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Biosynthetic Silver Nanoparticles- Current Trends and Future Scope: An Overview

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Abstract: *Nanoparticle (NPs) biosynthetic discipline is still under development and recognized to have a big impact on numerous manufactures for a long time. Now a days silver nanoparticles (AgNPs) is a thrust field for researchers in context to its antimicrobial property. There are three methods to synthesize AgNPs, which are charcaterized to be physically, chemically and biologically active. Physical and chemical techniques for the production of NPs are expensive, toxic, and non-ecofriendly. To overcome these problems, researchers have brought into practice the precise green routes. Now a days nanobiotechnological method is becoming popular because of its safe, non-toxic, cheap and ecofriendly nature using plants and microorganisms. Nanobiotechnology so far has been flourishing to produce AgNPs, which have rewarding applications in industry, health and medicinal sciences specifically due to their antimicrobial characteristics. This overview covers current trends of biosynthesis of AgNPs, and expression of their salient antimicrobial activity concomitant with their future biotechnological scope.*

Keywords: *Nanotechnology, Silver nanoparticles, Silver nitrate, Antimicrobial activity, Green synthesis.*

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I. Introduction

Nanotechnology research has recently been of extreme interest because of its perceived probability for various fields of science. Nanotechnology's tools have found application in different area, from biology to device physics (Kulkrarni, 2007). According to their shape, size and properties they can be arranged in to different classes (Ibrahim et al., 2017). Since last few years, metal NP less than 100 nm in diameter have made a considerable effect across different biomedical applications, such as diagnostic and medical devices, for personalized healthcare practice (Lee and Jun, 2019). Unusually, silver (Ag) NPs have received appreciable interest due to their distinct qualities, and proven applicability in different areas such as medicine, catalysis, textile engineering, biotechnology, nanobiotechnology, bio-engineering sciences, electronics, optics, and water treatment. These NPs have significant inhibitory effects against microbial pathogens, and are widely used as antimicrobial agents in a diverse range of products (Iravani et al., 2014). AgNPs became one of the most investigated and explored nanotechnology-derived nanostructures, given the fact that nanosilver-based materials proved to have engrossing, demanding, and encouraging feature acceptable for different biomedical applications (Burdusel et al., 2018).

AgNPs are also used in electronics, bio-sensing, clothing, food industry, paints, sunscreens, cosmetics and medical devices (Ahamed et al., 2010). During the last five years, many efforts were put into developing new greener and cheaper methods for the synthesis of nanoparticles (Rauwel et al., 2015).

NP can be synthesized by physical methods, chemical and biological methods. Biosynthesis of nanoparticles using biological agents have gained much attention in the area of nanotechnology in last few decades because of cost effective, nontoxic, and ecofriendly (Hassaan and Hosney, 2018).

Evaporation-condnsation and laser ablation are the most important physical method to synthesize nanoparticles. Pyatenko et al. (2004) successfully produced silver nanoparticles by irradiating an Ag target with a 532-nm laser beam in pure water. By working with high laser power and small spot sizes, they could synthesize very small spherical particles with a typical size of 2–5 nm. Sportelli et al. (2018) reported that Laser ablation synthesis is one of the best candidates, as compared to wet-chemical syntheses, for preparing Ag nano-antimicrobials. Awad et al. (2016) synthesized silver nanoparticles by wet chemical method, in which silver nitrate, trisodium citrate dehydrate (C6H5O7Na3.2H2O) and sodium borohydride (NaBH4) used as reducing agent.

Suriati et al. (2014) prepared silver nano particles by a simple chemical reduction method. The particles were synthesized via the reduction of AgNO3 by trisodium citrate and ascorbic acid as a surfactant. The resulting AgNPs were characterized by X-ray diffraction analysis, transmission electron microscopy, and scanning electron microscopy. It was found that the size of the AgNPs ranged from 35– 80 nm, with an average of 50 nm.

AgNPs play a great role in the study of biology and medicine due to their attractive physicochemical properties. Silver products have extended been familiar to have strong inhibitory and bactericidal effects, as considerably as a wide spectrum of antimicrobial activities, which has been practiced for centuries to prevent and care for various diseases, most notably infections (Nam et al., 2016). The recent strategy to improve the efficacy of drugs is to combine them with metal nanoparticles for the control of microbial infections (Kumar and Purnachandra, 2015).

A lot of literature has been reported till to date on biological synthesis of AgNPs using microorganisms including bacteria, fungi and plants; because of their antioxidant or reducing properties typically responsible for the reduction of metal compounds in their respective nanoparticles (Roy and Das, 2015).

