *Murraya koenigii* (Bonde et al. 2012), *Ocimum sanctum* (Mallikarjun et al. 2011), *Saururus chinensis* (Nagajyoti et al. 2011), *Foeniculum vulgare* (Bonde 2011).

The phytofabrication (fabrication by plants) of Ag-NPs from plant extracts has received some attention as a simple and viable alternative to bacterial and fungal system, also metal ions reduce much faster-using plant system as compare to microbes (Rai et al. 2008). The reduction of metal ions is known to using enzyme extracted from the plant extract, owing to this property the plant is selected for bio-reduction of silver ions in present study.

In the present study, we have for the first time exploited aquatic plants for the synthesis of Ag-NPs. The aquatic weed *Hydrilla verticillata* was used for the synthesis of Ag-NPs using 1mM silver nitrate (AgNO_3). The characterization of the phytofabricated Ag-NPs was carried out with the help of UV-Vis spectroscopy, FTIR, NTA, Zeta Potential and SEM.

MATERIAL AND METHODS

Extraction

The 20 g *Hydrilla verticillata* (Figure 1) plant part was washed 2-3 times with sterilized distilled water to avoid any microbial contamination, and then surface sterilized by HgCl_2 (0.1%) for 1 min, cut into small pieces and ground with 100 mL of sterilized distilled water in an omnimixer. Later, crude extract was filtered through muslin cloth and centrifuged at 10,000 g for 15 min to obtain clear leaf extract which was later used for the fabrication of Ag-NPs.

Fabrication of Ag-NPs

For the fabrication of Ag-NPs extract was challenged with AgNO_3 (1 mM) solution and incubated at room temperature. Control (without treatment with AgNO_3) (1 mM) i.e. only extract) was also maintained.

Detection of Ag-NPs

Visual observation

In conical flask 99 mL of plant filtrate was taken and 1 mL of AgNO_3 (100 mM) was added into it (final concentration becomes 1 mM). After incubation of filtrate at room

temperature for 24 hrs the color of filtrate changes from light green to dark brown. This color change indicates the formation of Ag-NPs.

UV-Visible Spectroscopy

The preliminary detection of Ag-NPs was done with the help of UV-Visible spectrophotometer (Perkin-Elmer, Lambda 25) by scanning the absorbance spectra in the range of 250-800 nm wavelengths.

Fourier Transform Spectroscopy

FTIR measurements of Ag-NPs synthesized from *Hydrilla verticillata* was carried out on a Perkin-Elmer FTIR Spectrophotometer in the range 450- 4000 cm^{-1} at resolution of 4 cm^{-1} . Scanning electron micrographs were taken using a JEOL 6380A instrument. The samples were fixed with 2.5% glutaraldehyde overnight at room temperature. The dehydration of fixed samples was carried out with gradient alcohol (10% to 95%), incubated for 20 min in each gradient and dipped in absolute alcohol for 2-5 min. The final specimen was prepared by placing a drop of dehydrated sample on a glass slide followed by coating with monolayer platinum for making the surface conducting.

NanoSight LM-20 analysis

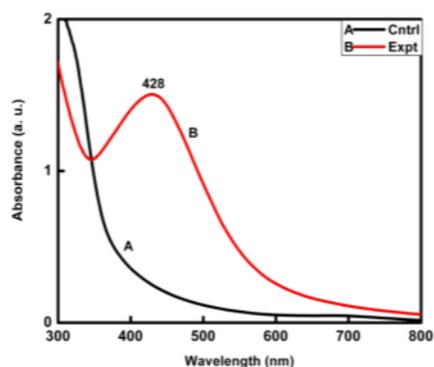
Liquid sample of Ag-NPs at the concentration range of 107-109/mL was introduced into a scattering cell through which a laser beam (approx. 40 mW at $k = 635 \text{ nm}$) was passed. Particles present within the path of the laser beam were observed via a dedicated non-microscope optical instrument (LM-20, NanoSight Pvt. Ltd., UK) having CCD



