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Review Article

A REVIEW ON USE OF PLANT EXTRACTS FOR GOLD AND SILVER NANOPARTICLE SYNTHESIS AND THEIR POTENTIAL ACTIVITIES AGAINST FOOD PATHOGENS

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ABSTRACT

Metal nanoparticle synthesis using plant-mediated method is a highly explored field of nanotechnology. It has many advantages such as less time consumption and non-effective to human beings. Gold and silver nanoparticles (AuNPs and AgNPs) have been chosen for this study because of its wide range of applications and importance in different fields. This review explains different plant sources for the synthesis of AuNPs and AgNPs, and their antimicrobial activity against food pathogens which will provide information to future studies.

Keywords: Green synthesis, Gold nanoparticle, Silver nanoparticle, Antioxidant activity, Antimicrobial activity, Food pathogens.

INTRODUCTION

Owing to the smaller particle size, various shapes, and increased surface area, nanoparticles exhibit different properties than their parent materials and are found to have many interesting applications particularly in biomedical science [1]. Due to their unique properties, it is applicable in medical, electronic, material sciences, pharmaceuticals, agriculture, catalyst, drug delivery, etc. Among all noble metal nanoparticles, silver and gold nanoparticles (AgNPs and AuNPs) are of great importance in the field of nanotechnology [2]. Nanoparticles are synthesized by physical, chemical, and biological or green methods. Various chemical and physical methods are proved to be quite expensive and potentially hazardous to the environments which involve the use of toxic and perilous chemicals that are responsible for various biological risks. This may be the reason for choosing biosynthesis of nanoparticles via green route that does not employ toxic chemicals and proved to be eco-friendly [3]. AgNPs are the most prototypical target of green methods [4-7] since it has many applications. AuNPs are also of considerable interest, although to a much lesser degree than AgNPs. Both the AgNPs and AuNPs have effect against animal pathogens [8]. AgNPs are used as antimicrobial agents in commercial medical and consumer products [9]. Gold, in both nanoparticle and ionic forms, has been studied for antibiotic activities. Food pathogens are highly disastrous to the food industry as they cause foodborne diseases and death. So, this review summarizes various plant extracts used for the green synthesis of AuNPs and AgNPs, their potential activity against food pathogens and other pharmacological activities.

GREEN SYNTHESIS OF AuNPs AND AgNPs AND THEIR ANTIMICROBIAL ACTIVITY

Nanoparticles can be synthesized using plant extracts. Various plant parts such as root, stem, bark, leaf, and flowers can be used for the same. Some of the plant extracts used for the synthesis of nanoparticles and their activity against food pathogens were discussed and are as follows.

AgNP synthesis using cauliflower extract

AgNPs using cauliflower extract was done by Sridhara *et al.* which showed the formation of AgNPs of average width 42-83 nm. The antibacterial effect of AgNPs was studied against two food pathogens: *Escherichia coli* and *Staphylococcus aureus* [10].

AgNP synthesis using papaya fruit extract

AgNP synthesis using leaf extract of papaya fruit extract was reported by Jain *et al.*, where the antimicrobial activity of the extract was checked. The characterization analysis, such as X-ray diffraction (XRD) and scanning electron microscope (SEM) analysis, showed the formation of AgNPs of size 15 nm. The resultant AgNPs showed potent activity against the common food borne pathogen *E. coli* [11].

AgNP synthesis using *Trianthema decandra* root extract

AgNP synthesis using *T. decandra* root extract was performed, and its antibacterial activity was studied. The resultant AgNPs were found to be of average size of 10 nm by XRD and SEM analysis. The AgNP exhibited high activity against the food pathogen *E. coli* [12].

AgNP using *Moringa oleifera* leaf extract

Green biosynthesis of AgNP using *M. oleifera* leaf extract was carried out by Das *et al*. The antimicrobial potential of AgNPs was systematically evaluated against two food pathogens: *E. coli* (ATCC 25922) and *S. aureus* (ATCC 25923). The higher activity was showed against *E. coli* than *S. aureus* [13].

AgNP synthesis using *Garcinia mangostana* fruit extract

A recent study on the biosynthesis of AgNPs using *G. mangostana* fruit extract was reported by Rajakannu *et al*. The transmission electron microscope (TEM) analysis showed the formation of AgNPs of size 1-100 nm. The antibacterial, antioxidant activity of AgNP were evaluated. AgNPs were tested for antibacterial activity against two food pathogens such as *E. coli* and *S. aureus*. The biosynthesized AgNPs showed significantly higher antioxidant activity compared to *G. mangostana* fruit extract [14].

