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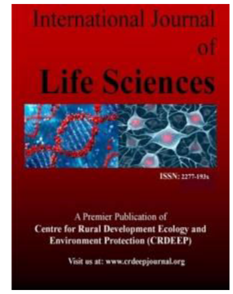

Review Paper

Green Nanotechnology: A Review on Green Synthesis of Bio-inspired Silver Nanoparticles — An Ecofriendly Approach

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ABSTRACT

Nanotechnology deals with the Nanoparticles having a size of 1-100 nm in one dimension used significantly concerning medical chemistry, atomic physics, and all other known fields. Nanoparticles are used immensely due to its small size, orientation, physical properties, which are reportedly shown to change the performance of any other material which is in contact with these tiny particles. These particles can be prepared easily by different chemical, physical, and biological approaches but the biological approach is the most emerging approach of preparation, because, this method is easier than the other methods, less time consuming and ecofriendly. Green synthesis of nanoparticle is a novel way to synthesis nanoparticles by using biological sources. It is gaining attention due to its cost effective, ecofriendly and large scale production possibilities.

Introduction

Review of Literature

Nanotechnology is an important field of modern research dealing with design, synthesis, and manipulation of particles structure ranging from approximately 1-100 nm in one dimension (Colvin *et al.,* 1994). The discipline of nanotechnology is swiftly evolving as an interdisciplinary science, medical, interfacing chemical, environmental and physical sciences not leaving behind diverse engineering fields, with myriad of applications in the development of biomedical devices, biosensors, alternative energy generation and environmental restoration (Silver *et al.,* 1996). Remarkable growth in this up-and-coming technology has opened novel fundamental and applied frontiers, including the synthesis of nanoscale materials and exploration or utilization of their exotic physicochemical and optoelectronic properties. Nanotechnology is rapidly gaining importance in a number of areas such as cosmetics, health care, environmental health, food and feed, mechanics, optics, chemical industries, electronics, biomedical sciences, drug-gene delivery, energy science, space industries, optoelectronics, catalysis, reorography, light emitters, nonlinear optical devices, single electron transistors, and photoelectrochemical applications (Wang, 1991).

Nanotechnology is fundamentally changing the way in which materials are synthesized and devices are fabricated. Various nanostructures such as thin films, nanorods, nanospheres, and a variety of nanoparticles (both metallic and non-metallic) are increasingly contributing to several innovative applications. Incorporation of nanoscale building blocks into functional assemblies and further into multifunctional devices can be achieved through a “bottom-up approach”. Research on the synthesis of nanosized material is of great interest because of their unique properties like magnetic, optoelectronic, and mechanical, which differs from bulk (Atul*et al.,* 2010).

In the twentieth century, Industrial revolution has led to the accumulation of huge quantities of harmful industrial wastes resulting in numerous health problems (Crabtree *et al.,*2003). Conventional procedures for nanoparticle synthesis incorporate chemical or physical routes, involving toxic chemicals as chemical precursors to transform bulk materials into the nanoparticulate forms (Catauro, 2004).

Application of green chemistry principles to the field of nanotechnology was introduced by researchers about a decade ago. Eco-friendly, "green" nanotechnological processes are assumed to have the capability to produce new products by utilizing ecofriendly materials (Cao, 2004). Such processes have involved plant extracts and plant metabolites and products of biological macromolecules such as peptides or proteins, nucleic acids, carbohydrates, and lipids as well. In the academic and industrial fields, Green nanotechnology encourages not only fundamental but also goal-oriented research for the development and designs of Green Nanoparticles (Klaus, 1999). Green nanoparticles have already been used in the design of life-saving nano-pharmaceuticals, smart electronic devices and in substitute green energy production devices as well (Shahverdi*et al.,* 2007).

In the present review, various methods involved in the green synthesis of Nanoparticles using specific bio-molecules present in plant extracts as precursors with emphasis on the antimicrobial activity of Nanoparticles (Ahmad *et al.,* 2003). In development of green silver nanoparticles, limitations of green nanotechnology and its antimicrobial activity along with the strategies to improve the production of green antimicrobial drugs have also been discussed. The size, shape, and surface morphology of Nanoparticles play a vital role in controlling their chemical, physical, optical, and electronic properties. The NPs that attract the attention of most researchers are produced from bulk silver and gold (Gade*et al.,* 2008).

