Review Article

Silver Nanoparticles: Green synthesis, characterization and its applications

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Abstract

Silver or metallic Nanoparticle is having tremendous application. The important technological advantages of nanoparticles used as drug carriers are high stability, high carrier capacity, feasibility of incorporation of both hydrophilic and hydrophobic substances, and feasibility of variable routes of administration, including oral application and inhalation. These properties of nanoparticles enable improvement of drug bioavailability and reduction of the dosing frequency. The incorporation of nanoparticles in industrial and biomedical applications has increased significantly in recent years, yet their hazardous and toxic effects have not been studied extensively. This study explores the green synthesis, characterization, and potential antimicrobial mechanisms of commercial silver nanoparticles in the environmental bacterium.

Keywords: antibacterial activity, characterization, green synthesis, silver nanoparticles

Introduction

Nanotechnology is a most important field of modern research dealing with synthesis, stability and manipulation of particle size ranging from approximately 1 to 100 nm in size. Within this size range all the properties (chemical, physical and biological) changes in fundamental ways of molecules and their corresponding bulk formulation. Novel applications of nanoparticles are growing rapidly on various fields due to their completely new or enhanced properties based on size, their distribution and morphology. It is swiftly gaining renovation in a large number of fields such as health care, cosmetics, biomedical, food and feed, drug-gene delivery, environment, health, mechanics, optics, chemical industries, electronics, space industries, energy science, catalysis, light emitters, single electron transistors, nonlinear optical devices and photo-electrochemical applications. Tremendous growth in these expanding technologies had opened applied frontiers and novel fundamentals. This includes the production of nanoscale materials afterwards in investigation or utilization of their mysterious physicochemical and optoelectronic properties (Korbekandi and Iravani, 2012; Khalil et al., 2013; Kaviya and Viswanathan, 2011). There are different methods (Figure 1) for synthesis of silver nanoparticles. In the end, a green synthesis approach for the synthesis of Silver nanoparticles shows much promise.

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Green synthesis

Green synthesis itself indicates the use of plant material without using chemicals. The present investigation is an effort in this direction. In this work, *Cycas*-leaf negotiated synthesis of silver nanoparticles (abbreviated Ag NPs) has been reported so that gymnosperms could also be taken as potential candidate plant specimens for the synthesis of metal as well as oxide nanoparticles. An effort has been also been made to understand the possible involved mechanism for the biosynthesis of Ag NPs (Anal and Jha 2010).

The recent reports include the synthesis using edible mushroom, henna, *Hibiscus rosasinensis*, tansi fruit and *Rosa rugosa*. Most of the reported biological synthesis methods using plants took more than 1 h for the formation of colloidal silver. Herein, a rapid biological synthesis of stable silver nanoparticles using aqueous extract of *Mangifera indica* leaves is reported. The effect of temperature and pH on the particle size and shape is also studied. The leaf is used traditionally to treat various infections and has anti-diabetic and anti-hyperglycaemic effect. The leaf extract is known for its antioxidant and antibacterial activity.

There are several instances (Table 1) (Ahmed et al., 2016)

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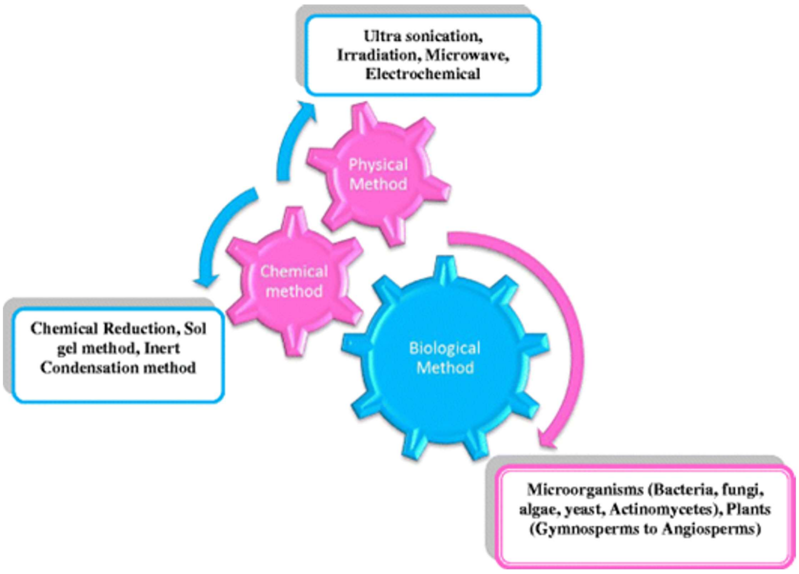