AgNP synthesis using *Withania somnifera* leaf extract

The bioreduction of AgNP using *W. somnifera* reported by Raut *et al.* revealed the importance of blue light in the reduction of silver ions. TEM analysis showed the formation of nanoparticles of size ranging from 5 to 30 nm. The synthesized nanoparticle showed antimicrobial activity against food pathogens such as *S. aureus*, *E. coli*, *Candida albicans*, *Aspergillus niger*, and *Aspergillus flavus*. The potent activity was found to be against *S. aureus* and *A. niger* [15].

AgNP synthesis using *Alternanthera dentae* aqueous extract

The green rapid syntheses of spherical shaped AgNPs were observed using *A. dentata* aqueous extract by Kumar *et al*. These AgNPs exhibit antibacterial activity against *Pseudomonas aeruginosa*, *E. coli*, *Klebsiella pneumonia,* and *Enterococcus faecal* [16].

AgNP synthesis using *Acorus calamus* extract

A. calamus was also used for the synthesis of AgNPs to evaluate its antioxidant, antibacterial as well as anticancer effects was reported by Nakkala *et al*. The formation of AgNPs was confirmed by ultraviolet (UV)-visible spectroscopy and their average size was found to be 31.83 nm. The synthesized nanoparticles were found to have remarkable antibacterial activity against three different food borne pathogens such as *Bacillus subtilis*, *Bacillus cereus,* and *S. aureus* [17].

AgNP synthesis using *Ocimum tenuiflorum* leaf extract

Bio inspired synthesis of AgNP using *O. tenuiflorum* leaf extract was carried out by Patil *et al*. TEM and power spectral density analysis showed that the size of AgNPs ranges from 25 to 40 nm. The antibacterial activities of formed AgNPs were checked against some of the food pathogens such as *E. coli* and *B. subtilis*. The maximum activity was found against *B. subtilis* [18].

AgNP synthesis using tea leaf extract

The tea leaf mediated bio-synthesis of AgNP was reported by Sun *et al.* showed the formation of nanoparticles size ranges from 20 to 90 nm. The antibacterial activity of formed AgNPs was found to be active against *E. coli* [19].

AgNP synthesis using *Sensitivum portulacastrum* callus extract

The ability of callus extract of *S. portulacastrum* Linn. to produce AgNPs was reported by Nabikhan *et al.* The resulted AgNPs showed size ranges from 5 to 20 nm. The fourier transform infrared spectroscopy (FTIR) analysis indicated the presence of the protein. The AgNPs were observed to have effective activity against clinical strains of bacterial and fungal food pathogens such as *S. aureus*, *Listeria monocytogenes,* and *Penicillium italicum* [20].

AgNP synthesis using *Tribulus terrestris* fruit extract

The dried fruit body extract of the plant *T. terrestris* Linn. was reported to be used as a capping agent in AgNP synthesis by Gopinath *et al*. AgNPs ranged in size from 16 to 28 nm. The extracts possess antibacterial property against multi-drug resistant food pathogens such as *B. subtilis*, *E. coli,* and *S. aureus. E. coli* showed a maximum zone of inhibition [21].

AgNP synthesis using *Cocos nucifera* inflorescence extract

AgNP was synthesized using inflorescence extracts of the tree *C. nucifera* was reported by Mariselvam *et al*. TEM anaslysis showed the formation of AgNP with the size of 22 nm. It showed significant antimicrobial activity against food pathogens such as *Salmonella paratyphi and B. subtilis.* The maximum activity was found against *S. paratyphi* [22].

AgNP synthesis using *Abutilon indicum* extract

Ashokkumar *et al.* reported the formation of AgNP ranges from 7 to 17 nm in size using the extract of *A. indicum*. The AgNPs thus obtained showed highly potent antibacterial activity against some of the most dangerous food pathogens such as *S. aureus*, *B. subtilis*, *Salmonella typhi*, and *E. coli*. The maximum activity was showed against *B. subtilis* and *E. coli* [23].