Current Trend of Biosynthesis of Silver Nanoparticles

AgNPs were synthesized by using chemical method in the first 20 decades. But due to the involvement of toxic and unsafe chemicals that are liable for different biological risk and they are expensive too. This led to the need of environment friendly processes by green synthesis and other biological methods. Therefore, biological methods are preferred later because of safe and environment friendly. Current trend, the biological method for synthesizing AgNPs is being preferably considered. This method is a green technology aimed at minimizing the negative environmental impact. It had been known that the synthesis of AgNPs using the chemical approach requires three main ingredients: a silver salt, a reducing agent, and a stabilizer or capping agent. In the biological approach, the reducing agent and the stabilizer are replaced using molecules obtained from living organisms such as plants, bacteria, fungi, yeast, and algae; their details are discussed in the following sections.

By microorganism

Microorganisms such as bacteria and yeast are recently used for rapidly synthesize AgNPs. Das et al. (2014) reported that biological synthesis of AgNPs using microorganisms has received profound interest because of their potential to synthesize nanoparticles of various size, shape and morphology. According to Luo et al. (2018) the growth media of bacterial culture plays an important role in the synthesis of metallic nanoparticles with regard to their size and shape. Rashed et al. (2018) synthesized of AgNPs from Cyanobacteria. Ajah et al. (2018) reported that extracellular of AgNPs by *Haemophilus influenza* and their size ranged between 80.05 nm-101.15 nm. State and Partila (2018) concluded that the extracellular biosynthesis of AgNPs by four bacterial species, namely, *Ochrobactrum sp.* (MAM-C9), *Achromobacter xylosoxidans* (MAM-29), *Pseusomonas aeruginosa* (MAM-42) and *Bacillus cereus* (MAM-I.11) were confirmed. AgNPs have also been successfully made from *Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Acinetobacter spp.* (Peiris et al., 2017, 2018). Shah et al. (2015) reported in their study the current research worldwide on the use of microorganisms like bacteria, algae, yeast, actinomycetes and fungi in the biosynthesis of metal nanoparticles achieved a major role and great success. The schematic diagram for the green synthesis of Ag-NPs using microorganism is shown in **Figure 1.**

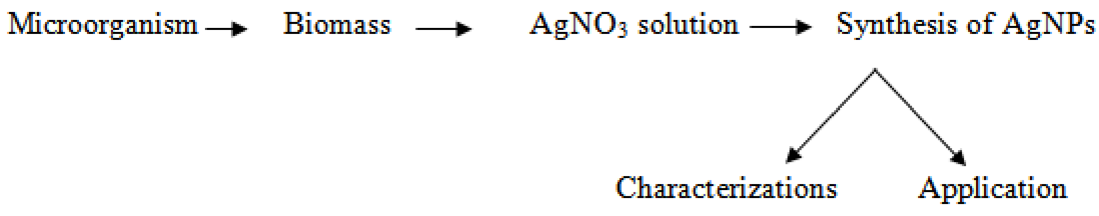


Figure 1: Schematic diagram for synthesis of AgNPs by using microorganism.

Krishna Gudikandula et al. (2017) could successfully synthesize AgNPs from two white rot fungal strains, and the characterization of the NPs was carried out employing UV–Vis spectroscopy, TEM and FT-IR. Abboud (2018) demonstrated that it is possible to perform the biogenic synthesis of silver AgNPs using *T. harzianum* as appropriate safe fungus. There are very few reports concerning with biosynthesis of AgNPs, having been reported using algae. Kathiraven et al. (2015) synthesized AgNPs and antibacterial activity of silver nanoparticles was assesses using *Caulerpa racemosa*, a marine algae. Salari *et al*. (2016) formulated AgNPs, which were synthesized through bio-reduction of silver ions using the *Spirogyra varians.*

Raouf et al. (2018) synthesized AgNPs by the reduction of aqueous solutions of silver nitrate ($AgNO_3$) with powder and solvent extracts of *Padina pavonia* (brown algae). They also reported that Marine macroalgae have various chemicals such as flavonoids, alkaloids, steroids, phenols, polysaccharides, saponins, hydroxyl, carboxyl and amino functional groups that can serve as effective metal-reducing and capping agents to provide a robust coating on the metal nanoparticles in a single step. Other micro-organisms which are used for synthesis, have been well documented by various individual researchers as well as research groups (Buszewski et al., 2018; Roy and Anantharaman, 2018; Kushwaha et al., 2015; Abdeen et al., 2014; Mohandass et al., 2013; Li et al., 2012; Raheman et al., 2011; Maheswari et al., 2012).

