



Synthesis of silver nanoparticles from medicinal plants and its biological application: A review

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Abstract

Nano-biotechnology holds a great potential in various fields of life sciences. Nanotechnology involves the use of materials with components that have dimensions less than 100 nm. The demand for green synthesis of nanoparticles increases day by day due to the drawbacks of chemical synthesis. Application of nano-sized materials is an emerging area of nanotechnology. Among various metal nanoparticles, silver nanoparticles gain special interest due to its remarkable properties. Silver nanoparticles are usually ranging from 1-100nm size. They have unique electrical, optical, and thermal properties and which can be incorporated into industrial application of electronics, catalysis, and photonics. Silver nanoparticles exhibit a broad spectrum of anti-bactericidal and anti-fungicidal activities making them extremely popular in a diverse range of consumer products, including plastics, soaps, pastes, food, and textiles, thus increasing their market value. The presence of soluble organics in the plant extracts was mainly responsible for the silver ions reduction to nano-sized silver particles. The present review provides information on silver nanoparticles synthesis from various medicinal plants, various methods of characterization and its biological applications.

Keywords: Nano-biotechnology; Spectrophotometer; Nanoparticles, Physico-chemical properties

Introduction

Nano-technology is a rapidly growing field in which research deals with the synthesis, design, and particle structures manipulation which are ranging from 1-100 nm. Nanoparticles show various applications such as environmental, food, health

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care, optics, healthcare, chemical industries, etc. Nanobiotechnology is a part of nanotechnology and multidisciplinary in nature which investigates the use of nanoparticles in the biological systems. Nanobiotechnology provides a crucial technique for the development of a clean, nontoxic, and environment-friendly process for metal nanoparticles synthesis which has the ability to reduce metals by specific metabolic pathways. Nanoparticles show specific characteristics as compared to large particles such as their morphology, size, and distribution. Chemical and physical methods for synthesis of nanoparticles are costly and releases toxic byproducts in nature. Due to these problems, there is a requirement of an alternative for synthesis of nanoparticles. It has also seen that silver nanoparticles synthesized from chemical methods show less antibacterial activity as compared to the nanoparticles synthesized from biological approach. This is may be due to the presence of protein coating of nanoparticles obtained from plant extract [1-5].

Various nanoparticles have been synthesized by using plant extracts which includes silver, gold, and copper oxide. Use of plant extracts for nanoparticles synthesis is favorable over the other biological material as it removes the long process of maintenance of cell culture. Among various metal nanoparticles, silver nanoparticles obtain more attention due to its good conductivity, stability and antimicrobial activity. The biological activity of silver nanoparticles depends on various factors such as size, shape, size, surface chemistry, distribution, particle composition, particle morphology, capping, agglomeration, etc. [3]. Nanoparticles physicochemical properties increase the bioavailability of therapeutic agents [6-26]. Therefore, development of silver nanoparticles with controlled structures that are uniform in morphology, size, and functionality is important for its various applications [27-40].

Syntheses of silver nanoparticles using different medicinal plant extracts

Utilization of various plants extracts for silver nanoparticles synthesis has to gain importance due to its various advantages such as eco-friendly, rapid, non-pathogenic and economical. Reduction and stabilization of silver ions are due to the combination of biomolecules such as amino acids, proteins, enzymes, alkaloids, saponins, terpenoids, phenolics, tannin and vitamins present in plant extracts. Plant extracts reduce the AgNO_3 which forms Ag^{3+} ions to AgO ions; this can be monitored by using a UV-Visible spectrophotometer. Large numbers of plants are reported to have the potential of synthesizing the silver nanoparticles are mentioned in FIG. 1 and TABLE 1.

Characterization of silver nanoparticles

Physico-chemical properties are significant for behavior, safety, bio-distribution, and efficacy of nanoparticles. Therefore silver nanoparticles characterization is necessary to evaluate the functional aspects of synthesized silver nanoparticles. Characterization of synthesized silver nanoparticles can be done by using various methods (FIG. 2) [41-60].