AgNP synthesis using *Allium cepa* extract

Biosynthesis of AgNPs using *A. cepa* was carried out by Saxena *et al.,* and it was found to have the particle size of 33.6 nm. The synthesized nanoparticle showed excellent antimicrobial activity against *E. coli* and *Salmonella typhimurium* [24].

AgNP synthesis using *Lantana camara* fruit extract

AgNP synthesis using *L. camara* fruit extract was done by Sivakumar *et al*. The spherical shaped AgNPs having size between 12.55 and 12.99 nm was confirmed by TEM analysis. The resulted AgNPs showed excellent antibacterial activity against some of the common food pathogens such as *B. subtilis* MTCC 1133, *S. aureus* MTCC 96, and *S. typhi* MTCC 733. The maximum activity was found to be 26 mm zone of inhibition for *B. subtilis* MTCC 1133 [25].

AgNP synthesis using *Cymbopogon citratus* leaf extract

C. citratus, (commonly known as lemon grass) a native aromatic herb of India, was used by Geetha *et al.* for the synthesis of AgNPs of size 32 nm. The formed AgNPs showed a strong antibacterial effect against food pathogens such as *E. coli, Shigella flexneri,* and *S. Sonnei* [26].

AgNP synthesis using *Acalypha indica* leaf extract

AgNPs synthesize from the leaf extract of *A. indica* was performed by Krishnaraj *et al*. The TEM analysis confirmed the formation of AgNPs ranging in size from 20 to 30 nm. The antibacterial activity of synthesized AgNPs showed effective inhibitory activity against food pathogens *E. coli* and *Vibrio cholera* [27].

AgNP synthesis using *Boerhaavia diffusa* plant extract

B. diffusa plant extract was used as a reducing agent by Nakkala *et al.* for the green synthesis of AgNPs. The characterization analysis XRD and TEM revealed an average particle size of 25 nm. These nanoparticles were tested for antibacterial activity against three fish pathogens such as *Pseudomonas fluorescens*, *Aeromonas hydrophila,* and *Flavobacterium branchiophilum* and showed the highest activity against *Flavobacterium* [28].

AgNP synthesis using *Euphorbia hirta* leaf extract

AgNP synthesis using leaf extract of *E. hirta* was performed by Elumalai *et al*. The size of the synthesized AgNPs ranges from 40 to 50 nm, and it shows antimicrobial activity against the potent food pathogen *B. cereus* [29].

AgNP synthesis using *Morinda citrifolia* extract

Phytosynthesis of AgNP using *M. citrifolia* Linn. was reported by Sathishkumar *et al*. SEM analysis confirmed the synthesis of nanoparticles of size 10-60 nm in diameter with an average size of 27 nm. The resulted AgNPs showed potent activity against food pathogens such as *B. cereus* and *E. coli*. *E. coli* showed maximum sensitivity against the formed nanoparticles [30].

AgNP synthesis using banana peel extract

The recent study reports by Ibrahim on the synthesis of AgNPs using banana peel extract as a reducing and capping agent. Typical nanoparticle characterization techniques showed the formation of the nanoparticle of size 23.7 nm. AgNPs showed effective antibacterial activity against representative food pathogens such as *B. subtilis*, *E. coli,* and *S. aureus*. Out of these organisms, *E. coli* showed maximum inhibitory zone [31].

AgNP synthesis using *Cassia roxburghii* plant extract

Biosynthesis characterization of AgNPs using *C. roxburghii* was carried out by Balashanmugam and Kalaichelvan, which synthesized nanoparticles of size 10-30 nm. The aqueous extract was recorded to have potent antibacterial activity. AgNPs were evaluated for their antibacterial activity against four different pathogenic food borne bacteria *B. subtilis*, *S. aureus*, *E. coli*, and *Enterobacter aerogenes*. *B. subtilis* showed high sensitivity toward AgNPs [32].

AgNP synthesis using peroxidase from *Euphorbia extract*

Green synthesis of AgNPs using peroxidase from *Euphorbia* was done by Cicek *et al.* to analyze its antibacterial activity. The synthesized AgNPs were characterized using SEM, XRD, which yield particles size ranges from 7 to 20 nm. Its antibacterial activity was checked against some food pathogens, viz., *Serratia marcescens*, *Yersinia pseudotuberculosis*, *S. aureus*, *S. typhimurium*, *L. monocytogenes,* and *E. coli*. *Y. pseudotuberculosis* and *S. typhimurium* showed high activity [33].

