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Preparation of Silver Nanoparticles (AgNPs) using Different Plants and Their Antibacterial and Antifungal Properties: A Review

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ABSTRACT

Since last decades, silver or its salt related materials applied as antimicrobial agents, water purification in clinics, in burn dressing. In addition, unique characters of AgNPs have leads to several study such as applications in engineering, nanomedicine, bio-based materials, clean energy, and food industry. Silver based compounds are more cost effective than other metal nanoparticles. Silver nanoparticles (AgNPs) has been documented as a widely used as antimicrobial agent for decades. AgNPs shown outstanding capacity in a various type of biological applications including antibacterial, antifungal, anti-parasites, anticancer etc. There are several methods for the synthesis of AgNPs such as physical, chemical and biological method. In physical and chemical methods production of unwanted hazardous by-product, use of high energy and problem in stability. Biological mode of synthesis is popular and advantageous over other methods. Therefore, there is urgent requirement for greener methods of preparation of AgNPs are gaining attention day by day. The main objective of greener synthesis of AgNPs is to decrease toxic by-products. In addition, these greener methods are cost-effective and in the abundance of reducing raw agents. In order to control the shape and size of AgNPs synthesis routes should be carried out in controlled ambient temperature and under near physiological pH. One of the major application of AgNPs is antimicrobial properties including antibacterial activity against multi-drug resistant bacteria and antifungal. This review dedicates a brief outline of the research on green synthesis of AgNPs and the impact of the protocols on their shape, size and morphology and its antimicrobial properties.

KEY WORDS: SILVER NANOPARTICLES, GREEN SYNTHESIS, ANTIBACTERIAL, ANTIFUNGAL PROPERTIES.

INTRODUCTION

In the scientific community, nanotechnology field shown very significant role in modern research area which are dealing with engineering and manipulation of structure of particles at nanoscale which size ranges from 1 to 100 nm (Sanchez et al., 2010). At nano scale the properties of nanostructures such as physiochemical and biological transformations in unique ways when compared with their corresponding bulk (Baer et al., 2010). Preparation of nanoparticles can be carried out by either physical, chemical or biological methods (Rycenga et al., 2011). But synthesis of nanoparticles using biological inspired methods are more easy and fruitful as compared to others (Raghunandan et al., 2010, Bahadur et al., 2011).

Applications of nanomaterial's are depending on various size, shape, uniformity, composition and topography (Chen et al., 2013). Using of nanoparticles in diverse areas including electronics (Rubilar et al., 2013), fashion

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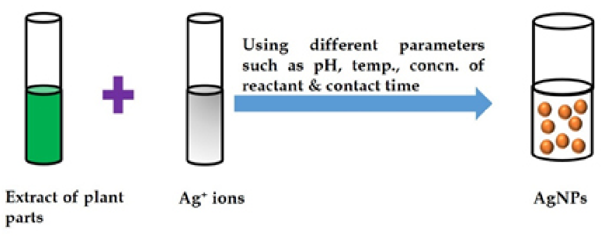
industry (Sonkaria et al., 2012), biomedical (Mishra et al., 2013, Ravindran et al., 2013), drug or gene delivery (Sripriya et al., 2013), sustainable environment (Hebbalalu et al., 2013), biomechanics (Subbiah et al., 2013), optics and lenses (Austin et al., 2014), biochemical and chemical manufacturing (Borase et al., 2014, Rajkumar et al., 2016), catalysis (Kästner et al., 2016), florescence (Anfossi et al., 2018), and photo-electrochemical (Guitoume et al., 2018, Sharma et al., 2019).

The nanoparticles can be applied in diverse areas for different purposes, but the AgNPs believed as the most encouraging nanostructures due to advent of significant antibacterial properties (Kotcherlakota et al., 2019, Ravi et al., 2019). AgNPs are more potentially antimicrobial because of their large surface area to volume ratio when compared to bulk silver metal (Fahimirad et al., 2019). AgNPs are also gain interest in scientific community due to the growing concern regarding increase in antibiotics resistance against several microbial strains (Menazea et al., 2020, Salleh et al., 2020). For nanomedicine applications such as in wound dressings, topical creams for burning case etc. AgNPs showed biocidal effect against several types of microorganisms (Garibo et al., 2020).

