NCNE-2020 Special Issue

J. Indian Chem. Soc.,
Vol. 97, July 2020, pp. 983-988

A review on green synthesis of silver nanoparticle through plant extract and its medicinal applications

Sarvaree Bano[a], Manisha Agrawal*[b] and Dharm Pal[c]

[a]Department of Chemistry, Kalinga University, Naya Raipur-492 101, Chhattisgarh, India

[b]Department of Chemistry, Rungta College of Engineering & Technology, Bhilai-490 024, Chhattisgarh, India

[c]Department of Chemical Engineering, National Institute of Technology Raipur, Raipur-492 010, Chhattisgarh, India

E-mail: dr.manisha.agrawal@rungta.ac.in

Manuscript received online 30 March 2020, accepted 01 June 2020

Silver nanoparticles (AgNPs) are gaining attention because of its wide application in medical science as antimicrobial and antibacterial properties. A conventional method for synthesis of AgNPs consumes hazardous chemicals and during production of NPs harmful by-products may also form. Proposed review suggests “greener technology” for synthesis of silver nanoparticles with the help of easily available plants. Aqueous extract of leaf or roots of *Impatiens balsamina*, *Lantana camara*, *Eriobotrya japonica*, *Berberis vulgaris*, *Azadirachta indica*, *Psidium guajava*, *Moringa oleifera* and *Catharanthus roseus* and other plant extracts are used as reducing agents to convert Ag^+ into Ag^0. Light or faint color of plant extract after addition of $AgNO_3$ turns to brown or deep brown in color, indicates the formation of AgNPs.

Fourier Transform Infra Red Spectroscopy (FTIR), X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Tunneling Electron Microscopy (TEM) and Dynamic Light Scattering Spectroscopy (DLSS) are techniques employed for characterization and morphological analysis of synthesized silver nanoparticles. Antibacterial, antifungal and antiparacitic applications of synthesized AgNPs have been also discussed. It is concluded that AgNPs synthesized by green way has great potency towards both Gram-negative and Gram-positive bacteria. Moreover, green synthesis of silver nanoparticles is a non-hazardous, eco-friendly, economic and safe technique and will envisaged better option for synthesis of AgNPs.

Keywords: Silver nanoparticle, green synthesis, plant extract, antimicrobial and antibacterial properties.

Introduction

Nanoparticles are sub microscopic in size which gives special quality to the particles. Associating multi-feature information from surface technology, chemistry, botany and other similar branches of science, the synthesis of NPs have a wide range. They attract more attention to researchers due to the large area of applications in catalysis[1], medicines[2–7], remediation of environmental pollution[8] and tremendous application in engineering and technology[9]. Present review deals about synthesis and medicinal applications of silver nanoparticles because; it is particularly utilized in the field of health and medication. Methods for synthesis of the AgNPs are photo chemical methods[10], thermal decomposition method[12], and chemical reduction method[13]. Above mentioned popular methods required various combinations of chemicals for preparations of silver nanoparticles. During synthesis, harmful chemicals may formed as byproducts and even traces of it cause a harmful effect on the environment. It's a need of the day to find out the environment-friendly and green method for the synthesis of AgNPs.

Now a day's parts of different plant materials are being used as reducing agent, in place of chemicals for the preparation of AgNPs. For present review 8 common plants are being discussed from available literatures.

Silver nanoparticles have the potential to damage the cell wall of bacteria, thereby inhibiting bacterial cell growth. The metabolism of the cell interrupted when the interaction of silver ion in cells occurs with macromolecules. Because of this specific nature AgNPs used as ingredient of medicine, which is also discussed in this paper.

Biosynthesis of AgNPs

Eight plants are chosen for the review from the literature, their botanical names are – *Eriobotrya japonica*[1], *Impatiens balsamina*[2], *Lantana camara*[2], *Berberis vulgaris*[3], *Azadirachta indica*[11], *Psidium guajava*[5], *Moringa oleifera*[4] and *Catharanthus roseus*[7]. Schematic representation of formation of AgNPs is shown in Fig. 1.