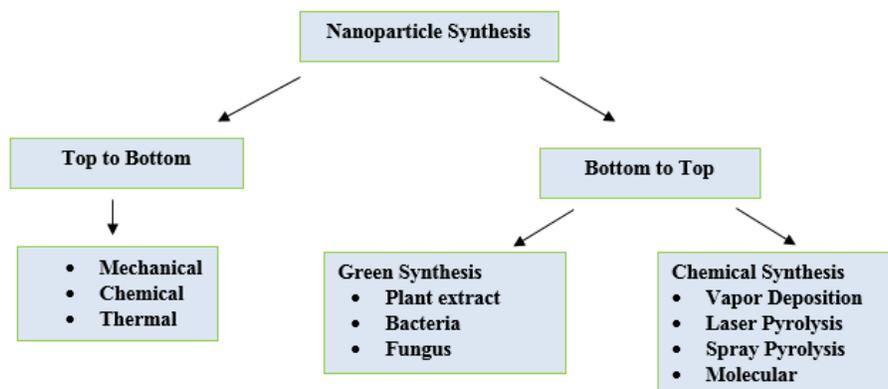


FIG. 1. Nanoparticle synthesis using different screening methods.

UV-VIS Spectroscopy

UV-VIS spectroscopy is an exceptionally valuable and essential for characterization of nanoparticles. AgNPs have unique optical properties which make them firmly cooperate with particular wavelengths of light (UV/VIS/IR Spectroscopy Analysis of Nanoparticles in 2012) [50-61]. UV-VIS spectroscopy is quick, simple, basic, and specific for various sorts of NPs, needs just a brief period of time for estimation [62-64]. In AgNPs, the conduction band and valence band lie near each other in which electrons move openly. These free electrons offer ascent to a surface plasmon reverberation (SPR) assimilation band, this is occurring because of the aggregate swaying of electrons of silver nanoparticles in reverberation with the light wave [53]. The assimilation of AgNPs relies upon the molecule estimate, dielectric medium, and synthetic surroundings [53]. Observation of this peak assigned to a surface plasmon is very much recorded for different metal nanoparticles with sizes running from 2 nm to 100 nm [51].

Fourier Transform Infrared (FTIR) Spectroscopy

FTIR can give exactness, reproducibility, and furthermore an ideal signal to noise ratio. By utilizing FTIR spectroscopy, it become possible to identify little absorbance changes on the order of 10^{-3} , which performs distinction spectroscopy, where one could recognize the little assimilation groups of practically dynamic deposits from the extensive foundation ingestion of the whole protein [20].

FTIR spectroscopy is often used to see if biomolecules are associated with amalgamation of nanoparticles, which is more articulated in scholarly and modern research [29]. Besides, FTIR has additionally been stretched out to the investigation of nano-scaled materials, for example, affirmation of useful atoms covalently united onto silver, carbon nanotubes, graphene and gold nanoparticles, or co-operations happening amongst catalyst and substrate amid the reactant procedure [8]. FTIR is an appropriate, important, non-invasive, cost effective, and basic strategy to recognize the role of biological molecules in the reduction of silver nitrate.

X-Ray Diffraction (XRD)

X-ray diffraction (XRD) is a popular analytical technique which has been utilized for the examination of both atomic and crystal structures, qualitative identification of various compounds, measuring the degree of crystallinity, quantitative resolution of chemical species, particle sizes, isomorphous substitutions, etc. [51]. At the point when X-ray light reflects on any crystal, it prompts the development of numerous diffraction designs, and a pattern reflects physico-chemical attributes of crystal structures. In a powder sample, diffracted patterns commonly originate from the specimen and reflect its structural physico-compound features. In this way, XRD can examine the basic features of an extensive variety of materials, for example, inorganic impetuses, superconductors, biomolecules, glasses, polymers, etc. [43-45].

TABLE 1. Synthesis of silver nanoparticles from different medicinal plants.

Plants	Size in nm	Plant part	References
<i>Alternanthera dentate</i>	50–100	Leaves	Nakkala et al. [33]
<i>Abutilon indicum</i>	7–17	Leaves	Sadeghi and Gholamhoseinpoor [48]
<i>Acorus calamus</i>	31.83	Rhizome	Nakkala et al. [34]
<i>Argyrea nervosa</i>	20–50	Seeds	Thombre et al. [55]
<i>Acalypha indica</i>	20–30	Leaves	Krishnaraj et al. [21]
<i>Brassica rapa</i>	16.4	Leaves	Narayanan et al. [35]
<i>Carica papaya</i>	25–50	Leaves	Jain et al. [15]
<i>Cymbopogon citratus</i>	32	Leaves	Masurkar et al. [30]
<i>Centella asiatica</i>	30–50	Leaves	Rout et al. [38], Roy and Bharadvaja [40]
<i>Coccinia indica</i>	10–20	Leaves	Kumar et al. [23]
<i>Citrus sinensis</i>	10–35	Peel	Kaviya et al. [25]
<i>Calotropis procera</i>	19–45	Plant	Gondwal et al. [12]
<i>Datura metel</i>	16–40	Leaves	Kesharwani et al. [26]
<i>Eucalyptus hybrid</i>	50–150	Peel	Dubey et al. [4]
<i>Eclipta prostrate</i>	35–60	Leaves	Rajakumar and Abdul Rahuman [45]
<i>Ficus carica</i>	13	Leaves	Ulug et al. [57]
<i>Musa paradisiacal</i>	20	Peel	Bankar et al. [2]
<i>Moringa oleifera</i>	57	Leaves	Prasad and Elumalai [37]
<i>Melia dubia</i>	35	Leaves	Kathiravan et al. [16]
<i>Memecylon edule</i>	20–50	Leaves	Elavazhagan and Arunachalam [6]
<i>Nelumbo nucifera</i>	25–80	Leaves	Santhoshkumar et al. [45]
<i>Plumbago zeylanica</i>	60	Leaves	Salunke et al. [46], Roy and Bharadvaja [39]