The focus of the researchers across the globe has shifted to the development of novel antimicrobial agents, Due to the outbreak of multi-drug resistant microorganisms to common antimicrobial drugs available in the market. Nano-materials provided a promising alternative to deal with this subject of concern in the form of biosensors for pathogen detection and as a therapeutic tool against bacteria, fungi, and viruses (Mukherjee *et al.,* 2001).

Since the ancient days, Silver has been known for its antimicrobial activity. It was used for storing drinking water in ancient times. Silver is highly toxic to microorganisms whether in ionic or nanoparticle form (sondi*et al.,* 2004). Silver is the most poisonous metal known for its activity against microorganisms. Other metals follow silver in respect of antimicrobial activity as shown below:
Ag > Hg > Cu > Cd > Cr >Pb> Co > Au > Zn > Fe >Mn> Mo >Sn

Likewise, Silver ions in terms of in its antimicrobial activity is less effective than silver in nanoparticle form (Shahverdi *et al.,* 2007). Antibacterial properties of silver for infectious diseases were observed by the discovery of antibiotics have been known for a long time, (Bosetti*et al.,* 2002). At present-day, household water filters, clothing respirators, contraceptives, cosmetics, detergent, antibacterial sprays, dietary supplements, laptop keyboards, cell phones, and children's toys are among the products being marketed that purportedly exploit the antimicrobial properties of silver nanomaterials. It is required to focus upon the green synthesis of silver nanoparticles so as to counter the environmental threat being caused by the comprehensive use of chemicals for the implementation and fabrication of silver nanoparticles (Subramaniam, 1971). Plant extracts, biomacromolecules and peptides have been involved for the production of Green silver nanoparticles (Hu *et al.,* 2006). Synthesis of Green silver nanoparticles using plant extracts is a very cost-effective and easy way that satisfies the demand of the research community and eliminates the opportunity of environmental hazards simultaneously. Synthesis of Ag-nanoparticles by green method using extracts of plant tissues, vegetables, fruits, microorganisms etc. had reported till date.

Silver nanoparticles (AgNPs) synthesis using *Polyalthia longifolia* leaf extract as capping and reducing agent along with D-sorbitol used to increase the stability of the nanoparticles has been reported by S. Kaviya*et al.* (Ellis, 1971). The experiment was lead with two different concentrations (10^{-3} M and 10^{-4} M) of silver nitrate. The effect of temperature on the synthesis of AgNPs was examined by stirring at room temperature (25°C) and at 60°C. The UV-visible spectra of NPs displayed a blue shift with increasing temperature at both concentrations. FT-IR analysis showed that the bio moieties played an important role in the reduction of Ag^+ ions and the growth of AgNPs. The size and morphology of nanoparticles were determined by TEM. The synthesized silver nanoparticles were found to be highly lethal against Gram-positive bacteria than Gram-negative bacteria.

A green rapid biogenic synthesis of silver nanoparticles (AgNPs) using *Terminalia chebula* (*T. chebula*) aqueous extract was established (Acharya*et al.,* 2009). The formation of silver nanoparticles was established by Surface Plasmon Resonance (SPR) at 452 nm using UV–visible spectrophotometer. Silver ions reduced into silver nanoparticles by *T. chebula* extract were completed within 20 min which was showed potentiometrically. Synthesized nanoparticles were characterized using UV–Vis spectroscopy; Fourier transformed infrared spectroscopy (FTIR), powder X-ray diffraction (XRD), transmission electron microscopy (TEM) and atomic force microscopy (AFM). In addition, it showed good antimicrobial activity towards both Gram-positive bacteria (*S. aureus* ATCC 25923) and Gram-negative bacteria (*E. coli* ATCC 25922).

It was reported, by eco-friendly route, production or extracellular synthesis of gold and silver nanoparticles using *Emblic aofficinalis* (Amla, Indian Gooseberry) fruit extract could be a smart option (Ellis, 1971). *Emblica officinalis* fruit extract was treated with chloroauric acid solutions and aqueous silver sulfate so that rapid reduction of the silver and chloro aurate ions is observed leading to the formation of highly stable silver and gold nanoparticles in solution. Silver and gold nanoparticles analyzed by transmission electron microscopy indicated that they ranged in size from 10 to 20 nm and 15 to 25 nm respectively.