By plants

Plants or their extracts can be efficiently used in the synthesis of silver nanoparticles as a greener route. Control over the shape and size of nanoparticles seems to be very easy with the use of plants (Roy et al., 2017). They synthesized AgNPs using *Azadirachta indica* aqueous leaf extract, and the AgNPs showed antibacterial activities against both gram positive and gram negative bacteria. Logeswari et al. (2012) formulated silver nanoparticles from bio-reduction of silver nitrate solution using *Ocimum tenuiflorum*, *Solanum tricobatum*, *Syzygium cumini*, *Centella asiatica* and *Citrus sinensis* leaves and peel. Antimicrobial activity of the silver bio-nanoparticles was performed by well diffusion method against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Klebsiella pneumonia.* Ponarulselvam et al. (2012) concluded in their study that the leaves of *C. roseus* can be good source for synthesis of AgNPs, revealing antiplasmodial activity against *P. falciparum*. Singh et al. (2014) synthesized AgNPs from the stem of *Tinospora cordifolia*, and analysed their antibacterial activity against multidrug-resistant strains of *Pseudomonas aeruginosa*. The researchers concluded that even a small concentration of AgNPs prepared from *T. cordifolia* possess decent antibacterial activity. The AgNPs of stem of *Tinospora cordifolia* showed the zone of inhibition ranges from 10 ± 0.58 to 21 ± 0.25 mm. The MIC of AgNPs from stem extract was found to be 6.25 - 200 μg/ml against *Pseudomonas aeruginosa* strains. Bindhani and Panigrahi (2015) synthesized AgNPs in aqueous medium using leaf extracts of *Ocimum sanctumL*. The researchers concluded that the prepared silver nanoparticles showed significant antibacterial activity against *Enterobacter cloacae*, *Staphylococcus aureus*, *Streptococcus haemolytius*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Proteus mirabilis* whereas less activity against *Pseudomonas aeruginosa*.

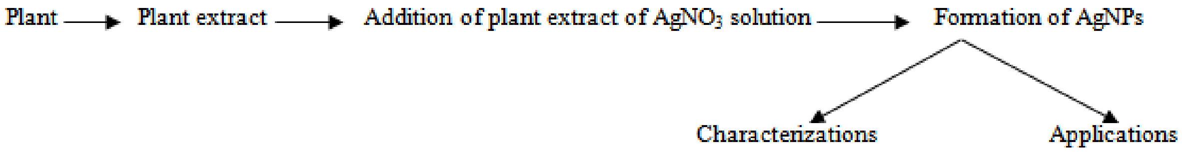
Khan et al. (2014) formulated AgNPs by using an aqueous solution of *Pulicaria glutinosa* plant extract as a bioreducing agent, which was used as capping and reducing agent and the activities were tested against various bacterial and fungal microorganisms including *Shigella sonnei*, *Micrococcus luteus*, *Escherichia coli*, *Aspergillus flavus*, *Alternaria alternate*, *Paecilomyces variotii*, *Phialophora alba*. According to Khan et al. (2014) AgNPs were prepared using an aqueous solution of *Pulicaria glutinosa* plant extract during this study, the antimicrobial activities of silver NPs, as well as the plant extract alone, were tested against *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Micrococcus luteus*.

Mohanta et al. (2017) biosynthesized AgNPs using the leaf extract of plant *Protium serratum*, and concluded that the prepared silver nanoparticles showed significant antibacterial activity against the food borne pathogens like *Pseudomonas aeruginosa*, *E. coli*, *Bacillus subtilis*. Kumar et al. (2017) biosynthesized AgNPs using *Prunus persica* plant leaf and biosynthesized AgNPs were found to have a higher inhibitory action against *E. coli*. Yadav et al. (2016) the comparative study of biosynthesized silver and iron nanoparticles, suggested that AgNPs of Aloe vera are more potent antibacterial than their iron counterpart. Sorbiun et al. (2018) reported in his study the green synthesis of AgNPs is much safer and environmentally friendly compared to chemical and physical synthesis. Biosynthesis of AgNPs using stem bark extract of *Diospyros montana* and their antioxidant and antibacterial activities reported by Patil et al. (2017). They also reported an efficient and rapid method for the green synthesis of colloidal AgNPs, established using medicinally important *T. bellirica* fruit aqueous extract. Skandalis et al .(2017) formulated two different concentrations of fresh leaf extract of the plant *Arbutus unedo* (LEA) as a reducing and stabilizing agent to produce two size variations of AgNPs. Kokila et al. (2017) reported an eco-friendly, biosynthesis of AgNPs using stem bark extract of *Diospyros montana*. Raja et al. (2017) synthesized AgNPs using *Calliandra haematocephala* leaf extract and successfully displayed antibacterial activity against *E. coli*. Kumar et al. (2017) formulated AgNPs using Andean blackberry and it could be a promising candidate for many biomedical applications. Soares et al. (2018) synthesized of AgNPs using a *Caesalpinia ferrea* seed extract as a reducing agent. Moodley et al. (2018) synthesized AgNPs from the leaf extracts of *Moringa oleifera* and revealed antimicrobial activity on both bacterial and fungal strains. Singh et al. (2018) used *Cannabis sativa* for synthesizing Ag-NPs are synthesized by utilizing *Argemone mexicana* leaf extract as capping as well as reducing agent by adding to the aqueous solution of $AgNO_3$. The properties of NPs are analyzed by using UV–Vis spectrometer, X-Ray diffractometer (XRD), Scanning Electron Microscopy (SEM), and Fourier Transmission Infrared (FTIR) Spectrophotometer.