<i>Premna herbacea</i>	10–30	Leaves	Kumar et al. [24]
<i>Psoralea corylifolia</i>	100–110	Seeds	Sunita et al. [49]
<i>Thevetia peruviana</i>	10–30	Latex	Rupiasih et al. [44]
<i>Vitex negundo</i>	5 and 10–30	Leaves	Zargar et al. [64]
<i>Vitis vinifera</i>	30–40	Fruit	Gnanajobitha et al. [11]
<i>Ziziphora tenuior</i>	8–40	Leaves	Sadeghi and Gholamhoseinpoor [51]

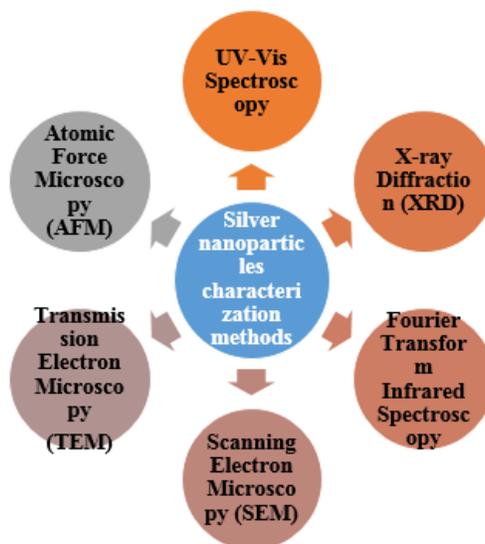


FIG 2. Various methods for silver nanoparticles characterization.

Scanning Electron Microscopy (SEM)

Field of nanotechnology has given a main thrust in the improvement of different high-determination microscopy procedures with a specific end goal to take in more about nanomaterials utilizing a light emission vigorous electrons to probe object on a fine scale [60]. Among different electron microscopy, SEM is a surface imaging technique, completely equipped for resolving various molecule sizes, size distributions, nanomaterials shapes, and the surface morphology of the particles at the small scale and nanoscales [29]. Utilizing SEM, we can test the morphology of particles and get a histogram from the image by either by measuring and checking the particles physically, or by utilizing particular programming [61].

Transmission Electron Microscopy (TEM)

TEM is a significant, frequently utilized, and critical system for the characterization of nanomaterials. It is used to get quantitative measures of molecule and additionally grain size, size distribution, and morphology [29]. Magnification of TEM is mainly controlled by the ratio of distance between the objective lens and the sample and the distance between objective lens and its image plane [59].

Atomic Force Microscopy (AFM)

AFM is used to investigate the aggregation and dispersion of nanomaterials, in addition to their size, shape, sorption, and structure; three different scanning modes are available, including contact mode, non-contact mode, and intermittent sample contact mode [60]. It can also be utilized to characterize the nanomaterials interaction with supported lipid bilayers in real time, which is not achievable with current electron microscopy techniques [53]. AFM does not require oxide-free, electrically conductive surfaces for measurement, does not because appreciable damage too many types of native surfaces and it can measure up to the sub-nanometer scales in aqueous fluids [61-64].

Biological activities of silver nanoparticles

Silver nanoparticles have been extensively used in health care, food, environment and biomedical sectors. Application of silver nanoparticles includes anti-bacterial, anti-viral, anti-fungal and anti-cancer activities.

