Green synthesis of silver nanoparticles: Current Scenario of Plant extract mediated synthesis and antimicrobial applications

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Abstract: In the search of environmentally safe nanomaterials, invention of novel ways to synthesize biodegradable agents is essential in the field of nanotechnology. As the world is in need of non-toxic alternatives, it is vital to develop products by green synthesis for nanotechnology. As a developing field of science nanoscience can assume increased employment in medicine and related healthcare sectors. Essential development of such methods has been done gradually in the past decade. By-products of current nanomaterial methods like Silver nanoparticles (Ag-NPs) are hazardous to the environment and are difficult to dispose or recycle. The aim of this article is to review methods of Ag-NP synthesis and their applications. We have compared the efficiencies of these green synthesis methods with those involving chemical and mechanical principles. The critical factors affecting particle size, structure and economics of the technology are also reviewed. The environmental impact and its measurement indices forecasted by radical changes in nanoparticle synthesis are discussed with reference to reduction in universal toxic effects.

Keywords: Silver nanoparticles; antimicrobial; green synthesis; plant extracts

Introduction

Nanoparticles are organic or inorganic composites produced by technology research focused on synthesis of nanoscale particles and their application in various fields (Ahmed, et al. 2015). Quantum dots and Carbon nanotubes can be produced from organic components and are safer than metal nanoparticles (NPs) (Muhammad, et al. 2017). The size range variation of NPs along with different shape and structure is the main reason for increased use in modern applications like drug delivery, optics health care, electronics and chemical industry. Inorganic NPs include semiconductors, metallic and magnetic NPs like ZnO, Ag and Fe respectively. The first illustration of plant extract mediated synthesis of metallic nanoparticles was described by in 2003 using *Alfalfa* sprouts. This was the first description when living plant systems were used for Ag-NP synthesis (Gardea-Torresdey, et al. 2003).

However, Ag-NPs in particular are of great importance in pure sciences as they have applications in biosensors, catalysis, antimicrobial activity, DNA sequencing and biomedical applications (Muhammad, et al. 2017). The Ag-NPs offer greater research scope as they have significant characteristics like large surface area to volume ratio, chemical stability, conductivity, catalytic, antibacterial, anti-viral, antifungal, anti-inflammatory activities (Shakeel, et al. 2016). In biomedicine, Ag-NPs are added to wound dressings, topical creams, antiseptic sprays and fabrics acting as an antiseptic.

Synthesis of nanoparticles is generally through chemical and physical methods which are not typically cost effective and can be quite detrimental to the environment due to toxic by-products. Green synthesis is developing as an alternative synthesis method and is inspired by the low risk of toxic by-products (Alsammarraie, et al. 2018).

There are two approaches for the synthesis of nanoparticles namely “bottom-up” and “top-down” approaches. Bulk material is broken down into fine particles in the top-down method. Different breakdown methods used include evaporation-condensation and pulse wire discharge (Behravan, et al. 2018). Most physical methods or top-down approach have various drawbacks, which include occupation of large spaces, high energy consumption and rising of environmental temperatures around the material (Rose and Priya 2017). Chemical and biological methods are employed in bottom up method to synthesize nanoparticles by growing nuclei of atoms by assembling more atoms through a branching process. Chemical methods have an advantage of large quantities of nanoparticles synthesized in a small time frame but this comes at a cost of production of highly toxic by-products.

Green synthesis is also a diverse alternative to both chemical and physical methods of NP synthesis. Naturally occurring sources and their products overcome most drawbacks of chemical and physical methods. Microorganisms like bacteria, yeast, fungi and actinomycetes can be used for synthesis along with plant extracts and biomolecules (Ruíz-Baltazar, et al. 2017).

Plants contain various phytomolecules, these compound possess strong reducing properties and are potential to adsorb on the surface of NPs. biologically active phytomolecules existing in the plant extracts effectively promote the synthesis of the AgNPs by acting as reducing agents, and also functionalize the resultant NPs . They can act as a reducing, capping and stabilizing agent. NPs obtained by green method can be more effective when compared with those by chemical method. There are number of papers have been reported involving the biosynthesis of AgNPs using extract of different plant parts as reducing agent (Carmona, Benito and Plaza 2017).

Plant powders are now commercially available which can help to advance synthesis of nanoparticles using and identical plant extract to achieve similar results with other scientists from different regions of the world. This also reduces the extraction of plant material in large quantities from the ecosystem.

The main focus of this article is on the review of plant extract synthesis of Ag-NPs. We have discussed nanoparticle synthesis using green technology employing plant extract treatment, done in comparison with synthesis of nanoparticles by other conventional methods. The factors that control nanoparticle morphology and dimensions are also discussed. Finally applications requiring appropriate composition and type of nanoparticle are investigated. Nowadays, biosynthesis of nanoparticles using plant extract is getting more popular due to its strong antibacterial activity. The future directions of such environmentally conservative green technology are highlighted for their significant role in sustainability.

Synthesis of Ag-NPs using plant extracts

Synthesis using plant extracts as reducing and stabilizing agents can be characterized by several techniques including high resolution TEM, UV-Vis spectrometer, energy-dispersive X-ray (EDX) spectroscopy and selected area diffraction (SAD). NP properties are analysed using UV-Vis spectrometry, SEM, and Fourier Transmission Infrared (FTIR) spectrometry (Shakeel, et al. 2016). Synthesis of metal nanoparticles is concluded within the metal salt solution in a short time frame at room temperature and pressure with other factors affecting synthesis times being pH, concentration of extract and metal salt and also contact times.

