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Plant as a natural source for synthesis of silver nanoparticles: A review

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Abstract
The present review provides a general idea of the plant-mediated synthesis of silver nanoparticles, possible active ingredients and mechanisms might be responsible for the bioreduction process. In general, various physical and chemical methods are used for the synthesis of silver nanoparticles and for this purpose needed strong and weak chemical reducing agents and protective agents like sodium citrate, alcohols, sodium borohydride etc. All of these are flammable, toxic and not easily disposable due to these properties to create an environmental problem. Green plant as a source of natural compounds like metabolites, chlorophyll, proteins and others compounds play a vital role in the synthesis of silver nanoparticles as natural capping and reducing agents. Some factors affecting on the synthesis of AgNPs, characterization of synthesized AgNPs and applications of plant-mediated silver nanoparticles are discussed. Green plant-mediated synthesis of nanoparticles has more advantages over the micro-mediated synthesis process because it mainly eliminates the maintenance of cell cultures, require fewer amounts of chemicals, cost-effective, less time-consuming process and there is no interference of any toxic chemicals and easily scaled up for large-scale synthesis.

Keywords: Silver Nanoparticles, Plant mediated, Biosynthesis

Introduction

The term Nanotechnology was coined by Professor Norio Taniguchi of Tokyo Science University (Taniguchi 1974) [45] but the history of the nanoparticles is very old. Now a day's nanotechnology is the budding branch of nanoscience from all discipline like physics, chemistry, biology, and engineering because nanomaterials not arise from a specific branch of science this is an interdisciplinary approach. Nanoparticles are common in nature, for example; life depends on many nanoscale materials, including proteins, enzymes, and DNA, and nano-sized particles occur naturally in the air, water, and soil, these all are nothing but the nonmaterial's (Matthew 2006) [17]. Nanotechnology can be defined in a number of ways as "the capacity to manipulate, measure, produce and make a prediction in the form of clusters of atoms at the nanoscale of 1–100 nm" (Matthew *et al*., 2006) [17] and recently it has a big influence on the industry from several years. "Nano" is a Greek word synonymous to dwarf meaning extremely small (Vadlapudi and Kaladhar, 2014) [49]. Tiny particles (NP) attract to young researchers with potentially wide-ranging therapeutic applications in various field like biology including nanomedicine, pharmaceutical, industrial, biotechnological for a drug, gene delivery and in agricultural field (Mondal *et al*., 2014; Singh and Mishra; 2013) [19, 41]. Nanoparticles also use in biosensing for forensic analysis and environmental monitoring and in Bioimaging like Optical imaging (OI) and Magnetic resonance imaging (MRI) (Kircher *et al*., 2003; Schellenberger *et al*., 2004) [14, 37]. In military Carbon nanotubes (CNTs) used since they have high electrical conductivity, and plastic composites based on them could provide lightweight shielding material for electromagnetic radiation. Computers and electronic devices for battlefield command, control and communication need to be protected from weapons that emit electromagnetic pulses. (Poole and Owens, 2003) [27]. Silver is well known for medical properties over 2,000 years and in the 19th century, many silver-based compounds have been used as antimicrobial agents (Prabhu and Poulose, 2012) [28]. In general various physical and chemical methods are used for the synthesis of silver nanoparticles and for this purpose needed strong and weak chemical reducing agents and protective agents like sodium citrate, alcohols sodium, borohydride, etc. all of these are flammable, toxic and not easily disposable due to this properties to creates environmental problem and production rate also very low (Mohanpuria *et al*. 2008; Sharma *et al.* 2009; Baier *et al*. 2009b) [18, 39, 4]. In the field of biology mostly microorganisms are used for the synthesis of nanoparticle's both intracellularly and extracellularly and this is an eco-friendly but more time-consuming process, which takes 24 to 120 h. and hence it is not the appropriate method (Ahmad *et al*. 2003; Thakkar *et al.* 2010) [1, 46]. Green plant-mediated synthesis of nanoparticles has more advantages over the micro-mediated synthesis process because it mainly eliminates the maintenance of cell cultures, require fewer amounts of chemicals, cost-effective (Ingle *et al.* 2008; Vanaja *et al.,* 2013a) [9, 52], less time-consuming process and there is no interference of any toxic chemicals and easily scaled up for large-scale synthesis (Vigneshwaran *et al.*, 2007; Mohanpuria, 2008; Shivshankar, 2004; Solgi, 2014) [57, 18, 40, 42]. Green plant as a source of natural compounds like metabolites, chlorophyll, proteins and others compounds play a vital role in synthesis of silver nanoparticles as natural capping and reducing agents by changing the pH to 3, 5, 7 and 9 of the reaction mixture desirable morphologies shapes like triangle, hexagons, spheres, and rods obtained (Gericke and Pinches 2006) [8]. The temperature modulating (Riddin *et al.* 2006) [33] also demonstrated that at 65 ^{0}C temperature less amount of nanoparticles were synthesized, whereas at 35 ^{0}C temperature more amount of nanoparticles were synthesized. These silver nanoparticles showed anticancer activity, used in drug delivery and most widely used silver nanoparticles in preparation of ointments and a cream to prevent infection of wound and burns (Murphy 2008; Vaidyanathan *et al.* 2009) [20, 50]. In another field like agriculture to prevent plant pathogens, food chemistry, cosmetics these silver nanoparticles are used (Li *et al*. 2009) [15].