Antibacterial activity

Silver nanoparticles are the alternative anti-bacterial agents which show the ability to overcome the resistance of bacteria against the antibiotics. A study reported the anti-microbial activity of silver nanoparticles against the *E.coli*, in which *E.coli* cells were treated with silver nanoparticles and these nanoparticles gets accumulated in cell wall and forms the pits in the cell walls which lead to the death of the cells [50]. Another study reported the role of silver nanoparticles against *E.coli*, yeast and *Staphylococcus aureus*. In this study, it was suggested that at a lower silver nanoparticles concentration inhibits the complete growth of *E.coli* and yeast whereas mild effect was observed in *S. aureus* [17]. Silver nanoparticles synthesized from biological method shows significant role against methicillin-resistant *Staphylococcus aureus*, methicillin-resistant *Staphylococcus epidermidis* and *Streptococcus pyogenes*, whereas in case of *Salmonella typhi* and *Klebsiella pneumoniae* it shows moderate [32]. Khurana et al. [18] investigated the physical and surface properties of silver nanoparticles against *S. aureus*, *B. megaterium*, *P. vulgaris* and *S. sonnei*.

Antifungal activity

Fungal infections are more common in patients who are immune-suppressed and overcoming this problem is not an easy process due to the less number of anti-fungal drugs [19]. Therefore there is a requirement to develop antifungal agents which is non-toxic, biocompatible and eco-friendly in nature. Silver nanoparticles play an important role in various fungi. Silver nanoparticles showed potential against clinical isolates and ATCC strains of *Candida* species and *Trichophyton*

mentagrophytes. Silver nanoparticles synthesized from biological method showed increased antifungal activity with fluconazole against *Phoma herbarum*, *Phoma glomerata*, *Fusarium semitectum*, *Candida albicans* and *Trichoderma* sp. [7]. Another study also reported the role of silver nanoparticles against several phyto-pathogenic fungi which include *Alternaria alternata*, *Macrophomina phaseolina*, *Sclerotinia sclerotiorum*, *Botrytis cinerea*, *Rhizoctonia solani*, and *Curvularia lunata* [22,31] Silver nanoparticles not only inhibits human and plant pathogenic fungi, but also able to inhibit other fungal species such as *Aspergillus fumigates*, *Penicillium brevicompactum*, *Chaetomium globosum*, *Cladosporium cladosporoides*, *Stachybotrys chartarum*, and *Mortierella alpine* [36].

Antiviral activity

Viral diseases are frequent and becoming more prominent all over the world, therefore, there is a requirement of developing new antiviral agents. Silver nanoparticles show unique interactions with bacteria and viruses due to its certain size and shapes. [5,28]. Anti-viral activity of silver nanoparticles incorporated into the polysulfone ultrafiltration membranes was evaluated against the MS2 bacteriophage and it showed the significant antiviral activity [63]. Lara et al. [27] demonstrated the anti-HIV activity at an early stage of viral replication. Polyvinyl pyrrolidone coated silver nanoparticles blocks the transmission of cell-associated HIV-1 and cell-free HIV-1 isolates [27]. Another study also reported the role of silver nanoparticles against HIV and hepatitis B virus [60].

Anticancer activity

Cancer is one of the prominent diseases which infect both developing as well as the developed country. Therefore, there is a requirement to develop new techniques which are able to reduce the systemic side effects. Gopinath et al. [10] investigated the molecular mechanism of silver nanoparticles and found that programmed cell death was concentration-dependent. Further, the synergistic effect on apoptosis using uracil phosphoribosyltransferase expressing cells and non- uracil phosphoribosyltransferase expressing cells in the presence of fluorouracil was observed. In these conditions, it was observed that silver nanoparticles not only induce apoptosis but also sensitize cancer cells. Jun et al. [14] also reported that silver-embedded magnetic nanoparticles showed significant activity against breast-cancer cells and floating leukemia cells. Plant extract synthesized silver nanoparticles showed a toxic effect on the human lung carcinoma cells (A549) which indicates that silver nanoparticles could target cell-specific toxicity [9].

Conclusion

An increasing attention towards green chemistry and utilization of plant extracts for metal nanoparticles synthesis lead to the development of environment-friendly techniques. A benefit of silver nanoparticles synthesis by using plant extracts is that it's economical, energy efficient and cost-effective, provides healthier workplaces, and protects human health and environment. Green synthesized silver nanoparticles play a significant role in the area of nanotechnology. Synthesis of nanoparticles using plants has several advantages over other biological organisms which overcome the time-consuming process of growing microbial cultures and maintenance. Therefore utilization of plant extract for the synthesis of silver nanoparticles has potential impact in coming decades. This review discusses the various approaches to nanoparticles synthesis, a protocol for

silver nanoparticles synthesis, various medicinal plant extracts utilized for the silver nanoparticles synthesis, characterization methods and its biological applications.

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