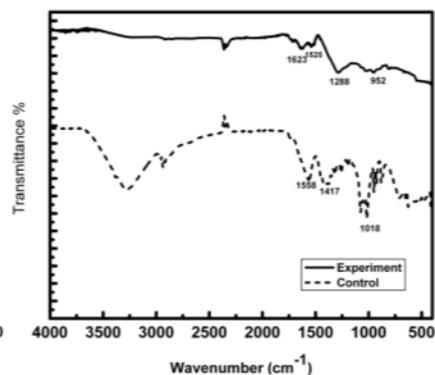
Figure 1. *Hydrilla verticillata* plant



2



3

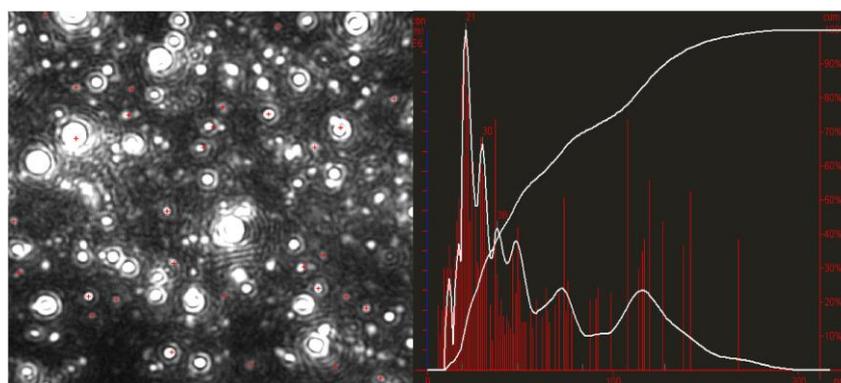


4

Figure 2. Control (left) and Ag-NPs (right) fabricated from *Hydrilla verticillata*

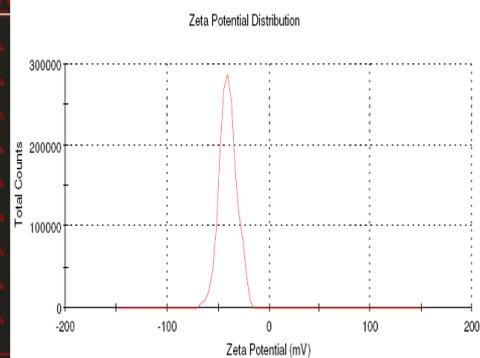
Figure 3. UV-Vis spectra of (A) leaf extract (control) and (B) Ag-NPs showing absorbance at about 428 nm.

Figure 4. FTIR spectrum for extract (control) and experimental after treatment with 1mM silver nitrate solution.



5A

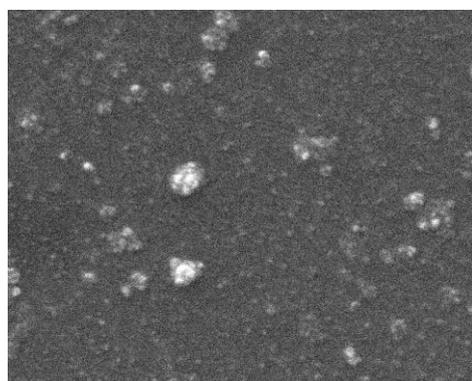
5B



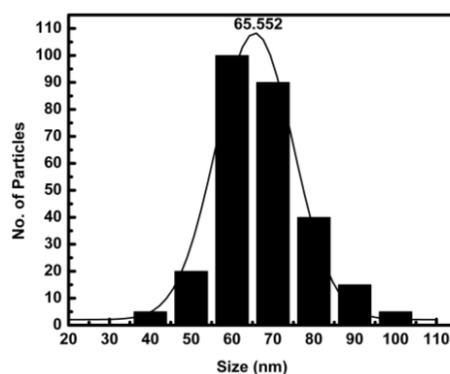
6

Figure 5. A. Particle size/concentration of Ag-NPs, B. Particle populations of Ag-NPs using NanoSight LM-20

Figure 6. Particle size distribution of Ag-NPs by intensity with Zeta Analyzer.



7A



7B

Figure 7. A. SEM micrograph of Ag-NPs (65.55 nm) (scale bar-100nm). B. A particle size distribution determined from the SEM images.

camera. The motion of the particles in the field of view (approx. 100 X 100 μm) was recorded (at 30 fps) and the subsequent video and images were analyzed.

Particle size measurement

Particle sizing experiments were carried out by means of laser diffractometry, using Zetasizer nano series (Malvern). Measurements were taken in the range between 0.1-1000 μm .

Scanning electron microscopy

Scanning electron microscopy of Ag-NPs was carried out by fixation of 2.5% glutaraldehyde overnight at room temperature. Then cell filtrate was dehydrated with gradient alcohol (10% to 95%) and incubated for 20 min for each gradient. It was dipped in absolute alcohol for 2-5 min. A drop of dehydrated sample placed on glass slide (1 cm x 1 cm). The sample was coated with monolayer platinum. The slide was observed under scanning electron microscope.