Figure 1. Methods involve in synthesis of Metallic nanoparticles

which have proved successful synthesis of AgNPs by using plants like *Aloe vera* (Daizy, 2011), *Tamarindus indica* (Chandran et al., 2006), *Cymbopogon flexuos* (Ankamwar et al., 2005), *Pelargonium graveolens, Azadirachta indica* (Shankar et al., 2003), *Cinnamommum camphora* (Shankar et al., 2004), and *Emblica officinalis* (Shankar et al., 2005). Phytochemicals present in these plants are rich in polyphenols, flavonoids, carbohydrates, and proteins which account for the antioxidant properties of plant. These antioxidant principles act as reducing agent for the synthesis of AgNPs (Ankamwar et al., 2005; Jha and Prasad, 2010; Jadhav et al., 2015).

Table 1. Green synthesis of silver nanoparticles by different researchers using plant extracts (Shakeel Ahmed et al., 2016)

Name of Plants	Parts of Plant
Cymbopogancitratus	Leaves
Alternanthera dentate	Leaves
Ficuscarica	Leaves
Centellaasiatica	Leaves
Acoruscalamus	Rhizome
Boerhaaviadiffusa	Whole plant
Tea extract	Leaves
Tribulusterrestris	Fruit
Cocousnucifera	Inflorescence
Abutilon indicum	Leaves
Pistaciaatlantica	Seeds
Ziziphoratenuior	Leaves
Acalyphaindica	Leaves
Premnaherbacea	Leaves
Argyreia nervosa	Seeds
Psoraleacorylifolia	Seeds
Brassica rapa	Leaves

Characterization of silver nanoparticles

After synthesis, precise particle characterization is necessary, because the physicochemical properties like size, shape, nature that is crystalline or amorphous of a particle could have a significant impact on their biological properties. In order to address the safety issue to use the full potential of any nanomaterial in the purpose of human welfare, in nano-medicines, or in the health care industry, etc., it is necessary to characterize the prepared nanoparticles before application. The characteristic feature of nanomaterials, suchas size, shape, size distribution, surface area, shape, solubility, aggregation, etc. need to be evaluatedbefore assessing toxicity or biocompatibility. To evaluate the synthesized nanomaterials, many analytical techniques have been used, including ultraviolet visible spectroscopy (UV-vis spectroscopy),X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), X-ray photo electronspectroscopy (XPS), dynamic light scattering (DLS), scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), and so on. The physicochemical properties of nanoparticles are important for their behavior, bio-distribution, safety, and efficacy. Therefore, characterization of AgNPs is important in order to evaluate the functional aspects of the synthesized particles. Characterization is performed using a variety of analytical techniques, including UV-vis spectroscopy, X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), dynamic light scattering (DLS), scanning electron microscopy (SEM), transmission electron microscopy (TEM), andatomic force microscopy (AFM).

Surface Plasmon Resonance (SPR) Studies

UV–Vis spectrophotometer (S-ican) was used to confirm the presence of SPR peak after each synthesis. This peak is the indicator for the presence of AgNPs. The samples were scanned in wavelength range of 200–700 nm.

Dynamic Light Scattering Studies

Malvern Zetasizer was used to determine the zeta potential, particle size, and particle size distribution of colloidal dispersion of AgNPs. The nanoparticles were appropriately diluted using deionized water and analyzed.

Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectra of lyophilized AgNPs were recorded by using Shimadzu FTIR spectrophotometer. Samples were analyzed by KBr pellet technique in the range 450–4000 cm^{-1} at resolution of 4 cm^{-1}.

X-Ray Diffraction

X-ray diffraction (XRD) data of AgNPs was obtained by using Philips PRO expert diffractometer. Data was recorded.at room temperature using nickel filtered Cu Ka radiations which was operated at 40 Kv voltage, 30mA current, and 7 to 70°C (2h) range.

Scanning Electron Microscopy-Energy Dispersive X-Ray Spectroscopy (SEM-EDAX=EDS=EDX=XEDS)

For SEM-EDAX analyses, samples were scanned using FEISEM Quanta 200 coupled with EDAX system. A drop of AgNPs colloidal suspension was deposited on carbon grid and dried under low vacuum (10–130 pa) and voltage was kept at 20 Kev. Initially sample was scanned at magnification of 3000x. The spot was fixed and was analyzed by EDAX system to confirm the presence of silver. After confirmation scanning was done at magnification of 6000xand12000x.

