ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. IX, Issue 7/ October 2021

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

A mini review on synthesis of silver nanoparticles through green chemistry methods

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Abstract

Nanotechnology, a multidisciplinary field that deals with the particle structures with size ranges from 1-100 nm at least one dimension. Silver nanoparticles (AgNPs) have been the area of research interest because of their unique properties from last decade as they have wide applications cosmetics, foodstuff and feed, environmental health, mechanics, optics, biomedical sciences, chemical industries, electronics, space industries, drug-gene delivery, optoelectronics, single electron transistors, light emitters, nonlinear optical devices, and photo-electrochemical and many more. The important area of research in nano biotechnology is the synthesis of AgNPs with different methods include chemical, physical and biological methods. Among these synthetic procedure biological method is the use of biological organisms and their extracts for the formation AgNPs. The biological method of nanoparticle synthesis is a simpler, cheaper, and environmentally friendly method than the conventional chemical synthesis method and thus benefited. The aim of this mini review article describes the methods of green synthesis for Ag-NPs which provides an appropriate method for synthesis of silver nanoparticles.

Key words: Silver, nanoparticles, green method, plants, Bacteria

INTRODUCTION

Bio nanotechnology is an emerging new field from last few decades that has revolutionized many aspect of human life. (Muthukumaran, Govindarajan, and Rajeswary 2015) The term nanotechnology denotes fabrication, depiction, manipulation, and applying structures governing their shape and size at nanoscale. (Sarsar, Selwal, and Selwal 2013) The particles typically size up to 100 nm are termed as nanoparticles. (Simi and Abraham 2007) Structures and materials in the nano scale dimensions (1 - 100 nm) are due to difference in physiochemical properties and surface to volume ratio have notable difference in the properties compared to the same material in the bulk. These differences lie in the physical and structural properties of atoms, molecules and bulk materials of the element. From the few past decades, metal nanoparticles of gold, silver and zinc have attracted significant interest over a wide range of fields including electrochemical applications, chemical and biological sensing, catalysis, food applications and medical diagnosis. (Saha et al. 2012, Hajipour et al. 2012)

Due to distinctive characteristics of nanoparticles interest in nanotechnology research has been increased globally. (Zargar et al. 2011) Among nanomaterials noble metal nanoparticles have been researched widely due to their peculiar optical properties. The nanoparticles of Gold and silver show distinct absorption spectrum band in the visible region due to conduction band electrons. (KREIBIG 1995, Mulvaney 1996). The Peculiar optical properties of noble metal nanoparticles can be tuning by the geometric shape, size, and the surrounding medium of nanaoparticles. That's why, they have been used in wide applications eg. They are used as drug delivery vector, biosensors, imaging and tracking materials, medicines, cosmetics, opto-electronics and control of vectors. (Che and Bennett 1989, Elghanian et al. 1997, Haruta 1997, Fujimoto 2003) Among different elements silver is a multipurpose element that has wide applications in industries like textile industry, electrical devices, and medical field. Silver nanoparticles have antimicrobial properties for eukaryotes, bacteria and viruses. (Magana et al. 2008, Rai, Yadav, and Gade 2009) There are different methods present for synthesizing nanomaterial's that includes chemical, physical, and biological methods. Basically reduction of metal complexes in dilute solutions is the basic process for the making of nanoparticles. The chemical and physical way of forming nanoparticles has been documented earlier and still used by many researchers but trend is now on the making metal nanoparticles through green methods as this method have natural compounds, these bio compounds (including alkaloids, phenolic compounds, terpenoids, enzymes, co-enzymes, proteins, and sugars *etc).* Size and size distribution of metal nanoparticles depend on these natural compounds present in the extract which make reduction. The function of nanoparticles produced by biological reducing agent enhances biological. This enhanced biocidal activity of metal nanoparticles is due to attached biomolecules on the surface of nanoparticles. (Rai, Prabhune, and Perry 2010, Demurtas and Perry 2014, Roy et al. 2019) So, there is need of biological method through "green nanotechnology" for formation of nanoparticles that is safe, environmental friendly and enhanced properties. (Savithramma, Rao, and Suhrulatha 2011) This method uses the bacterial, fungal and plant extracts for the formation of nanoparticles. (Saxena, Tripathi, and Singh 2010).

Basically the nanoparticles of silver are synthesized practically from organisms of all kingdoms. In verity, molecules from different organisms may directly proceed in the formation of nanoparticles by act as stabilizing and reduction agent including microorganisms and plants. (Balasooriya et al. 2017)

In general, whichever method is followed, it is often concluded that chemical methods have some limitations in which they can be chemical contaminants during their manufacturing processes or in recent applications. However; one cannot deny their ever-increasing demands in everyday life. Conditions; "Noble Silver Nanoparticles" strives for excellence in all aspects of science and technology, including the medical field; therefore it cannot be ignored because of their generational source. Thanks to their therapeutic and antimicrobial properties, silver nanoparticles have been incorporated into more unlimited consumer products, including clothing, pharmaceuticals, and cosmetics. Their growing applications include chemists, physicist, material scientist, biologist and physician / pharmacist to continue their latest research. Therefore, it is the responsibility of all researchers to emphasize the alternative as a cost-effective alternative but to be equally friendly. Keeping a sense of beauty, the green combination offers itself as a key process and proves its power at the top.