AuNP synthesis using *A. calamus* rhizome extract

AuNPs were synthesized using herbal *A. calamus* rhizome extract was reported by Ganesan and Gurumallesh Prabu, and it was coating on cotton fabric for checking its antibacterial activity against *S. aureus* and *E. coli*. The resulted AuNP was found to be having a particle size below 100 nm. The extract containing AuNPs coated cotton fabric had higher antibacterial activity than other test samples against *E. coli* [34].

AgNP synthesis using leaf extract of *Coleus aromaticus*

C. aromaticus leaf extract was used as a capping agent for the synthesis of AgNPs by Vanaja *and* Annadurai. SEM analysis showed the formation of nanoparticles of size 40-50 nm. The antimicrobial activity of thus formed AgNP was checked against a food pathogen *B. subtilis*, which showed excellent result [35].

AuNP synthesis using *Artocarpus heterophyllus f*ruit extract

One-step synthesis of highly-biocompatible spherical AuNPs of size 20-25 nm using *A. heterophyllus* Lam. (jackfruit) fruit extract was done to check its effect on pathogens by Basavegowda *et al*. AuNP thus synthesized from *A. heterophyllus* Lam. fruit extract was found to be effective against *E. coli* [36].

AgNP synthesis using *Musa balbisiana*, *A. indica,* and *O. tenuiflorum* plant extracts

The green synthesis of AgNP using three plants, viz., *M. balbisiana* (banana), *A. indica* (neem), and *O. tenuiflorum* (black tulsi) was reported by Banerjee *et al*. SEM analysis confirmed the formation of nanoparticles of size 200 nm, and its antibacterial effect against *Bacillus* and *E. coli* was checked. *Bacillus* showed maximum sensitivity against the nanoparticle [37].

AuNP synthesis using *Nepenthes khasiana* leaf extract

Green synthesis of AuNPs from the leaf extract of *N. khasiana* was reported by Bhau *et al.,* and its antimicrobial assay was done. The synthesized AuNPs were characterized by UV-visible spectroscopy, SEM, X-ray diffraction, FTIR, and TEM, which show the formation of the nanoparticle of size 50-80 nm. The antimicrobial property of the AuNPs was checked against food pathogens such as *Bacillus*, *E. coli,* and *A. niger*. *A. niger* showed high sensitivity against AgNPs [38].

AgNP synthesis using *Argemone mexicana* leaf extract

Biomediated synthesis of AgNPs was carried out by Singh *et al.* using the leaf extract of *A. mexicana*. SEM analysis showed the average particle size of 30 nm. It showed antifungal activity against *A. flavus*, a food pathogen [39].

AgNP synthesis using *Aloe vera* leaf extract

Biosynthesis of AgNPs was done using *A. vera* leaf extract by Medda *et al.*, and its antifungal activity was checked against two food spoiling pathogens *Aspergillus* and *Rhizopus*. The average size of an individual particle was estimated to be 70 nm by SEM analysis. The resultant nanoparticles showed high activity against *Aspergillus sp* [40].

AgNP synthesis using *Crataegus douglasii* extract

Plant-mediated green synthesis of AgNP and its antibacterial activity using *C. douglasii* was reported by Ghaffari-Moghaddam and Hadi-Dabanlou SEM analysis confirmed the formation of nanoparticles of size 29.28 nm. Antibacterial activity of resultant nanoparticles was checked against food pathogens *E. coli* and *S. aureus*. The assay showed the potent activity of nanoparticle against both *E. coli* and *S. aureus* [41].

AgNP synthesis using *Afzelia quanzensis* bark extract

A. quanzensis bark extract was used by Singh *et al.* for the green synthesis of AgNPs and to study their antibacterial activity. SEM analysis confirmed the formation of nanoparticles of size 10-80 nm. The antimicrobial activity of synthesized nanoparticle was checked against *E. coli* and *S. aureus*. The AgNP was more active against *E. coli* [42].

AgNP synthesis using *Eucalyptus globulus* extract

Microwave accelerated green synthesis of AgNPs from *E. globulus* was recently reported by Ali *et al*. The characterization techniques yield AgNP of size ranges from 1.9 to 4.3 nm and 5-25 nm. The antimicrobial activity was checked against food pathogens such as *E. coli* and *S. aureus. S. aureus* showed maximum sensitivity [43].