Biosynthesis of AgNPs: Biosynthesis of AgNPs using plants: For the first time AgNPs were synthesized using alfalfa sprouts i.e. using a living plant system (Marchiol et al., 2014). When biosynthesis of AgNPs using plant is compared to microorganisms including bacteria and fungi, plants looks better option. Plant/plant parts extracts are able to generate Ag NPs very rapidly (Chokriwal et al., 2015). By the virtue of simplicity, easy to handle and readily availability, biosynthesis of AgNPs was maximum achieved using plants (Khatami et al., 2016). Judicious selection of the plant extract, and the major exceptional affecting surrounding parameters are the concentration of the plant extract and metal salt, the temperature, the pH, and the incubation time (Anjum et al.,2016). By controlling the synthesis parameters, desired shape and size of AgNPs can be achieved. Plant parts such as fresh or dried leaves, roots, latex, gum, bark, stem, and seeds are being used for nanoparticle synthesis. Schematic representation of synthesis of AgNPs using plant extract is demonstrated by Figure 1.

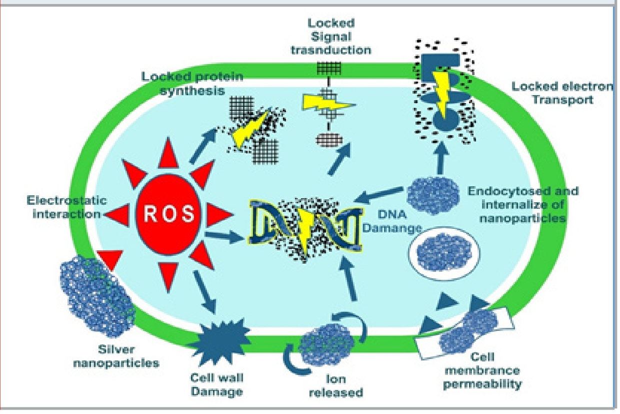
Figure 1: Illustration of biosynthesis of AgNPs using plant extract



Plant extract contains active biomolecules leads to reduction and stabilization process during synthesis process of AgNPs (Rajeshkumar et al., 2017). Active biomolecules including phenolics, polysaccharides, flavonoids, alkaloids, proteins, enzymes, and amino acids. The phytochemicals such as flavonoids and phenols have exceptional capability to reduce AgNPs, which inhibits agglomeration (Selvan et al., 2018). Mishra et al., (2013), shown biosynthesis of AgNPs using neem leaf extract and TEM observation showed size of nanoparticles ranges from 2-8 nm. Further, AgNPs was characterized by several standard techniques such as Surface Plasmon Resonance Spectra, Fourier Transform Infrared Spectroscopy (FTIR), Circular Dichroism (CD), Dynamic Light Spectroscopy (DLS), and Surface Tunneling Microscopy (STM). Ashoka leaf extract was also used for synthesis of AgNPs. This AgNPs was used as antiplasmodial agent (Mohammadi et al., 2019). Recently, enhanced antibacterial properties shown by ultrasonic-assisted green synthesis of AgNPs using *Mentha aquatica* leaf extract (Nouri et al., 2020). Another paper shown by Uddin et al., (2020) showed *Cocos nucifera* leaf extract mediated preparation of AgNPs (14.2 nm) for enhanced antibacterial activity. Table I. shows plant extract mediated synthesis of AgNPs.

Antimicrobial activity of plant mediated AgNPs: AgNPs has been extensively used across the scientific world for several applications. Ag+ is a famous antimicrobial agent which has been used against approx. 650 microorganisms including bacteria, fungi or viruses (Boateng et al., 2020). It was observed that AgNPs has the outstanding antibacterial activity and is minimum toxic to animal or human cells. Anticipated mechanism of AgNPs against bacteria is described in Figure 2.

Figure 2: Illustration of antibacterial activity of A¬¬gNPs (Vega-Jiménez et al., 2019)



Antibacterial activity of AgNPs: Few research papers describing the electrostatic attraction between +ve charged AgNPs and -ve charged bacterial cells. AgNPs may gathered inside the plasma membrane of bacterial cells leads to damage cell wall or membranes (Erol et al., 2020). It is speculated that Ag atoms may bind to thiol groups (-SH) of protein/enzymes and thus forming stable bonds. Binding of silver atoms with –SH group causes the deactivation of proteins/enzymes in the cytosol or biological.

