



GREEN SYNTHESIS OF SILVER NANOPARTICLES AND ITS ANTIBACTERIAL ACTIVITY: A REVIEW

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Abstract

Nanoparticles being the smallest unit of nanotechnology are playing an important role in various fields of our life now a day. frequent usage of antibiotic drug is the reason for the emergence of multidrug resistance (MDR) of the pathogenic microorganisms, representing a major impediment for the successful diagnosis and management of infectious diseases, Nanoparticle-based therapy is a promising approach to improve the balance between the efficacy and toxicity of systemic therapeutic intervention. Among the various metal nanoparticles available, silver nanoparticles (AgNPs) have attracted tremendous interest in biomedical applications, including for antimicrobial therapy, wound dressings, diagnosis and treatment, and contraceptive devices. Thus, AgNPs represent a very promising therapeutic agent with unique potential against various microbial pathogens, with a particularly high capacity to effectively act on antibiotic-resistant bacteria. Therefore, developing a therapeutic strategy based on AgNPs to enhance the antibacterial effect represents a novel and promising approach. Green synthesis of nanoparticle using plant extracts is an efficient alternative for the conventional process of preparation of nanoparticles by chemical and physical methods which leads to non-eco-friendly by-products.

Keywords : Silver Nanoparticle, Green synthesis, antibacterial activity.

Brief Introduction of Silver Nanoparticle

Nanoparticles (NPs) are the simplest form of structures with sizes in the range of 1-100 nm, Generally, any collection of atoms bonded together with a structural radius of less than 100 nm can be considered as a nanoparticle, these nanoparticles are a link between bulk materials and atomic or molecular structures (Horikoshi & Serpone, 2013; Nikalje, 2015; Pal, 2014).

As the material approaches nanoscale dimensions, it shows new behavior and properties that are different from its bulk counterparts and these properties are size and shape, the small size of the nanomaterial leads to an increased surface area to volume ratio, which ensures an increase in the number of atoms at the surface in comparison to those in interior, recent advancements in understanding the properties of nanomaterials have enabled researchers to create new materials showing novel behavior for various applications (Sharma, 2012).

Some of nanoparticles are positively charged while some are negatively while others are neutrals, nanoparticles may be either magnetic or nonmagnetic types and they can also be classified as organic (mainly carbon) and inorganic (silver nanoparticles, gold nanoparticles etc.) (Kumar, 2014).

Silver nanoparticles have emerged as an important class of nanomaterials for a wide range of industrial and medical applications (Ahamed *et al.*, 2010).

It is estimated that of all the nanoparticles in consumer products, silver nanoparticle (Ag NP) applications currently have the highest degree of commercialization, A wide range of Ag NP applications has emerged in consumer products ranging from disinfecting medical devices and home appliances to water treatment (Tolaymat *et al.*, 2010, Vigneshwaran *et al.*, 2007), Furthermore, their unique plasmon-resonance optical scattering properties allow Ag NP use in bio-sensing and imaging applications (Dubas & Pimpan, 2008, Schrand *et al.*, 2008). More importantly is the

potential for the application of Ag NP in the treatment of diseases that require maintenance of circulating drug concentration or targeting of specific cells or organs, For example, Ag NPs have been shown to interact with the HIV-1 virus and inhibit its ability to bind host cells in vitro (Elechiguerra *et al.*, 2005).

Synthesis of Silver Nanoparticles

There are numerous techniques can be developed day by day for the easier and effective synthesis of the nanoparticles, there are basic three techniques used for synthesis of nanoparticles which are physical method, chemical method, and biological method (Iravani, 2014).