In this current study we will report the various methods for the production of nanoparticles from natural sources. Therefore, it is included in this review synthesis of silver bio-nanoparticles that provide further development of friendly, cost-effective and efficient methods for a wide variety of species.

Highlighted biological methods for the synthesis of Silver nanoparticles

A vast number of biological organisms were used for the synthesis of silver nanoparticles these includes plant extracts, fungus and bacterias. It is reported the formation of well-dispersed silver nanoparticles in the range of 10–31 nm were synthesized when silver nitrate was added into 100 ml of *Serratia nematodiphila* culture supernatant. (Malarkodi et al. 2013) monodispersed spherical shaped, size ranges 2-11 silver nanoparticles synthesized by using *Shewanella oneidensis*, upon incubation with aqueous silver nitrate solution. (Suresh et al. 2010) It is also reported Ag-NPs were synthesized by using culture supernatants of *psychrophilic bacteria* and culture supernatants of *Staphylococcus aureus*. (Shivaji, Madhu, and Singh 2011) (Nanda and Saravanan 2009) In addition to the benefits, it is important to point out that bacteria continue to grow after the formation of Ag-NPs. Apart from this, the main disadvantage of using bacteria as nanofactories is the slow rate of synthesis and the limited amount of size and shape you receive compared to conventional methods. Therefore, plant-based compounds are investigated by Ag-NPs synthesis. (Kharissova et al. 2013) The rapid green synthesis of 50-100 nm round shaped silver nanoparticles was observed using Alternanthera aqueous extraction. The reduction of silver ions in the silver nanoparticles by this extraction was completed within 10 minutes. This synthesis of silver extracted by aqueous leaf extracts ensures a quick, easy, cost-effective process such as chemical and methods. (Kumar, Palanichamy, and Roopan 2014) Using the *Abutilon indicum* extracts spherical and stable silver nanoparticles were synthesized. These nanoparticles show extraordinary antimicrobial activities against *S. typhi, E. coli, S. aureus* and *B. substilus* microorganisms. (Kathiravan 2018) Krishnaraj et al. reported rapid synthesis of silver nanoparticles by using leaf extract of *Acalypha indica* an easy approach method. (Krishnaraj et al. 2010) Spherical mono dispersed and 20nm silver nanoparticles were produced by using extracts of *Mulberry* leaves and their efficacy revealed their effective antibacterial activity towards *Staphylococcus aureus* and *Shigella* sp. (Awwad and Salem 2012) Spherical shaped with diameter of 20–25 nm Agnps were synthesized by the reduction of $AgNO_3$ solution through *olive* leaf extract and persist antibacterial activities. (Khalil et al. 2014) In another method Ag-NPs were synthesized by using *Acacia leucophloea* extract in size range upto 38–72 nm. (Murugan et al. 2014) the synthesis of spherical-shaped AgNPs were illustrated by using *Ocimum sanctum* leaf extract as stabilizing agent and characteristics of particles were studied by using UV–Vis spectrometer, XRD, and SEM. (Rout et al. 2012) It is also reported that, Ag-NPs were successfully synthesized within the size range 17–29 nm using *Chrysanthemum indicum. L.* (Arokiyaraj et al. 2014) In a recent report, these nanoparticles have been synthesized Using *Carica papaya* Leaf Extract (AgNPs-PLE) Causes Cell Cycle Arrest and Apoptosis in Human Prostate (DU145) Cancer Cells. (Singh et al. 2021) It is being investigated that green combinations using plants extracts appear to be faster than other organisms, such as bacteria and fungi. The use of plant extracts in green synthesis is eye-catching due to its rapid growth, providing a one-step process, a non-pathogenic, and eco-friendly AgNPs synthesis process. Further AgNPs synthesized using different green sources bacteria, fungi and plant extracts have been shown in Table. 1

Table 1. Silver nanoparticles synthesized by green method using different reducing organisms