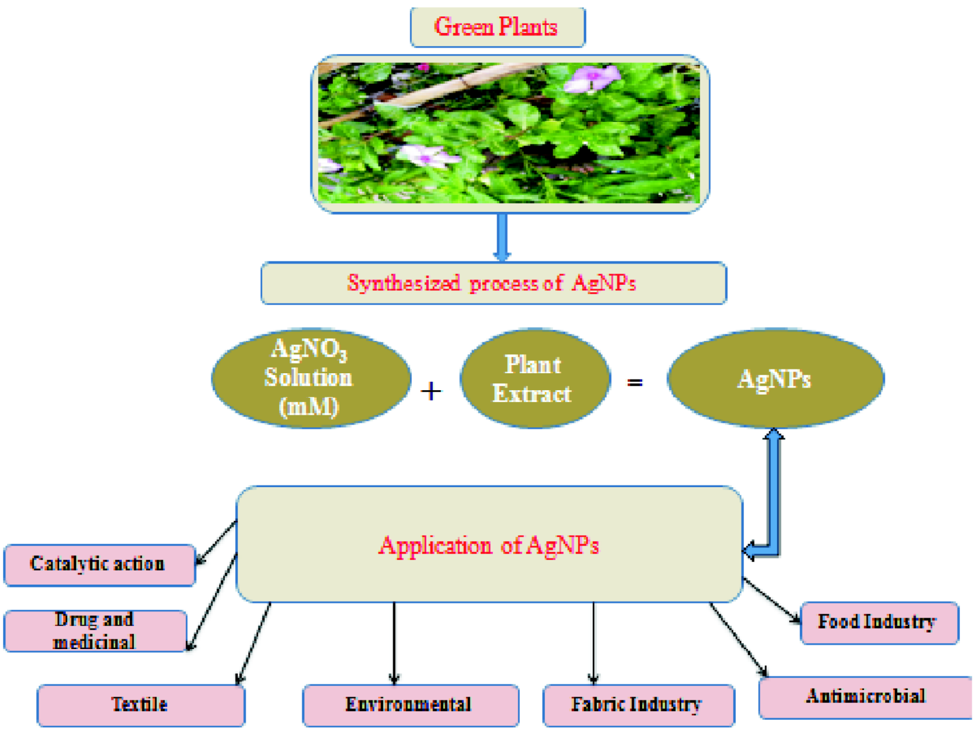

Fig 1. Steps involved in green synthesis of Ag nanoparticles and its applications.

Leaf extract of *Eriobotrya japonica*[1] was prepared in aqueous medium. Optimization of reaction temperature varied at three conditions. These are at room temperature, 20°C, at moderate temperature 50°C, and at high temperature 80°C. Mixing of $AgNO_3$ in leaf extract is done using magnetic stirrer. The fast change colors from light yellow to dark brown inside 5 min apparent the reduction of Ag^+ into Ag^0. Aritonang *et al.*[2] have taken fresh leaf of *Impatiens balsamina* and *Lantana camara* plant for synthesis of AgNPs. Leafs were washed, crushed and prepared aqueous extract of it. After addition of $AgNO_3$ in warm solution of leaf extract color of both solutions get changed. Color of *I. balsamina* extract change to yellowish brown and the color of *L. camara* extract changed to grayish brown, color of *L. camara* changed to grayish brown, while the *I. balsamina* extract to yellowish brown. Due to the effect of heat silver ions change into silver complex and color changes indicated the formation of silver nanoparticles. *Catharanthus roseus* leaf extract was studied by Ponarulselvam *et al.*[7] in 2012. In this study 1 mM $AgNO_3$ solution was mixed in leaf extract at room temperature. After sometime formation of silver nanoparticles is indicated by appearance of brown yellow color. Sairam *et al.*[5] had taken ethanol extract of *Psidium guajava*. Extract was prepared by soxhlet extraction. Ethanolic leaf extract of *P. guajava* was added to aqueous solution of 0.1 *M* $AgNO_3$. Greenish-brown colour of the solution indicated the formation of silver nanoparticle. Aqueous extract of dry and fresh leafs of *Moringa oleifera*[4] was prepared. In which direct sunlight were used in solution mixture for the formation of nanoparticles. After complete reaction dark brown color was appeared which indicated the formation of silver nanoparticles. Behravan *et al.*[3] have taken aqueous extract of leaf and root parts from *Berberis vulgaris* plant. After addition of $AgNO_3$ in extract colour of solution turns to dark brown and thick in appearance, it indicates the formation of AgNPs in mixture of solution. *Azadirachta indica*[11] leaf extract was prepared in water and addition of 10 mL of $AgNO_3$ solution was produced in a dark chamber to reduce photo-activation of $AgNO_3$ at room temperature. The solution change from colorless to brown indicated the reduction of Ag^+ to Ag^0. Formation of silver nanoparticles by various concentrations of $AgNO_3$ using extracts of different plants and diameter of AgNPs have been reported in Table 2 with references of concerned research papers.