RESULTS AND DISCUSSION

The change in color of plant extracts from light green to dark brown when challenged against silver ions (1 mM AgNO_3) at room temperature. The color change in the extract was noted by visual observation (Figure 2). The characterization of Ag-NPs fabrication was done by using UV-visible spectrophotometer which confirms the presence of the absorbance peak at 428 nm (Figure 3).

Further characterization was done by Fourier Transform Infrared Spectroscopy (FTIR) measurements to identify the possible biomolecules responsible for the reduction of the Ag^+ ions and capping of the bioreduced Ag-NPs by protein. The amide linkages between amino acid residues in proteins give rise to the well-known signatures in the infrared region of the electromagnetic spectrum (Basavaraja et al. 2007). FTIR spectrum showed peaks in the range 1000-2000 cm^{-1} . Representative spectra of obtained nanoparticles manifest absorption peaks of respective functional groups and indicated the presence of stabilized protein molecules (Figure 4).

Nanoparticle Tracking and Analysis (NTA) was used to measure the dispersion characteristics, i.e. size and size distribution. In particular, it is the most recently developed system, NTA, was assessed in-depth due to its ability to see and size of particles individually on a particle-by-particle basis. NTA allows individual nanoparticles in a suspension to be microscopically visualized and their Brownian motion to be separately but simultaneously analyzed and from which the particle size distribution can be obtained on a particle-by-particle basis (Figure 5A). Figure 5B showed particle populations by size and intensity. The distribution data were mean 64 nm, mode 21 nm and standard deviation 43 nm. This result corroborates the results obtained by Montes-Burgos et al. 2010.

Particle size determination of the formulated nanoparticles was shown under different categories like

size distribution by volume, by intensity (Figure 6). The average zeta potential of peak was found to be -40.1 mV, area 100% and width 8.51 mV.

The formed Ag-NPs are well distributed with respect to volume and intensity is an indication of the formation of well built Ag-NPs and their monodispersity.

Scanning Electron Microscopy (SEM) study reveals the synthesis of spherical polydispersed Ag-NPs in the reaction mixture, which showed the spherical nanoparticles of size of 65.55 nm (Figure 7A). The particle size histogram showed average size of Ag-NPs (Figure 7B). Ag-NPs analyzed in NTA and scanning electron microscopy corroborates in their size.

CONCLUSION

It has been demonstrated that the extract of plant *Hydrilla verticillata* is capable of fabricating Ag-NPs and these Ag-NPs are quite stable in solution due to capping likely by the proteins present in the extract. This is an efficient, eco-friendly and simple process and more efficient with appreciable control over size, composition and even the shape of the nanoparticles. Ag-NPs have more applications as antimicrobial agents.

REFERENCES

- Amkamwar B, Damle C, Ahmad A, Sastry M. 2005. Biosynthesis of gold and silver nanoparticles using *Emblia officinalis* fruit extract, their phase transfer and transmetalation in an organic solution. *J Nanosci Nanotechnol* 5: 1665-1671.
- Basavaraja S, Vijayanand H, Venkataraman A, Deshpande UP, Shripathi T. 2007. Characterization of $\gamma\text{-Fe}_2\text{O}_3$ Nanoparticles Synthesized Through Self-Propagating Combustion Route. *Synth React Inorg Met-Org Nano-Metal Chem* 37: 409-412.
- Bonde SR. 2011. A biogenic approach for green synthesis of silver nanoparticles using extract of *Foeniculum vulgare* and its activity against *Staphylococcus aureus* and *Escherichia coli*. *Nusantara Bioscience* 3(2): 59-63.
- Bonde SR, Rathod DP, Ingle AP, Ade RB, Gade AK, Rai MK. 2012. *Murraya koenigii* Mediated Synthesis of Silver Nanoparticles and Its Activity against Three Human Pathogenic Bacteria. *Nanoscience Methods* 1: 25-36.
- Chandran SP, Chaudhary M, Pasricha R, Ahmad A, Sastry M. 2006. Synthesis of gold nanotriangles and silver nanotriangles using *Aloe vera* plant extract. *Biotech Prog* 22: 577-579
- Gade AK, Gaikwad SC, Tiwari V, Yadav A, Ingle AP, Rai MK. 2010. Biofabrication of silver nanoparticles by *Opuntia ficus-indica*: In vitro antibacterial activity and study of the mechanism involved in the synthesis. *Curr Nanosci* 6: 370-375.
- Gade AK, Bonde P, Ingle AP, Marcato PD, Durán N, Rai MK. 2008. Exploitation of *Aspergillus niger* for Synthesis of Silver Nanoparticles. *Journal of Biobased Materials and Bioenergy* 2 (3): 243-247.
- Gardea-Torresdey JL, Gómez E, Peralta-Videa JR, Parsons JG, Troiani H, Jose-Yacamán M. 2003. Alfalfa sprouts: a natural source for the synthesis of silver nanoparticles. *Langmuir* 19 (4): 1357-1361.
- Gardea-Torresdey JL, Parson JG, Gomez E, Peralta-Videa J, Troiani HE, Santiago P, Yacamán MJ. 2002. Formation and growth of Au nanoparticles inside live alfalfa plants. *Nano Letters* 2 (4): 397-401.
- Huang J, Li Q, Sun D, Lu Y, Su Y, Yang X, Wang H, Wang Y, Shao W, He N, Hong J, Chen C. 2007. Biosynthesis of silver and gold nanoparticles by novel sundried *Cinnamomum camphora* leaf. *Nanotechnology* 18:11-20.