Green source	Species name	Nanoparticles size	References
Bacteria	*Pseudomonas deceptionensis*	10-30	(Jo et al. 2016)
Bacteria	*Weissella oryzae*	-	(Singh et al. 2016)
Bacteria	*Bacillus methylotrophicus*	10-30	(Wang et al. 2016)
Bacteria	*Bhargavaea indica*	111	(Singh et al. 2015)
Bacteria	*Bacillus amyloliquefaciens*	3-4	(Singh et al. 2011)
Bacteria	*Listeria monocytogenes*	----	(Soni and Prakash 2015)
Bacteria	*Elettaria cardamomom*		(GnanaJobitha, Annadurai, and Kannan 2012)
Fungus	*Neurospora crassa*	11	(Castro-Longoria, Vilchis-Nestor, and Avalos-Borja 2011)
Fungus	*Yarrowia lipolytica*	----	(Apte et al. 2013)
Fungus	*Pleurotus sajor*	30-100	(Nithya and Ragunathan 2009)
Fungus	*Extremophilic yeast*	30-70	(Mourato et al. 2011)
Fungus	*Candida utilis*	--------	Waghmare, Mulla, Marathe, & Sonawane, 2015)
Plant	*Avicennia marina*	20-80	(Balakrishnan, Srinivasan, and Mohanraj 2016)
Plant	*Aloe Vera*	80	(Dinesh et al. 2015)
Plant	*Phyllanthus niruri*	30-60	*(Suresh et al. 2015)*
Plant	*Moringa oleifera*	100	*(Sujitha et al. 2015)*
Plant	*Chomelia asiatica*	---------	*(Govindarajan, Rajeswary, Muthukumaran, et al. 2016)*
Plant	*Zornia diphylla*	-----------	(Govindarajan, Rajeswary, Muthukumaran, et al. 2016)
Plant	*Clerodendrum chinense*	35-65	(Govindarajan, Rajeswary, Hoti, et al. 2016)
Plant	*Psychotria nilgiriensis*	--------	(Kovendan et al. 2016)

Plant	*Manihote sculenta*	102-202	(Velayutham, Ramanibai, and Umadevi 2016)
Plant	*Bauhinia variegate*	44-60	*(Govindarajan, Rajeswary, Veerakumar, et al. 2016)*
Plant	*Barleria cristata*	40-78	*(Govindarajan and Benelli 2016)*
Plant	*Hybanthus enneaspermus*	45-67	*(Suman et al. 2016)*
Plant	*Lippia citriodora*	--------	*(Elemike et al. 2017)*
Plant	*Manilkara zapota*	66	(Shaniba et al. 2019)
Plant	*Syzygium aromaticum*	----------	(Singh et al. 2010)
Plant	*Alternanthera dentate*	50-100	(Nakkala et al. 2014)
Plant	*Acorus calamus*	32	(Kumar et al. 2014)
Plant	*Boerhaavia diffusa*	25	(Sun et al. 2014)
Plant	*Tea extract*	20-95	(Nabikhan et al. 2010)
Plant	*Tribulus terrestris*	17-30	(Mariselvam et al. 2014)
Plant	*Cocous nucifera*	22-25	(Mariselvam et al. 2014)
Plant	*Abutilon indicum*	8-20	(Sadeghi and Gholamhoseinpoor 2015)
Plant	*Pistacia atlantica*	10-50	(Sadeghi, Rostami, and Momeni 2015)
Plant	*Ziziphora tenuior*	10-40	(Ulug et al. 2015)
Plant	*Ficus carica*	15	(Geetha et al. 2014)
Plant	*Calotropis procera*	15-40	(Gondwal and Pant 2013)
Plant	*Brassica rapa*	17	(Narayanan and Park 2014)
Plant	*Coccinia indica*	10-20	(Kumar, Ravi, and Kathiravan 2013)
Plant	*Vitex negundo*	10-30	(Zargar et al. 2011)
Plant	*Melia dubia*	35	(Kathiravan, Ravi, and Ashokkumar 2014)
Plant	*Portulaca oleracea*	50	(Kathiravan, Ravi, and Ashokkumar 2014)
Plant	*Thevetia peruviana*	15-30	(Rupiasih et al. 2013)
Plant	*Pogostemon benghalensis*	70	(SJ 2013)
Plant	*Trachyspermum ammi*	90-100	(Vijayaraghavan et al. 2012)
Plant	*Swietenia mahogany*	45-50	(Mondal et al. 2011)
Plant	*Musa paradisiacal*	20	(Bankar et al. 2010)
Plant	*Moringa oleifera*	57	(Bankar et al. 2010)
Plant	*Garcinia mangostana*	35	(Veerasamy et al. 2011)
Plant	*Eclipta prostrate*	40	(Rajakumar and Rahuman 2011)
Plant	*Nelumbo nucifera*	25-80	(Santhoshkumar et al. 2011)
Plant	*Acalypha indica*	20-30	(Krishnaraj et al. 2010)

CONCLUSION

Over all it is concluded that importance and use of NPs has been increased from past few decades due to their peculiar properties. In the past decade among NPs silver nanoparticles that have unique properties are widely prepared and used for different purposes, these includes medicine, catalysis, textile engineering, biotechnology, nano-biotechnology, bio-engineering science, electronics, optics, and water treatment. AgNPs can be synthesized by chemical, physical and green synthesis, Biological method (green synthesis) is the use of organisms and their extracts rather than other conventional chemical methods. Synthesis of silver nanoparticle by green method can do it profitable in various ways such as products can be safe with competitive costs (savings), energy efficiency and waste will be minimal. According to literature, various types of silver nanoparticles have been synthesized through green routes by using bacteria fungi and plants and their extracts. The above reports clearly indicate that extensive studies have been conducted on biosynthesis of silver nanoparticles AgNPs and is still being explored.

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