Characterization of biosynthesized AgNPs

Comparative analysis, characterization and morphological studies by UV, SEM, TEM, FTIR, DSLR and SAED of AgNPs prepared by different plant extract have been reported in Table 1 with references of concerned research papers.

Eriobotrya japonica[1], the UV-Vis spectra showed a 469 nm absorbance of AgNPs. Size of silver nanoparticles ranging from 2 to 100 nm. Shapes created were triangular and hexagonal shapes.

Morphological analysis was conducted using FESEM, TEM, XRD and FTIR analysis. FESEM investigation was done to comprehend the monodisperse spherical shape of the biogenic silver nanoparticles. TEM picture affirms the sizes extending between 3–30 nm. The lattice spacing measured by utilizing HR-TEM was 0.24 nm. The SAED example of the Ag nanoparticles demonstrates the ring-like design based on the *fcc* structure of silver. Four bright rings were found to the lattice planes of *fcc* silver, which affirms the crystalline structure of synthesized AgNPs. Crystalline nature of the incorporated AgNPs is affirmed by XRD design. FTIR was used to observe a functional groups of aldehydes, ketones and carboxylic acids of AgNPs. It shows presence of natural acids, terpenoids, flavonoids etc. These phytocompounds are responsible for the fast reduction of silver particles into silver nanoparticles.

In UV spectra of *Impatiens balsamina* broth AgNPs gave a peak 441–455 nm and *Lantana camara* broth AgNPs gave at 420–450 nm.[2] TEM analysis used for analysis of morphology and size of nanoparticles. The TEM image of AgNPs of both plant extracts was well dispersed. It clearly indicates the covering of Ag nanoparticles with an organic layer. The reduction of Ag ions encouraged by the presence of a few polyphenolic components and balanced the surface of the resultant AgNPs. The UV-Vis range of synthesized AgNPs by *C. roseus* [7] was recorded at 390 nm. SEM analysis demonstrated the formation of silver nanoparticles as well as their morphological dimensions. The average size of AgNPs was founded at 35–55 nm. The shapes of the AgNPs proved to be spherical. The Braggs reflections were seen in the XRD design at 2θ = 32.4, 46.4 and 28.0. Reflections obviously showed the presence of lattice planes (111), (200) and (311) and can be recorded as *fcc* structure and crystalline in nature of Ag nanoparticles[7]. UV analysis of *Psidium guajava*[5] in which absorbance appears at 460 nm, demonstrated the formation of silver nanoparticles in the solution. Size of silver nanoparticle was measured by the help of Scanning Electron Microscope (SEM) analysis. The measured range of size of silver nanoparticle was between 0.1–0.5 μm.

Color changes to dark brown indicate the formation of AgNPs at preliminary level from *Moringa oleifera*[4]. AgNPs was prepared by fresh leaf and dry leaf extract. Their maximum UV absorbance peak was measured at nearly 440 nm and 450 nm, respectively and SEM analysis measured a highly absorption peak around 3 keV. EDX analysis of silver nanoparticles detected at signal 3 keV. FTIR spectral peaks represent the linkages of functional groups[4]. UV spectra of AgNPs synthesized by extract of plant *Berberis vulgaris*[3] shows peak at 450 nm. With the help of XRD analysis, the structure and crystals of silver nanoparticles was analyzed.

The DLS (Dynamic Light Scattering) diagram in optimal conditions shows that the average size of synthesised particle was in the range of 100–90 nm. Transmission Electron Microscopy (TEM) of silver nanoparticles confirms spherical shape and size of AgNPs[3].

Medicinal application of synthesized AgNPs

Silver metal has antimicrobial quality and it NPs used for medicinal application from the ancient time. According to Bo Rao *et al.*[14] antibacterial observation of synthesised AgNPs was measured against two bacteria *S. aureus* and *E. coli.* Synthesized AgNPs of *Eriobotrya japonica*. *S. aureus* had shown a high inhibition zone on 100 mg L^{-1}.