From last decade, minimum reviews continuous focusing on the naturally synthesis of AgNPs were published. Among all of these reviews mostly focused on several plants as well as microbial sources for synthesis, for the synthesized AgNPs materials characterization purpose several biophysical techniques are used, shape and size and information pertaining to various applications are given in the tabulated form. The present review, distinct the previous ones, summarizes the synthesis methods, parameters, characterizations, application and forecast antimicrobial action in a proper mode, a focal point on various greenway used for AgNPs synthesis.

Material for Green synthesis

The requirement for the synthesis of AgNPs is Silver metal ion solution, natural reducing and capping agents present in plant extracts.

An indication of synthesized AgNPs

The colorless mixture solution of silver ion (A+) plus plant extracts (natural capping and reducing agents) change yellow to dark brownish or reddish yellow to deep red in color A0 (Sadeghi and Gholamhoseinpoor 2015) [34]

Separation of Silver nanoparticles

Most of the centrifugation techniques at 8000 rpm/min for 10 min are used for obtaining the bottom settled down materials as bulky pellet or powder form synthesized AgNPs. (Bagerzade *et al.*, 2017) [3]

Characterization of AgNPs

Synthesized nanoparticles are characterized by some biophysical techniques like UV-visible, XRD, FTIR, energy dispersive X-ray analysis (EDAX), TEM and SEM to assess their superiority. Synthesized nanoparticles characterized with various biophysical techniques like UV-Vis Spectrophotometric analysis for pH dependency, silver nitrate ion concentration, the formation of AgNPs. The Scanning electron microscopy (SEM) and Transmission electron microscopy (TEM) used for shape, size and morphological study of AgNPs like spherical triangular hexagonal rod shape etc. Use of XRD study to the formation of face-centered cubic (FCC) crystalline structure of AgNPs. EDAX for analysis of elemental concentration with silver weight percentage range from 40 to 80%. Stability of AgNPs is about 1 year it's depending on reducing compounds and other conditions (Thirumalai *et al.*, 2010; Solgi, 2014; Gaddala and Nataru 2015) [47, 42, 7].

Synthesis process and factors affecting on AgNPs

The Synthesis process totally depends on the presence of a large number of active ingredients in the plant like primary and secondary metabolites Proteins, Carbohydrates, Fats, various enzymes, coenzymes, Alkaloids, Flavonoids, terpenoids, Polyphenols, gum tannin, Lignin etc. having the ability to reduction of Ag+ ion to Ao particles. Reduction process of synthesis of AgNPs varies from species to species because varying the concentration of active compounds in plants.

During synthesis of AgNPs various chemical and physical factors affect the reaction Another factor pH, changing the pH to 3, 5, 7 and 9 of the reaction mixture desirable morphologies shapes like triangle, hexagons, spheres, and rods obtained (Gericke and Pinches 2006) [8]. One of the important factor temperature, temperature modulating (Riddin *et al.* 2006) [33] also demonstrated that at 65 ^{0}C temperature less amount of nanoparticles were synthesized, whereas at 35 ^{0}C temperature more amount of nanoparticles were synthesized. The aqueous extracts various plants parts (Table 1) have been shown produce silver nanoparticles (AgNPs) with a wide range of size and shape by adjusting various reaction parameters such as time, temperature and characterized of synthesized nanoparticles with various biophysical techniques and its activities were demonstrated in some of the studies.