Physical methods are including pulsed laser desorption, plasma arcing, spray pyrolysis, ball milling, thermal evaporate, ultra-thin films, sputter deposition, lithographic techniques, layer by layer growth, molecular beam epitaxy and diffusion flame synthesis of nanoparticles (Joerger *et al.*, 2000). Similarly, the chemical methods are used to synthesized NPs by electrodeposition, sol-gel process, chemical vapour deposition, chemical solution deposition (Oliveira *et al.*, 2005, Panigrahi *et al.*, 2004), soft chemical method, Langmuir Blodgett method, hydrolysis and catalytic route, wet chemical method and co-precipitation method (Gan *et al.*, 2012). Chemical and Physical methods have been using high radiation and highly concentrated reductants and stabilizing that are harmful to environmental and to human health. Hence, biological synthesis of nanoparticles is a single step bio-reduction method and less energy is used to synthesize eco-friendly NPs (Sathishkumar *et al.*, 2009). Apart from that, the biological methods are using eco-friendly resources such as plant extracts, bacteria, fungi, micro algae such as diatom, cyanobacteria, seaweed (macroalgae) and enzymes (Iravani, 2011).

Green Synthesis of Silver Nanoparticles

Synthesis of Silver Nanoparticles by Bacteria:

The first evidence of bacteria synthesizing silver nanoparticles was established using the *Pseudomonas stutzeri* AG259 strain that was isolated from silver mine (Iravani, 2014). There are some microorganisms that can survive metal ion concentrations and can also grow under those conditions, this phenomenon is due to their resistance to that metal, the mechanisms involved in the resistance are efflux systems, alteration of solubility and toxicity via reduction or oxidation, biosorption, bioaccumulation, extracellular complex formation or precipitation of metals and lack of specific metal transport systems (Husseiny *et al.*, 2007). There is also another aspect that though these organisms can grow at lower concentrations, their exposure to higher concentrations of metal ions can induce toxicity, the most widely accepted mechanism of silver biosynthesis is the presence of the nitrate reductase enzyme, the enzyme converts nitrate into nitrite, in in vitro synthesis of silver using bacteria, the presence of alpha-nicotinamide adenine dinucleotide phosphate reduced form (NADPH)-dependent nitrate reductase would remove the downstream processing step that is required in other cases (Vaidyanathan *et al.*, 2010).

Synthesis of Silver Nanoparticles by Fungi

When in comparison with bacteria, fungi can produce larger amounts of nanoparticles because they can secrete larger amounts of proteins which directly translate to higher productivity of nanoparticles (Mohanpuria *et al.*, 2008). The mechanism of silver nanoparticle production by fungi is said to follow the following steps: trapping of Ag⁺ ions at the surface of the fungal cells and the subsequent reduction of the silver ions by the enzymes present in the fungal system (Mukherjee *et al.*, 2001). The extracellular enzymes like naphthoquinones and anthraquinones are said to facilitate the reduction, considering the example of *F. oxysporum*, it is believed that the NADPH-dependent nitrate reductase and a shuttle quinone extracellular process are responsible for nanoparticle formation (Ahmad *et al.*, 2003). Though the exact mechanism involved in silver nanoparticle production by fungi is not fully deciphered, it is believed that the above mentioned phenomenon is responsible for the process. A major drawback of using microbes to synthesize silver nanoparticles is that it is a very slow process when in comparison with plant extracts. Hence, the use of plant extracts to synthesize silver nanoparticles becomes an option that is feasible (Prabhu & Poulouse, 2012).

Synthesis of Silver Nanoparticles by Plants

The major advantage of using plant extracts for silver nanoparticle synthesis is that they are easily available, safe, and nontoxic in most cases, have a broad variety of metabolites that can aid in the reduction of silver ions and are quicker than microbes in the synthesis (Jha *et al.*, 2009). The main mechanism considered for the process is plant-assisted reduction due to phytochemicals, the main phytochemicals involved are terpenoids, flavones, ketones, aldehydes, amides, and carboxylic acids. Flavones, organic acids, and quinones are water-soluble phytochemicals that are responsible for the immediate reduction of the ions (Makarov *et al.*, 2014). Studies have revealed that xerophytes contain emodin, an anthraquinone that undergoes tautomerization,

leading to the formation of the silver nanoparticles (Shah, 2014). In the case of mesophytes, it was found that they contain three types of benzoquinones: cyperoquinone, dietchequinone, and remirin, it was suggested that the phytochemicals are involved directly in the reduction of the ions and formation of silver nanoparticles (Jha *et al.*, 2009). the proposed mechanism of biological synthesis of silver nanoparticles using plant extract is showed in figure 1 (Tripathy *et al.*, 2010).