Nevertheless, a number of research studies have been accomplished so far concerning with biosynthetic aspect of Ag-NPs using different plant extracts and their significant antimicrobial activities, principally referring to *E.coli* (Aziza and Jassimb, 2018; Mane Gavade et al., 2015; Awwad et al., 2012; Linga Rao and Savithramma, 2011; Ahmed et al., 2016), *S. aureus* (Aziza and Jassimb, 2018; Elumalai et al., 2010; Geethalakshmi and Sarada,2010; Park et al., 2014), *B. subtilis* (Khan et al., 2017) *Klebsiella pneumonia* (Khan et al., 2017; Surya et al., 2016; Awwad et al., 2012; Ibraheim et al., 2016), *Salmonella typhimurium* (Ali et al., 2016; Sreenivasulu et al., 2016), *Candida albicans* (Mane Gavade et al., 2015; Ibraheim et al., 2016).

In the current trend of the nanotechnology, plants are better synthesizers as compared to the other biological methods due to the abundance of the availability of the plant resources when compared to the other forms of bio- logical resources. Also, plants provide a better platform for NPs synthesis as they are nontoxic chemicals and provide natural capping agents. Additionally, use of plant extracts also reduces the cost of microorganism isolation and culture media enhancing the cost competitive feasibility over nanoparticles synthesis by microorganisms (Sumitha et al., 2019). The schematic diagram for the green synthesis of AgNPs using plant or plant extract is shown **in Figure 2.**

Figure 2. Schematic diagram for synthesis of AgNPs by using plant.



Future perspectives of silver nanoparticles

Everyone knows the importance of AgNPs in medicine. AgNPs are extensively used in many applications, mainly medical and biological applications. AgNPs have been broadly used as antibacterial coat in therapeutic applications, such as cardiovascular implants, wound dressings, catheters, orthopedic implants, dental composites, nano-biosensing, and agriculture engineering (Lin et al., 2011; Sumitha et al., 2019). Ag NPs have played pivotal role in inhibiting various infectious disease caused by microbes. The Indian Ayurvedic medicinal plant *F. indica* is being used in the treatment of cancer. Application of Ag NPs in medical can be divided into two types namely diagnostic and therapeutic applications. Surface Enhanced Raman Spectroscopy (SERS) based on Ag NPs can be used in cancer detection in non-invasive way. This process of cancer detection will be inevitable part of cancer detection in near future. For the biomedical application, AgNPs have been reported to have a good inhibitory effect against both Gram-positive and Gram-negative (Sumitha et al., 2011). Based upon the previous discussion it can be said that the synthesis of nanoparticles may serve as a future direction in biomedical nanotechnology in developing antimicrobial compounds.

II. Conclusion

The central of attention of this review is an, the green synthesis of AgNPs through plant and microbes. It’s concluded that green synthesis using plant and plant extracts looks to be rapid than other microorganisms, such as bacteria and fungi. The use of plant in biological synthesis has drawn attention because of its rapid growth, providing single step technique, economical protocol, non-pathogenic, and eco-friendly for Ag NPs synthesis. AgNPs are viewed as imperative expansion in the range of nano-materials due to the differing qualities it gives as far as application in different stroll of science. Based upon the previous discussion it can be said that the synthesis of NP may serve as a future direction in biomedical nanotechnology in developing antimicrobial compounds. The previously used metal antimicrobial may come with lots of possibilities with the advancement of green nanotechnology in combating multidrug resistance. The current trend of research is mainly carried out using the plant extracts as reducing and capping agents. From the previous discussion it can be concluded that this is the beginning of green NP synthesis. Never-the-less, taken together studies carried out on medicinal and aromatic plants (Mishra and Sangwan, 1996; Mishra et al., 1998; Sangwan et al., 1998; Mishra et al., 2006; Mishra and Sangwan, 2008) and studies referring to current trends on NP synthesis, green NP synthesis may serve many medicinal and cosmetic applications in near future.

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