Plant use is encouraged by the easy access to material and handling safety while also bolstered by the ability to use different parts of the plants like roots, shoots and seeds. Secondary metabolites contained within the plant act as stabilizing and reducing agents advancing the reduction of silver ions (Rao, et al. 2016). Other essential plant compounds like chlorophyll and vitamins have also been found to influence capping and reduction. The size and shape of these nanoparticles are determined by these chemical compositions in various plants.

Particle size and structure

Chemical methods make use of reducing agents in organic and inorganic forms and capping agents to stabilize the size of the nanoparticles. Shakeel Ahmed et al. synthesized silver nanoparticles using *Azadirachtaindica* leaf extract and found an average size of 34nm while homogeneous and spherical (Ahmed, et al. 2015). Synthesis using *Melissa officinalis* extract by Ruiz-Baltazar et al. yielded 12nm Ag-NPs with spherical morphologies (Ruíz-Baltazar, et al. 2017). Size differences can be explained by variances in phytochemical compositions of the different plants used to obtain extracts. Reducing agents differ in presence and quantities through varying species of plants and this difference can also be observed in plants of the same species but from different regions. Many other Ag-NPs synthesized by plant material possess varying sizes and irregular shapes. For the synthesis of specific shapes and sizes, the use of chemical, physical and electrochemical processes is still preferred as the results are predictable.

The green rapid synthesis of spherical shaped silver nanoparticles with dimension of 3-20 nm were observed using *Arbutus unedo* leaf extract. *Salvia spinosa* grown under *in vitro* condition was used to synthesis AgNPs (Pirtarighat, Ghannadnia and Baghshahi 2019). XRD analysis showed them to be crystalline. FTIR analysis revealed responsible metabolites for the reduction of Ag. These AgNPs were tested for antimicrobial activity against *B. subtilis, B. vallismortis and E. Coli* and shown inhibitory function. A silver nanoparticle of size 16nm was synthesized using extract of *Buddleja globosa* hope (Carmona, Benito and Plaza 2017). FTIR analysis showed some functional group like phenol and carboxylic group in extract. Silver nanoparticles were rapidly synthesized by Abraham et al., used plant extract from *Ocimum tenuiflorum*, *Solanum tricobatum*, *Syzygium cumini*, *Centella asiatica* and *Citrus sinensis* (Logeswari, Silambarasan and Abraham 2012). Synthesized AgNPs were characterized by uv-vis, XRD, SEM. The silver nanoparticles were formed after 24hrs treated with 1 ml solution. Nanoparticles showed efficient antibacterial activity against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Klebsiella pneumonia* microorganism.

Nanoparticles have also found a role in plant tissue culture by removing microbial contaminants from callus and other plant cultures. The size of the nanoparticles causes challenges which have resulted in the field of nanotoxicology

which focuses on the negative effects of nanoparticles (Kim, Gopal and Sivanesan 2017).

The most environmentally sustainable methods of Ag-NP synthesis are still in their infancy stage therefore the use of chemical and physical methods are still considered inevitable.

Applications of Ag-NPs

Silver is already widely used in a variety of human essentials such as cutlery. This is because silver was found in history to prevent microbial contamination while being one of the least toxic to humans. In 1984, it was common during childbirth in India to administer drops of aqueous silver nitrate to new born baby's eyes to prevent transmission of Neisseria gonorrhoea from infected mothers (Ahmed, et al. 2015).

Ag-NPs have also been found to have antifungal and antiviral activity. These properties allow for essential use in medicine through dental cements, wound care, cosmetics, surgery, medical devices, cancer therapy, implant coating and even surgery clothing (Shrivastava, et al. 2007). They can also be used in environmental disinfection, consumer goods and personal care products, food packaging and electronic components.

Conclusion

The last ten years have shown an exponential increase in research related to green synthesis of nanoparticles and development of further methods and perfection of previous ones. Current reports indicate that chemical and physical methods are overshadowed by green methods due to factors involving cost, environmental impact on the ecosystems and space management for bulk synthesis. As more scientific fields develop greener methods of manufacturing essential materials, it is imperative that nanoparticles need to be synthesised using eco-friendly methods to sustain natural resources for future. Green methods offer variety of resources for synthesis, ranging from microscopic bacteria to complex eukaryotes in the form of plants. Plants have an advantage over microorganisms in terms of isolation and culturing procedures, thereby defeating the purpose of minimal media components usage in synthesis of NPs. Another disadvantage of microorganisms that we have discussed is the difficulty in maintaining pure cultures with unaltered genomes resulting in risk of losing the ability to produce NPs. In this report, various plant species have been reviewed for production of different Ag-NP sizes and shapes allowing for controlled synthesis for specific nanoparticles. We have also hinted the concern of plants species from different geographical locations exhibiting different chemical signatures which can impact NPs synthesis in different laboratories. The nanoparticles synthesized using green methods have been found to be more stable with less waste production and requiring less complex facilities. Finally we have discussed the applications of nanoparticles, in particular Ag-NPs, in surface coating in medicine, dentistry, surgery and biosensors while also being employed in complex instrumentation for physics and other related disciplines.

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