Transmission Electron Microscopy (TEM)

TEM images were recorded using Hitachi (H-7500, Japan) 120 kV equipped with CCD camera. Samples were spotted onto a carbon-coated copper grid and scanned through 1,50,000x to 3,00,000xmagnification to get clear images (Jadhav et al., 2015).

Applications of silver nanoparticles

As the silver having anti-bacterial properties, silver nanoparticles have been used most widely in the health industry, food storage, textile coatings and a number of environmental applications. In spite of decades of its use, it is important to note that the evidences of toxicity of silver are still not clear. Products prepared with silver nanoparticles have been approved by a range of accredited bodies including the US FDA, US EPA, Korea's Testing, SIAA of Japan and Research Institute for Chemical Industry and FITI Testing and Research Institute. The antimicrobial properties of silver nanoparticles have also been exploited both in the medicine and at home. Silver sulfadiazine creams use sometimes to prevent infection at the burn site and at least one appliance company has incorporated silver into their washing machines. Currently silver is used in the expanding field of nanotechnology and appears in many consumer products that include baby pacifiers, acne creams, and computer's keyboard, clothing (e.g. socks and athletic wear) that protects from emitting body odour in addition to deodorizing sprays.

Antimicrobial property of silver nanoparticles and its mechanism

Silver metal has been used widely across the civilizations for different purposes. Many societies use silver as jewellery, ornamentation and fine cutlery. Silver as jewellery, wares and cutlery was considered to impart health benefits to the users.

Silver is generally used in the nitrate form to induce antimicrobial effect but when silver nanoparticles are used, there is a huge increase in the surface area available for the microbes to be exposed to. Silver nanoparticles synthesized using plant extracts (from different sources) have been used for analyzing their antimicrobial activities against different microbes (Table 2) (Ahmed et al., 2016).

Table 2. Antimicrobial activities of silver nanoparticles synthesized using plant extracts (Shakeel Ahmed et al., 2016)

Sr. No.	Biological entity	Test microorganisms
1	*Boerhaavia diffusa*	*Aeromonash ydrophila, Pseudomonas fluorescens*
2	Tea	*E. coli*
3	*Alternanthera dentate*	*Escherichia coli, Pseudomonas aeruginosa*
4	*Tribulus terrestris*	*Streptococcus pyogens, Pseudomonas aeruginosa*
5	*Cocous nucifera*	*Klebsiellapneumoniae, Bacillus subtilis*
6	*Aloe vera*	*E. coli*
7	*Solanus torvum*	*P. aeruginosa, S. aureus, A. flavus*
8	*Trianthema decandra*	*E. coli and P. aeruginosa*
9	*Argimone mexicana*	*Escherichia coli; Pseudomonas aeruginosa*
10	*Abutilon indicum*	*S. typhi, E. coli, S. aureus and B. substilus*

The exact mechanisms of antimicrobial or toxicity activities by silver nanoparticles are still in investigation and a well debated topic. The positive charge on the Ag ions is suggested vital for antimicrobial activities. In order for silver to have any antimicrobial properties, it must be in its ionized form. In its ionized form, silver is inert but on coming in contact with moisture it releases silver ions (Klueh et al., 2000).

Conclusion

An increasing awareness towards green chemistry and use of green route for synthesis of metal nanoparticles lead a desire to develop environment-friendly techniques. Benefit of synthesis of silver nanoparticles using plant extracts is that it is an economical, energy efficient, cost effective; provide healthier work places and communities, protecting human health and environment leading to lesser waste and safer products. Many reports have been published about the syntheses of silver nanoparticles using plant extracts like those as already discussed. There is still a need for commercially viable, economic and environment friendly route to find capacity of natural reducing constituent to form silver or gold nanoparticles which has not yet been studied. There is a significant variation in chemical compositions of plant extract of same species when it collected from different parts of world and may lead to different results in different laboratories. This is the major drawback of syntheses of metallic nanoparticles using plant extracts as reducing and stabilizing agents and there is need to resolve this problem. On identifying biomolecules present in the plant which are responsible for mediating the nanoparticles production for rapid single step protocol to overcome the above said problem can give a new direction towards green syntheses of silver or gold nanoparticles.

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Conflicts of interest

All the authors are not having any conflicts of interest in this article.

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