- Ingle A, Gade A, Pierrat S, Sonnichsen C, Rai M. 2008. Mycosynthesis of silver nanoparticles using the fungus *Fusarium acuminatum* and its activity against some human pathogenic bacteria. *Curr Nanosci* 4:141-144.
- Kholoud MM, El-Nour A, Eftaiha A, Abdulrhman AQ, Ammar AA. 2010. Synthesis and applications of silver nanoparticles. *Arabian J Chem* 3:135-140.
- Li S, Qui L, Shen Y, Xie A, Yu X, Zhang L, Zhang Q. 2007. Green synthesis of silver nanoparticles using *Capsicum annum* L. extract. *Green Chem* 9: 852-858.
- Li Y, Leung P, Song QW, Newton E. 2006. Antimicrobial effects of surgical masks coated with 869 nanoparticles. *J Hosp Infect* 62:58-63.
- Mallikarjun K, Narsimha G, Dillip GR, Praveen B, Shreedhar B, Lakshmi S, Reddy VS, Raju DP. 2011. Green synthesis of silver nanoparticles using *Ocimum* leaf extract and their characterization. *Digest J Nanomat Biostruct* 6 (1): 181-186.
- Montes-Burgos I, Walczyk D, Hole P, Smith J, Lynch I, Dawson K.. 2010. Characterisation of nanoparticle size and state prior to nanotoxicological studies. *J Nanopart Res.* 12:47-53.
- Mude N, Ingle A, Gade A, Rai M. 2009. Synthesis of silver nanoparticles using callus extract of *Carica papaya-A* first report. *J Pl Biochem Biotechnol* 18: 83-86.
- Mukherjee P, Senapati S, Mandal D, Ahmad A, Khan MI, Kumar R, Sastry M. 2002. Extracellular biosynthesis of bimetallic Au-Ag alloy nanoparticles. *Chem. Biochem* 3:461-463.
- Nagajyoti PC, Prasad TN, Shreekanth VM, Lee KD. 2011. Biofabrication of silver nanoparticles using leaf of *Saururus chinensis*. *Digest J Nanomat Biostruct* 6 (1): 121-133.
- Rai M, Yadav A, Gade A. 2008. Current trends in phytosynthesis of metal nanoparticles. *Crit Rev Biotechnol* 28(4):277-284.
- Raut RW, Lakkakula JR, Kolekar NS, Mendhulkar VD, Kashid SB. 2009. Phytosynthesis of silver nanoparticle using *Gliricidia sepium* (Jacq.). *Curr Nanosci* 5: 117-122.
- Riddin TL, Gericke M, Whiteley CG. 2006. Analysis of the inter- and extracellular formation of platinum nanoparticles by *Fusarium oxysporum* f. sp. *lycopersici* using response surface methodology. *Nanotechnology* 17:3482-3489.
- Shankar SS, Rai A, Ahmad A, Sastry MJ. 2004. Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using Neem (*Azadirachta indica*) leaf broth. *J Colloid Interface Sci* 275: 496-502.
- Shivshankar S, Ahmad A, Sastry M. 2003. *Geranium* leaf assisted biosynthesis of silver nanoparticles. *Biotechnol Prog* 19:1627-1631.
- Shivshankar S, Rai A, Ahmad A, Sastry M. 2004. Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using Neem (*Azadirachta indica*) leaf broth. *J Colloid Interface Sci* 275:496-502.
- Shivshankar S, Rai A, Ahmad A, Sastry M. 2005. Controlling the optical properties of lemongrass extract synthesized gold nanotriangles and potential application in infrared-absorbing optical coatings. *Chem. Mater* 17:566-572.
- Song JY, Beom SK. 2008. Rapid biological synthesis of silver nanoparticles using plant leaf extracts. *Bioproc Biosyst Engineer* 32 (1): 79-84.