Table 1: Synthesis of nanoparticles by using plant parts and synthesized nanoparticles size, shape and characterization by various techniques

Sr. No.	Name of plants	Part used	AgNPs size and shape	Color variation		Time required	Temp. ºC	Characterization	Activity	Ref.
				Before	After					
1	*Allium cepa*	Aqueous leaf extract	25nm and spherical	yellow	brown	30 min.	room	UV-Vis, FTIR,XRD,AFM, and SEM	antibacterial	Kalifawi *et al.* (2015) [12]
2	*Parthenium hysterophorus*	Aqueous root extract	spherical	colorless	Deep redish brown	72 h	room	UV-Vis, FTIR, SEM and fluorescent spectro.	Mosquito larvecidal	Mondal *et al.* (2014)
3	Ziziphora tenuior	Dried leaf	20 nm spherical	colorless	Deep red	1 h	room	UV-Vis, FTIR, SEM, TEM XRD	-	Sadeghi and Gholamhoseinpoor (2015)
4	*Caltropis procera*	Leaves and fruits	90 nm	colorless	Dark brown	45 min.	80	UV-Vis	antibacterial	Salem *et al.* (2014)a
5	*Ficus sycomorus*	leaves aqueous extracts and Latex	Elipsoidal, spherical and irregular	colorless	Dark brown and Dark gray	45 min	80	UV-Vis,TEM, EDX	antibacterial	Salem *et al.* (2014)b
6	*Erythrina indica lam*	Aqueous root extracts	20-118 nm spherical	colorless	brown	Overnight	room	UV-Vis, FTIR, HR-TEM, XRD, DLS, EDX	Antibacterial and cytotoxic effect	Rathi sre *et al.* (2015)
7	*Nargini crenulata*	Leaves extracts	72-98nm Spherical and cubic	Yellow	Brown	24 h	Room in dark	UV-Vis, XRD, FTIR, FESEM and EDX	Wound healing activity	Bhuveneshwari *et al.* (2014)
8	*Desmodium gangeticum*	Leaf	spherical	Greenish	Dark brown	24h	35	UV-Vis, FTIR, TEM, SEM and EDX	Antimicrobial	Thirunavoukkarasu *et al.* (2013)
9	*Coriandrum sativum*	Seed extracts	113 nm Spherical beadlike	yellow	Blackish brown	24 h	room	UV-Vis,TEM, SEM and EDX	Antimicrobial	Nazeruddin *et al.* (2014a)
10	*Euphorbia nivulia*	Green stem latex	5-10 nm spherical	yellow	brown	24h	room	UV-Vis, FTIR, PL, TEM and XRD	Antimicrobial	Valodkar *et al.* (2011)
11	*Cyamposis tetragonaloba*	Guar gum	<10nm spherical	Light Yellow	brown	90 min	70	UV-Vis, SEM, TEM and XRD	Calorimetric sensing application	Pandey *et al.* (2012)
12	*Delphinium denudatum*	Root extracts	<85nm	Clear solution	Yellowish brown	2 h	Room in dark	UV-Vis, XRD, FESEM and FTIR	Antibacterial and mosquito larvicidal	Suresh *et al.* (2014)
13	*Olive*	leaf	30 nm Quasi spherical	Light yellow	Brownish yellow	24h	room	UV-Vis, FTIR, TEM and XRD	antibacterial	Khalil *et al.* (2014)
14	*Adhatoda vasica*	Leaf extract	11.5nm spherical	colorless	Dark brown	2h	room	UV-Vis, SEM, TEM and XRD	Antimicrobial	Nazeruddin *et al.* (2014b)
15	*Aloe vera*	Aloin active compoud	70 nm Cubical, rectangular, triangular and spherical	Pale yellow	Brown	24 h	95	UV-Vis,DLS, FTIR,and SEM	Antimicrobial	Chaitanya kumar *et al.* (2014)
16	*Withania somnifera*	Dried leaf powder	22 nm Spherical	colorless	brown	5min	room	UV-Vis, FTIR, TEM and XRD, EDS NTA, ZP and CVS	Antimicrobial	Raut *et al.* (2014)
17	*Sesuvium portulacastrum L.*	Leaf and callus	5-20 Spherical	colorless	Yellowish brown	24 h	room	UV-Vis, FTIR, TEM	Antimicrobial	Nabikhan *et al.*(2010)
18	*Catharanthus roseus Linn*	Leaves extract	35-55nm cubic	colorless	Brown yellow	6 h	room	UV-Vis, SEM, EDX and XRD	antiplasmodial	Ponarulselvum *et al.*(2012)
19	*Ocimum tenuiflorium, Solanum tricobatum, Syzygium cumini, Centella asiatica and Citrus sinensis*	Leaves and peel	0.22nm crystaline	Bright yellow	Dark brown	1,24-48 h	Steam bath	UV-Vis, XRD AFM and SEM	antimicrobial	Logeswari *et al.* (2015)