In another experiment, five plant leaves extracts *Pine*, *Persimmon*, *Ginkgo*, *Magnolia* and *Platanus* were used and compared for their extracellular synthesis of metallic silver nanoparticles (Catauro, 2004). By treating aqueous solution of $AgNO_3$ with the plant leaf extracts as reducing agent of Ag (+) to Ag (0), Stable silver nanoparticles were formed. Quantitative formation of silver nanoparticles was used to monitor by UV-visible spectroscopy. Magnolia leaf broth was the best reducing agent in terms of synthesis rate and conversion to silver nanoparticles. Only 11 min was required for more than 90% conversion at the reaction temperature of 950C using Magnolia leaf broth. The synthesized silver nanoparticles were characterized with inductively coupled energy dispersive X-ray spectroscopy (EDS), plasma spectrometry (ICP), transmission electron microscopy (TEM), scanning electron microscopy (SEM), and particle analyzer. The average particle size ranged from 15 to 500 nm. The particle size could be controlled by changing the leaf broth concentration, AgNO3 concentration and reaction temperature. Synthesis rates of biological silver nanoparticles were faster than chemical methods and can possibly be used in various human contacting areas such as foods, cosmetics and medical applications. The environmental synthesis of nanoparticles through various biological means helped to explore various plants for their ability to produce silver nanoparticles (AgNPs) (Magudapathy*et al.,* 2001).

It was reported that by using rhizome extract of *Dioscorea batatas*, AgNPs were synthesized at 80oC as well as room temperature at 25oC. By UV-Vis spectrophotometer, SEM, FTIR, XRD, and EDX AgNPs were characterized. The antimicrobial activity of silver nanoparticles was evaluated on gram positive (*B. substilis* and *S. aureus*), gram negative (*E. coli*), and fungi (*S. cerivisae* and *C. albicans*). *S. cerivisae* and *C. albicans* were found to be more susceptible to AgNPs than at $80O^{C}$ (Crabtree *et al.,* 2003).

It was found in a report that AgNPs were synthesized by using extract of *Foeniculum vulgare* and its activity against *Escherichia coli* and *Staphylococcus aureus* was reported. In this study, synthesized silver nanoparticles were identified by changing color from green to brown after treatment with AgNO3 (1mM) and analyzed by UV-visible spectrophotometer indicated the absorbance peak at about 427 nm indicating the synthesis of silver nanoparticles (Hussain*et al.,* 2003). Phyto-synthesized silver nanoparticles presented antibacterial activity against the *Staphylococcus aureus* (ATCC-25923) and *Escherichia coli* (ATCC-39403). The silver nanoparticles also demonstrated remarkable antibacterial activity against two human pathogenic bacteria when used in combination with commercially available antibiotics. The bactericidal activity of the standard antibiotics was significantly enhanced in presence of silver nanoparticles against pathogenic bacteria.

For this purpose, the medicinal plants have also been used. Green synthesis of silver nanoparticles using tobacco leaf extract was reported also (Zhao, 1998). Characterization of Synthesized nanoparticles UV-Vis absorption spectroscopy, TEM, EDAX, FT-IR and photoluminescence study, respectively. UV-Vis absorption spectroscopy of prepared silver colloidal solution showed absorption maxima at 418 nm. Excitation maximum and emission maximum obtained from photoluminescence study were found at 414 and 576 nm, respectively. TEM analysis showed average particle size of 8 nm, while SAED pattern confirmed the crystalline nature of synthesized nanoparticles. EDAX analysis showed proportion of silver (54.55%) among other elements in nanoparticle. *Pseudomonas aeruginosa* and *Escherichia coli* showed highest sensitivity towards silver nanoparticles.

Silver nanoparticles were prepared using extract of leaves of lemon tree (*Citrus limon*) that can act as reducing agent for the silver nanoparticles (Sanghi and Verma, 2009). On cotton and silk fabrics, these silver nanoparticles were used for durable textile finish and antimicrobial activity was observed in the treated fabrics. The antimicrobial activity of silver nanoparticles derived from lemon leaves showed enhancement in activity due to synergistic effect of silver and essential oil components of lemon leaves. This report showed the extracellular synthesis of highly stable silver nanoparticles by biotransformation using the extract of lemon leaves by controlled reduction of the Ag+ ion to Ag0. For antifungal treatment of fabrics, the silver nanoparticles were used which was tested by antifungal activity assessment of textile material by Agar diffusion method against *Fusarium oxysporum* and *Alternaria brassicicola*. Formation of the metallic nanoparticles was established by UV-Visible spectroscopy, Fourier transmission infrared spectroscopy, transmission electron microscopy, scanning electron microscopy, atomic force microscopy (Sharma *et al.,* 2009).