AgNP synthesis using olive leaf extract

Green synthesis of AgNPs using olive leaf extract and its antibacterial activity was reported by Khalil *et al*. SEM analysis showed the formation of nanoparticles of size 20-25 nm. The antimicrobial activity of resultant nanoparticles was checked against food pathogens *E. coli* and *S. aureus*. The antimicrobial assay proved potent activity against both the pathogens [44].

AgNP synthesis using *Origanum vulgare* extract

O. vulgare mediated AgNP synthesis was reported by Sankar *et al*. SEM analysis showed particles of size 63-85 nm. The resultant particles showed antibacterial activity against *E. coli*, *S. dysenteriae*, *S. typhi,* and *Shigella sonnei* [45].

AgNP synthesis using *Pulicaria glutinosa* extract

Green synthesis of AgNPs mediated by *P. glutinosa* extract was done by Khan *et al.* and its antibacterial activity was also checked. TEM analysis confirmed the synthesis of nanoparticles of an average size ranges from 40 to 60 nm. Antibacterial activity showed excellent results against food borne pathogens *E. coli* and *S. aureus* [46].

AgNP synthesis using tuber extract

Tuber extract mediated biosynthesis of AgNPs is a recent nanotech innovative work done by Sivakumar *et al*. The prepared materials were characterized by UV-visible spectroscopy, XRD, and FTIR. TEM analysis showed the formation of AgNPs of size ranges from 4.77 to 5.6 nm. Green synthesized AgNPs exhibited strong antioxidant and effective antibacterial activity against food pathogens such as *B. subtilis*, *E. coli*, *S. typhi,* and *S. aureus*. Maximum activity was found against *E. coli* [47].

AgNP synthesis using *Rhinacanthus nasutus* leaf extract

Leaf extract of *R. nasutus* was used by Pasupuleti *et al.* for the green routed AgNP synthesis. Characterization technique like TEM confirmed the formation of AgNPs of size <22 nm. The *in vitro* antimicrobial activity of the AgNPs synthesized using *R. nasutus* leaf extract was investigated against some common food pathogens such as *B. subtilis*, *S. aureus*, *E. coli*, *A. niger*, and *A. flavus.* The nanoparticle showed maximum activity against gram positive *S. aureus* and two fungi *A. niger* and *A. flavus* [48].

AuNP synthesis using *Pistacia integerrima* gall extract

P. integerrima gall extract was used for green synthesis of AuNPs and its biological activities were analyzed by Islam *et al*. SEM analysis showed the formation of nanoparticles of size ranges from 20 to 200 nm. The synthesized AuNPs showed antibacterial and antifungal activities against some of food pathogens such as *B. subtilis*, *S. aureus*, *A. niger,* and *A. flavus* [49].

AgNP synthesis using *Petroselinum crispum* leaf extract

Plant-mediated synthesis of AgNPs using *P. crispum* (parsley) leaf extract was reported by Roy *et al*. Spectral analysis and antibacterial activity was also checked. TEM analysis showed the formation of nanoparticles with the size 30-32 nm. The antibacterial analysis was done against food pathogens such as *E. coli* and *S. aureus*. AgNPs showed maximum activity against *E. coli* [50].

AgNP synthesis using *Dioscorea bulbifera* tuber extract

Synthesis of AgNPs using *D. bulbifera* tuber extract was reported by Ghosh *et al.,* and its antimicrobial activity was also reported. TEM analysis confirmed the formation of nanoparticles of size ranges from 8 to 20 nm. The resulting AgNPs were found to possess potent antibacterial activity against pathogenic food borne organisms such as *E. coli*, *B. subtilis*, *S. typhi,* and *S. aureus*. *E. coli* showed maximum sensitivity against AgNPs [51].

AuNP synthesis using *Ananas comosus* fruit extract

Plant-mediated synthesis of AuNP using fruit extract of *A. comosus* plant confirmed the formation of nanoparticles by Basavegowda *et al*. The resulted particles were of size 20 nm. Its activity was checked against some of the common food pathogens such as *A. niger*, *A. flavus,* and *E. coli. E. coli* showed positive result [52].

AuNP synthesis using *Zingiber officinale* root extract

Green synthesis of AuNPs using *Z. officinale* root extract was done by Velmurugan *et al.*, which resulted the formation of nanoparticles of size 10-20 nm. The resultant nanoparticles were used to check antimicrobial activity against some of the food pathogens such as *Staphylococcus* spp., *Listeria* spp., and *Bacillus* spp. *Staphylococcus* and *Listeria* spp. showed maximum activity [53].