AgNPs prepared by extract of *I. balsamina* and *L. camara* both[2] and its antimicrobial activity was tested separately against the bacteria. According to literature study results demonstrated that the bacterial developments were inhibited. Which demonstrates that the concentrates of new *L. camara* leafs containing AgNPs were similar to ciprofloxacin

Table 1. Comparison of analysis of AgNPs synthesized by different plant extract

Sr. No.	Name of plant[a]	Parts of plant[b]	Spectroscopic techniques[c]	Properties[d] Structural	Medicinal	Ref.[e]
1.	*Impatiens balsamina*	Leaf	UV-Vis	λ_{max} = 420–450 nm, (0.667–3.386 absorbance)	Antibacterial activity observed against *S. aureus* and *E. coli* bacteria	[2]
			TEM	12±2.1 diameter size (1 mM $AgNO_3$), 20±3.3 diameter size (5mM $AgNO_3$)		
2.	*Lantana camara*	Leaf	UV-Vis	λ_{max} = 441–455 nm (0.894–1.736 absorbance)	Antibacterial activity observed against *S. aureus* and *E. coli* bacteria	[2]
			TEM	3.2±1.2 diameter size (1 mM $AgNO_3$), 12±2.1 diameter size (5 mM $AgNO_3$)		
3.	*Eriobotrya japonica*	Leaf	UV-Vis	λ_{max} = 469 nm	Antibacterial activity observed against *E. coli* and *S. aureus*	[1, 14]
			XRD	Diffraction planes (111), (200), (220) and (311)		
			TEM	3–30 nm		
			HR-TEM	0.24 nm		
			SAED	*fcc* crystal lattice plane of silver observed – (111), (200), (220), and (311) four bright rings		
			FTIR	2921.49 (O-H stretching), 1621.99 (N-H stretching), 1064.48 (stretching vibrations of the C=O) cm^{-1}		
4.	*Berberis vulgaris*	Leaf and root	UV-Vis	λ_{max} = 450 nm	Antimicrobial activity observed against *S. aureus* and *E. coli*	[3]
			XRD	4 peaks are observed at planes 111, 200, 220 and 311		
			TEM	Spherical Shape, 30–70 nm		
5.	*Psidium guajava*	Leaf	UV-Vis	λ_{max} = 450 nm	Antibacterial activity observed against *E. coli* and *S. aureus*	[5]
			SEM	0.1–0.5 μm		
			FTIR	The region of 1000–4000 cm^{-1} are 4000, 2000, 1649, 1541, 1074, 966, 883 cm^{-1}		
6.	*Azadirachta Indica*	Leaf	UV-Vis	λ_{max} = 430 nm	Antibacterial activity observed against *E. coli* and *S. aureus*	[11]
			TEM	34 nm		

Table-1 (contd.)

7.	*Catharanthus roseus*	Leaf	UV-Vis	λ_{max} = peaks 410 nm and 400 nm	Antiplasmodial activity of silver nanoparticles observed against *P. falciparum*	[7]
			XRD	*fcc*, diffraction peaks 2θ = 32.4°, 46.4°, 28.0° and diffraction planes (111), (200), and (311),		
			SEM	35–55 nm		
8.	*Moringa oleifera*	Leaf	UV-Vis	440 and 450 nm	(a) Antibacterial activity observed against *E. coli, E. faecalis, S. aureus, K. pneumoniae, P. aeruginosa*, (b) Antifungal activity observed against *C. albicans, C. Krusei, C. parapsilosisnia*	[4]
			SEM and EDX	Absorption peak around 3 keV		
			TEM	Spherical shape		
			FTIR	Peaks are 3000–3300, 2800–3000, 1626, 1400–1550, 1380–1403 and 1000–1100 cm^{-1}		

[a]Name of plant, [b]Parts of plant, [c]Spectroscopic techniques, [d]Properties, [e]Reference.

Table 2. Diameter of AgNPs formed from various concentrations of $AgNO_3$ using extracts of different plants[1–5,7,11]

Plant name	Concentration of $AgNO_3$ (mM)	Diameter of AgNPs (nm and μm)
Impatiens balsamina	1 mM	12±2 nm
Lantana camara	1 mM	3.2±1.2 nm
Eriobotrya japonica	1 mM	9.26±2.72 nm
Berberis vulgaris	3 mM	30–70 nm
Moringa oleifera	1 mM	11±4.3 nm and 9±4.2 nm
Psidium guajava	0.1 *M*	0.1–0.5 μm
Catharanthus roseus	1 mM	35–55 nm
Azadirachta indica	1 mM	34 nm

for stifling bacterial development[2]. Plasmodium activity of parasites was performed on *P. falciparum* by taking AgNPs containing extract of *C. roseus*[7]. Malaria positive blood samples were collected. 1 mM concentration of $AgNO_3$, was mixed to check inhibition rate against *P. falciparum* parasite. Result become positives and values are reported[7]. According to the literature of Sriram *et al.*[5] studied the antibacterial properties of synthesised AgNPs measured against two bacteria *E. coli* and *S. aureus*. Result showed very strong inhibitory actions against *S. aureus* (11 mm zone of inhibition) and *E. coli* (15 mm zone of inhibition).