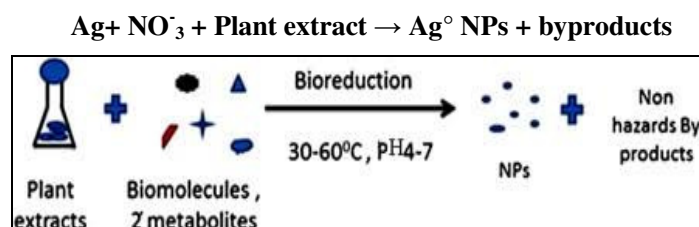


Fig. 1: Proposed mechanism of nanoparticle synthesis using plant extracts

Need for Green Synthesis

Green synthesis is an environmental friendly approach where no toxic chemicals involved (Logeswari *et al.*, 2015). It is a revolutionary technique which leads to new era that unfolds potential of plants in synthesizing stable NPs, increase the life span of NPs synthesized and also overcome the limitations of chemical and physical methods (Kavitha *et al.*, 2013, Malik *et al.*, 2014). It is faster and reliable technique comparative to conventional techniques which scale up the process of production of commercially applicable NPs with less or no toxicity, plants therefore, used for NPs synthesis because they actively uptake and reduce metal ions in bioremediation and thereby can form complex metal NPs (Gardea-Torresdey *et al.*, 2002). Green synthesis provides advancement over physical and chemical method as it is cost effective environment friendly, easily scaled up for large scale synthesis and in this method there is no need to use high pressure, temperature, energy and toxic chemical (Malabadi *et al.*, 2012). Green synthesis of nanoparticles makes use of environmental friendly non-toxic and safe reagent, Phytomining is the uses of hyper accumulating plants to extract a metal from the biomass to return an economic profit (Lamb *et al.*, 2001).

Recently the plant intervened nanomaterial has drawn more consideration because of its immense application in different fields due to their physicochemical properties. The different metallic nanoparticles such as gold, silver, platinum, zinc, copper, titanium oxide, magnetite and nickel were synthesized from natural resources and have been studied exclusively (Dhuper *et al.*, 2012). The different parts of plant such as stem, root, fruit, seed, callus, peel, leaves and flower are being used to syntheses of metallic nanoparticles in various shapes and sizes by biological approaches. Though bacterial, fungal, and plant extract sources can be used for nanosilver synthesis, the easy availability, the nontoxic nature, the various options available, and the advantage of quicker synthesis make plant extracts the best and an excellent choice for nanosilver synthesis (Kulkarni & Muddapur, 2014). Biosynthesis reaction can be altered by wide range of metal concentration and amount of plant extract in the reaction medium, it may transform the shapes and size of the nanoparticles (Chandran *et al.*, 2006).

Biological Applications of Silver Nanoparticles

Due to their unique properties, AgNPs have been used extensively in house-hold utensils, the health care industry, food storage, environmental, and biomedical applications. Several reviews and book chapters have been dedicated in various areas of the application of AgNPs. Herein, we are interested in emphasizing the applications of AgNPs in various biological and biomedical applications, such as antibacterial, antifungal, antiviral, anti-inflammatory, anti-cancer, and anti-angiogenic. Herein, we specifically addressed previously-published seminal papers and end with recent updates (Zhang *et al.*, 2016). A schematic diagram representing various applications of AgNPs is provided in Figure 2.

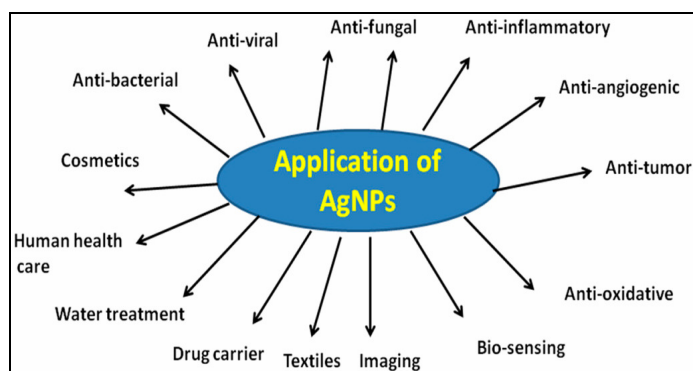


Fig. 2 : Various applications of AgNPs.