AgNP synthesis using *Mangosteen leaf* extract

Biosynthesis of AgNPs using *Mangosteen* leaf extract and evaluation of their antimicrobial activity was carried out by Veerasamy *et al*. Characterization analysis, SEM showed the formation of nanoparticles of size 35 nm. Antimicrobial activity was checked against food borne pathogens such as *E. coli* and *S. aureus*. *S. aureus* showed positive result for the antimicrobial assay [54].

AuNP synthesis using *Diospyros ferrea* extract

AuNP synthesis using *D. ferrea* was reported by Ramesh and Armash. SEM analysis confirmed the formation of nanoparticle of average size 70-90 nm. Its activity was checked against the food pathogen *B. cereus,* and it showed the positive result [55].

AuNP synthesis using *Mentha piperita* extract

M. piperita extract was used by Mubarak Ali *et al.* to synthesis spherical shaped AuNPs with size around 150 nm and showed antimicrobial activities against the two common food pathogens *S. aureus* and *E. coli* [8].

AgNP synthesis using aqueous bark extract of *Cinnamon zeylanicum*

The aqueous bark extract of *C. zeylanicum* was used as a green agent by Sathishkumar *et al.* to synthesis AgNPs and its bactericidal activity was also checked. TEM and XRD analysis confirmed the formation of nanoparticles of size 31-40 nm. Its antibacterial activity was checked against the most common food pathogen *E. coli* [56].

AgNP synthesis using *Piper longum* fruit extract

P. longum fruit extract was used by Reddy *et al.* to synthesis AgNPs. Characterization analysis, such as FTIR and SEM, was done and the analysis confirmed the formation of nanoparticles of size 40-70 nm. The formed AgNP showed potent activity against food pathogens such as *B. cereus*, *B. subtilis,* and *S. aureus* [57].

AuNP synthesis using *Abelmoschus esculentus* seed extract

The aqueous seed extract of *A. esculentus* was used as a capping agent by Jayaseelan *et al.* to synthesize AuNPs of size 45-75 nm and its antifungal activities were tested against *Puccinia graminis tritici*, *A. flavus*, *A. niger,* and *C. albicans*. Resultant AuNPs showed maximum activity against *C. albicans* [58].

AgNP synthesis using *Cajanus cajan* leaf extract

AgNP synthesis using *C. cajan* leaf extract was reported by Nagati *et al*. TEM analysis confirmed the formation of nanoparticle of size 5-60 nm. Antibacterial activity of resultant nanoparticles was checked against *E. coli* and *S. aureus*. *S. aureus* showed highly sensitive against nanoparticles [59].

AgNP synthesis using *Dolichos biflorus* seed extract

Phytofabrication of AgNPs using *D. biflorus* Linn. (Horse Gram) seed extract, and its bactericidal and antioxidant activities were recently reported by Vijayalakshmi *et al*. The AgNPs exhibited antibacterial efficacy against different human pathogens [60].

APPLICATIONS OF AgNPs AND AuNPs

Nanotechnology applications are highly useful for biological molecules because of their unique properties. It is a growing field of material science and biological science [61]. AgNPs have broad applications in diverse areas such as integrated circuits [62], sensors [63], biolabeling filters, antimicrobial deodorant fibers [64], cell electrodes [65], and low cost paper batteries [66]. It also has important role in health industry, food industry, textile coatings, and environmental applications [67]. The use of AuNPs has found application in analytical methods such as colorimetric techniques for the determination of heavy metal ions in aqueous solutions [68]. The catalytic activity of AuNPs makes them use in water gas shift reactions [69-71]. They are also used in the field of sensors [72,73]. AuNPs are used in the development of biosensors and also for DNA labeling [74,75]. Spherical AuNPs are used to develop functional electrical coatings [76,77].

CONCLUSION

Plants or their extracts can be used in the synthesis of AuNPs and AgNPs as a green route. Such nanoparticles produced using plants have been used in various applications for human benefit. Elucidation of the mechanism of plant-mediated synthesis of nanoparticles is a very promising area of research. Therefore, the information compiled in this review might be useful in elucidating the mechanism of nanoparticle synthesis using plants as well as opening way for exploring other plants for this purpose.

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