Antibacterial and antifungal studies have been done for AgNPs prepared by *M. oleifera* fresh and dry leaf extracts. AgNPs exhibit inhibition of both Gram-positive and Gram-negative types of bacteria[5]. The development of *S. aureus K. pneumoniae*, and *P. aeruginosa* strains are inhibited at a concentration of 25 μg ml^{-1}. Although, *E. coli* and *E. faecal* get inhibited at 12.5 μg ml^{-1}. It was also mentioned by the author, that *S. aureus E. faecalis*, and *P. aeruginosa* strains were unaffected to neomycin but very sensitive to the silver nanoparticles. Antifungal potency of the AgNPs was experimented on the three reference strains and growth of all fungal strains inhibited[5]. By *B. vulgaris* plant[3] AgNPs were prepared and antimicrobial activity of AgNPs was examined by disc diffusion method on Gram-negative *E. coli* and Gram-positive *S. aureus* microscopic organisms. MIC test was used and MIC of nanoparticles was employed on the *S. aureus* and *E. coli*. This test carry out the negative controls and positive controls. It was concluded that, NPs had more antimicrobial properties and it can be also utilized as an antibacterial agent to supplant antibiotic agents[3]. Ahmed *et al.*[11] prepared AgNPs using leaf extract of *Azadirachta indica.* Antibacterial activity of AgNPs against two bacteria S*taphylococcus aureus* and *E. coli* strains were found positive using disc diffusion method[11].

Conclusions

It may be concluded after the exhaustive exploration of research papers and reported data that extract of plants such as leaf have great potential to synthesize silver nanoparticles due to presences of organic metabolites, which was confirmed by FTIR analysis. Comparative analysis of reported SEM and TEM analysis concludes that shapes of AgNPs are hexagonal, irregular or crystalline. The sizes of synthesized silver nanoparticles are influenced by the reaction temperature. It was also an indicative aspect that the bio-synthesized AgNPs additionally behave as a capping as well as reducing agents. AgNPs has great antibacterial potency towards Gram-negative and Gram-positive bacteria. It has antibacterial and antimicrobial properties.

All the analysis and comparisons of bio-green techniques supports the synthesis of silver nanoparticles in a green way.

Acknowledgements

The authors are thankful to CSVTU, Bhilai TEQIP III for financial support.

References

1. C. Yu, J. Tang, X. Liu, X. Ren, M. Zhen and L. Wang, *Materials,* 2019, **12**, 189.
2. H. F. Aritonang, H. Koleangan and A. D. Wuntu, *Int. J. Microbiol.*, 2019, 2019.
3. M. Behravan, A. H. Panahi, A. Naghizadeh, M. Ziaee, R. Mahdavi and A. Mirzapour, *Int. J. Biol. Macromol.*, 2019, **124**, 148.
4. J. S. Moodley, S. B. N. Krishna, K. Pillay, Sershen and P. Govender, *Adv. Nat. Sci. Nanosci. Nanotechnol.*, 2018, **9**, 015011.
5. T. Sriram and V. Pandidurai, *Int. J. Curr. Microbiol. App. Sci.*, 2014, **3**, 146.
6. D. Hebbalalu, J. Lalley, M. N. Nadagouda and R. S. Varma, *ACS Sustain. Chem. Engine.*, 2013, **1**, 703.
7. S. Ponarulselvam, C. Panneerselvam, K. Murugan, N. Aarthi, K. Kalimuthu and S. Thangamani, *Asian. Paci. J. Trop. Biomedi.*, 2012, **2**, 574.
8. P. G. Tratnyek and R. L. Johnson, *Nano Today*, 2006, **1**, 44.
9. S. S. Shankar, A. Rai, A. Ahmad and M. Sastry, *J. Colloid. Interface Sci.*, 2004, **275**, 496.
10. A. Henglein, *Chem. Mater.*, 1998, **10**, 444.
11. S. Ahmed, Saifullah, M. Ahmad, B. L. Swami and S. Ikram, *J. Radiat. Res. Appl. Sci.*, 2016, **9**, 1.
12. K. Esumi, T. Tano, K. Torigoe and K. Meguro, *Chem. Mater.*, 1990, **2**, 564.
13. A. Henglein, *Langmuir*, 2001, **17**, 2329.
14. B. Rao and R. C. Tang, *Adv. Natur. Sci. Nanosci. Nanotechno.*, 2017, **8**, 015014.