Table 1. Use of Silver (Ag) NPs as an Antibacterial agent				
S.N.	Method of Synthesis	Size of Silver (Ag) Nanoparticle (nm)	Name of Bacteria	Ref.
1	*Gum kondagogu*	18.9-55.0	*Staphylococcus aureus*	Kora et al., 2010
			E. coli	
			Pseudomonas aeruginosa	
2	*Acalypha indica* Leaf	20-30	*E. coli*	Krishnaraj et al., 2010
			Vibrio cholerae	
3	*Carob Leaf* Extract	5-40	*E. coli*	Awwad et al., 2013
4	Mango Peel Extract	7-27	*E. coli*	Yang et al. 2013
			S. aureus	
			B. subtilis	
5	*Artocarpus heterophyllus* Lam.	10.7	*Bacillus cereus*	Jagtap et al.,2013
			Bacillus subtilis	
			Pseudomonas aeruginosa	
6	*Coffea arabica* seed extract	20-30	*E. coli*	Dhand et al., 2016
			S. aureus	
7	Medicinal plant leaf extract	10-18	*E. coli*	Jain et al., 2017
8	*Thymus kotschyanus* extract	50-60	*E. coli*	Hamelian et al., 2018
			P. aeruginosa	
			S. aureus	
			B. subtilis	
9	*Berberis vulgaris*	30-70	*E. coli*, *S. aureus*	Behravan et al., 2019
10	*Lysiloma acapulcensis*	5	*E. coli*	Garibo et al., 2020
			S. aureus	
			P. aeruginosa	

Table 2. Use of Silver (Ag) NPs as an Antifungal agent				
S.N.	Method of Synthesis	Size of Silver (Ag) Nanoparticle (nm)	Name of Fungi	Ref.
1	*Croton sparsiflorus* morong	22-52	*Mucor Sp*	Kathiravan et al., 2015
			Tricoderma sp	
			Aspergillus nigar	
2	*Mentha pulegium*	-	*Candida albicans*	Abd Kelkawi et al., 2016
3	*Pelargonium/Geranium leaf extract*	29	*Aspergillus flavus*	Mohammadlou et al., 2017
			Aspergillus terreus	
4	Grass waste	15	*F. solani*	Khatami et al., 2018
			R. solani	
5	Starch	-	ERG11	Prasher et al., 2018
6	*Rosa canina*	13-21	*Candida albicans*	Gulbagca et al., 2019
7	*Citrus limetta* peel extract	18	*Candida species*	Dutta et al., 2020
8	*Ferulago macrocarpa* flowers extract	14-25	*Candida albicans*	Azarbani et al., 2020
9	*Teucrium polium* L.	10 -100	*F. oxysporum.*	Ghojavand et al., 2020
10	*Phyllanthus urinaria*, *Pouzolzia zeylanica*, and *Scoparia dulcis* Leaf Extracts	26.7	*Aspergillus niger*	Nguyen et al., 2020
			Aspergillus flavus	
			Fusarium oxysporum	

Membrane which cause inhibition of physiological processes such as trans membrane ATP production and ion transport (Makvandi et al., 2020) Table I. shows different plant mediated synthesis of AgNPs and its antibacterial application in different strains of bacteria.

Antifungal activity of AgNPs: Due to the regular increase of drug resistance in clinical strains of fungi, the researchers' communities and pharmaceutical companies are exploring for novel antifungal agents such as AgNPs (Varier et al., 2019) Plant extract derived AgNPs showed higher antifungal activities clinical fungal pathogens when compared with the presently available antifungal drugs. Antifungal properties of AgNPs was tabulated in Table II.

CONCLUSION

Cleaner production of AgNPs using green chemistry route is demanding to improve and maintain sustainable environment. Advantages of fabrication of AgNPs including cost effective, easy to synthesis at large scale, taking lesser time as compared to other processes. Synthesis of AgNPs using plants could be beneficial over other biological based materials. As a matter of fact, identification and characterization of biomolecules from plant extract which are solely responsible for synthesis and stabilization of AgNPs will be the crucial to overcome the problems. Biosynthesized AgNPs shows excellent antibacterial and antifungal activity. The biocidal activity of AgNPs against pathogenic bacteria and fungi with minimum toxic effects on normal cells could open a new avenue of research in the nanomedicine area.

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