20	*Piper nigrum Linn. or black piper*	Leaves extract	5-50 spherical	white	Brick red	1 min	Heating to boiling	UV-Vis, FTIR, TEM and XRD	antimicrobial	Augustine *et al.* (2013)
21	*Coleus aromaticus*	Leaf extract	40-50 Spherical	colorless	brown	10 min	room	UV-Vis, FTIR, SEM and XRD,EDAX	Bactericidal	Vanaja and annadurai (2012)
22	*Musa paradisiaca*	Banana peel	50-150	Light brown	Dark brown	1 h	room	UV-Vis, FTIR, SEM and XRD,EDAX	Acaricidal and larvicidal activity	Jayaseelan *et al.* (2012)
23	*Solanum trilobatum Linn*	Leaves extract	15-20nm Cubic and hexagonal	yellow	Dark brown	48h	Sunlight,microwaves and room	UV-Vis, FTIR, SEM and XRD	Antidandruff	Pant *et al.* (2012)
24	*Crocus sativus*	Petal extract	-	Yellow	Brown	30 min	room	UV-Vis, XRD and FTIR	Post harvest physiology in cut flower	Solgi (2014)
25	*Heliotropium indicum*	Dried leaf extract	32 nm Spherical,triangle, truncated, decahedral	Colorless	Dark Brown	6 h	room	UV-Vis, TEM, SEM, EDX and FTIR	Anti mosquitoes	Veerakumar *et al.* (2014)
26	*Murraya koenigii*	Dried leaves	20-35 nm Cubic and spherical	colorless	Brown yellow	120 min	room	UV-Vis, EDS, SEM, EDX and FTIR	Mosquitocidal activity	Suganya *et al.* (2013)
27	*Sida acuta*	Fresh leaves	20-60nm Triangular, pentagonal and hexagonal	colorless	Dark brown	6h	room	UV-Vis,, TEM, SEM, XDL and FTIR	Larvicidal	Veerakumar *et al.* (2013)
28	*Feronia elephantum*	Shade dried leaves	20-60nm Triangular, pentagonal and hexagonal	colorless	Brown yellow	10 min	room	UV-Vis, FTIR EDX and SEM	Larvicidal	Veerakumar *et al.* (2014)
29	*Morinda tinctoria*	Dried leaves	60-95nm Spherical and crystalline	colorless	Reddish brown	1 h	room	UV-Vis, AFM, FTIR,	Larvicidal	Rameshkumar *et al.* (2014)
30	*Tinospora cordifolia*	Fresh leaves		colorless	Brown-yellow	10min	room	UV-Vis, FTIR XRD and SEM	--	Jayaseelan *et al.* (2011)

Conclusion

A huge number of biological resource present on the earth like green plant and microorganisms a vital source of various primary and secondary metabolites like protein, carbohydrates, alkaloids, flavonoids etc. Due to the presence of these components in the plants and microorganisms, we called them biological factory responsible to produce silver nanoparticles has been shown in many studies. Plant-mediated synthesis of AgNPs are more potent and useful for human being because natural components are highly involved in the production of AgNPs, another reason it mainly eliminates the maintenance of cell cultures, require fewer amounts of chemicals, cost-effective, less time-consuming process and there is no interference of any toxic chemicals and easily scaled up for large-scale synthesis.

Now a day's increasing demand of silver nanoparticles is used in the field of agriculture because major problem arising in agriculture field as for how to prevent plant pathogens like fungi, bacteria and viruses invasion during post-harvest storages of major vegetables and fruits. Therefore, urgent need to develop the new relevant technology to control of these pathogens. Nanotechnology is a budding stage in this field but after few years will be popular and everyone will be used plant-mediated synthesized silver nanoparticles or nanomaterials is their important role in protecting the environment.

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