A number of plants are being currently investigated for their role in the synthesis of nanoparticles such as *Cinnamomum camphora* leaf (Huang *et al.,* 2007), *Pelargonium graueolens* leaf (Shankar *et al.,* 2003), *Emblica officinalis* leaf (Ankamware*t al.,* 2005), *Azadirachta indica* leaf (Shankar *et al.,* 2004), *Aloe vera* leaf (Chandran *et al.,* 2006), *Alfalfa* sprouts (Gardea-Torresdey*et al.,* 2003), *Helianthus annus*, *Basella alba*, and *Saccharum officinarum* (Leela *et al.,* 2008), *Carica papaya* callus (Mude*et al.,* 2009), *Jatropha curcas* leaf (Bar *et al.,* 2009), *Eclipta leaf* (Jha*et al.,* 2009), *Glycine max* (soybean) leaf (Vivekanandan *et al.,* 2009), *Coriandrum sativum* leaf (Sathyavathi *et al.,* 2010), *Syzygium cumini* leaf (Kumar *et al.,* 2010), *Cycas leaf* (Jha*et al.,* 2010), *Argimone mexicana* leaf (Khandelwal*et al.,* 2010), *Allium cepa* (Saxena*et al.,* 2010), *Stevia rebaudiana* leaves (Varshney*et al.,* 2010), *Solanum torvum* (Govindaraju*et al.,* 2010), *Zingiber officinale* (Singh *et al.,* 2011), *Capsicum annuum* (Li *et al.,* 2007), *Phytolacca decandra*, *Gelsemium sempervirens*, *Hydrastis canadensis* and *Thuja occidentalis* (*Pinusdesiflora*), *Diopyros kaki*, *Ginkobiloba*, *Magnolia Kobus*.

Plants retain primary metabolites such as reducing sugars, proteins, peptides,amino acids etc. play a key role in stabilization and reduction of metallic silver into silver nanoparticles. The role of polysaccharides in Gold silver nanoparticles has been reported (Park *et al.,* 2011).For the synthesis of AgNPs, beta D-glucose serves as the reducing agent and while starch as a stabilizing agent ((Raveendran*et al.,* 2003). The efficiency of sugars act as reducing agents in the production of metal nanoparticles was investigated (Panigrahi*et al.,* 2004). *Aloe vera* contains natural phytochemicals which provide natural capping and reducing agents so these are used for the synthesis of silver nanoparticles (Yebpella*et al.,* 2011). It was reported that the major polyphenol in *Coleus aromaticus*, the rosmarinic acid was more likely to be responsible for most of the observed antioxidant activity, it may involve in the reduction of silver ions (Ag+) to AgNPs (Ag0) (Vanaja and Annadurai, 2013). For the synthesis of silver nanoparticles, Flavonoids play a vital role in the reduction process. Due to high concentrations of carbazoles, a water soluble heterocyclic compound, reasonably responsible for the reduction and stabilization of metal ions, curry leaf has been found to be a potent.

Dioscorea bulbifera tuber is a rich source of flavonoids and phenolic acid derivatives. In the phytochemical analysis, *Dioscorea bulbifera* tuber extract strongly supports bioreduction of Ag+ to Ag0. *Pulicaria glutinosa* plant extract contains many phenolic compounds, which are known to play a vigorous role in the reduction of silver ions. *Astragalus gummifer* aqueous extract reduced into silver ions because of the oxidation of the hydroxyl and carbonyl groups (Kora and Arunachalam, 2012).

Conclusion and Recommendations

Future investigations should be preparation of silver nanoparticles (AgNps) which aim at overcoming these kinds of challenges and would be useful in designing effective drug delivery agent, treating and diagnosing fatal diseases besides ensuring higher efficacy and safety. We will prove the effective antibacterial property of these nanoparticles; hence we can think of its medicinal usage. Due to the highest conductive properties, we can implement these Silver nanoparticles in advanced portable gadgets. We can specifically use these nanoparticles in the production of clothing, leather items and coatings because it can protect these items from the attack of harmful microbes. Nanoparticles may be used in agriculture and food production in the form of Nano sensors for monitoring crop growth and pest control by early identification of plant diseases

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