Antibacterial Activity of silver nanoparticles

Silver Nano particles show not only enhanced but also novel properties in the nanometer scale, nevertheless, the antimicrobial effects seem to be the most discussed aspect in the scientific literature, thereby, the enhanced antibacterial effects were shown against bacteria and fungi (Kittler *et al.*, 2010; Navarro *et al.*, 2008), also the antiviral effects (e.g., against HIV-1 virus) of AgNPs were reported (Elechiguerra *et al.*, 2005).

Their influence was recognized previously in ancient times, silver and its compounds have long been used for water purification and disinfection of medical devices, in medicine, silver compounds are generally used to treat wounds, burns and a variety of infectious diseases (Aditya *et al.*, 2013; Avalos *et al.*, 2016; Elliott, 2010).

In recent years, Silver Nano particles were considered, particularly attractive for the production of a new kinds of antimicrobials opening up a completely new way to resist a wide range of bacterial pathogens (Dos Santos *et al.*, 2014; Lara *et al.*, 2011).

It was thought that the bacteria are less prone to develop resistance against silver as they are doing against conventional and narrow-target antibiotics, because the metal attacks a broad range of targets in the organisms, which means that they would have to develop a host of mutations simultaneously to protect themselves (Gameel, 2014).

Sondi and Salopek-Sondi (2004) studied silver nanoparticles which synthesized through reduction of silver nitrate by ascorbic acid as antimicrobial agent with *E. coli* as a model for Gram-negative bacteria.

Morones *et al.* (2005) pointed out that the silver nanoparticles were found to be cytotoxic to *E. coli*, It was also shown that the antibacterial activity of silver

nanoparticles was size dependent, Silver nanoparticles mainly in the range of 1-10 nm attach to the surface of cell membrane and drastically disturb its proper function like respiration and permeability.

In 2006 Gogoi investigated the antibacterial effect of silver nanoparticles against *E. coli* expressing green fluorescent protein (GFP) bacteria. The green fluorescent proteins (GFPs) were adapted to these studies. The result showed that silver nanoparticles get attached to sulfur containing proteins of bacteria cell causing the death of the bacteria. The fluorescent measurements of the cell-free supernatant reflected the effect of silver on recombination of bacteria (Gogoi *et al.*, 2006).

Lok *et al.* (2006) elucidated that AgNPs exhibited destabilization of the outer membrane and rupture of the plasma membrane, thereby causing depletion of intracellular ATP

Also Shahverdi *et al.* (2007) studied the high synergistic activity of silver nanoparticles and antibiotics with erythromycin against *Staphylococcus aureus*.

After that, Kong and Jang (2008) were studied the antibacterial properties of the biosynthesized silver nanoparticles when incorporated on to textile fabric resulting in effective inhibition.

Birla *et al.* (2009) outlined that the silver nanoparticles have important applications in the field of biology such as antibacterial agents and DNA sequencing. Antibacterial property of silver nanoparticles against *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* has been investigated.

Lara *et al.* (2010) proposed another mechanism of bactericidal action of silver based on the inhibition of cell wall synthesis, protein synthesis mediated by the 30s ribosomal subunit and nucleic acid synthesis.

In 2012 Dipankar and Murugan studied the synthesis and characterization of silver nanoparticles using Iresine herbstii and evaluation of their antibacterial activities (Dipankar& Murugan, 2012).

Vijayakumar *et al.* (2013) reported silver nanoparticles synthesized Asteraceae have great susceptibility to different microbes.

Silver nanoparticles synthesized by Priyadarshini *et al.* (2013) using *Bacillus flexus* S-27 bacterial strain showed effective antibacterial property.

The local study by Fouda *et al.* (2013) investigated the antimicrobial activity of carboxymethyl chitosan/polyethylene oxide nanofibers embedded silver nanoparticles.

Also the silver nanoparticles were synthesized from Eucalyptus leaves extracts by (Sulaiman *et al.* (2013)) then antimicrobial effect was tested against different pathogenic bacteria, yeast, and its toxicity against human acute promyelocytic leukaemia (HL-60) cell lines.

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