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Research Article

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Properties of Phtyo-Reducing Agents Utilize for Production of Nano-Particles, Existing Knowledge and Gaps

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ABSTRACT

Biomimetic synthesis of nanoparticles is a burgeoning field with its environmentally friendly and reproducibility approaches. Nowadays different nanoparticles with various physical and chemical parameters have been synthesized by using different plant or plant parts. This paper highlighted the knowledge and gaps related with phyto-synthesis of nanoparticles. 83 three plants along-with various related information viz., habit and modules of phyto-reducing agents, their selection criteria, characterization, factor affecting for their synthesis, size, shape and stabilization have been discussed. Their antimicrobial properties as well as their potential to improve the limitation of herbal drugs have also been addressed. Gap analysis revealed the need for the synthesis of important nutrients (like phosphorus, zinc, magnesium, iron etc.) in nano-particle forms so that their availability and targeted distribution may be achieved. Biological Distribution of various green nano-particles also need to evaluated

Key Words: *Biomimetic Synthesis, Nano-Particles, FTIR, Phyto-reducing Agents.*

INTRODUCTION

Nanotechnology broadly refers to a field of applied science and technology whose unifying theme is the control of matter on the molecular level in scales smaller than 1 μm, normally 1-100nm, and its fabrication of devices within the range. It is a highly multi-disciplinary drawing from fields such as pharmaceutical sciences, applied physics, material sciences, colloidal sciences, device physics, supra molecular chemistry and even mechanical and electrical engineering[1] .

Nanotechnology mainly consists of the processing, separation, consolidation, and deformation of material by one atom or one molecule. A number of approaches are available for the synthesis of nanoparticles such as chemical reduction of silver and other metals in aqueous solutions with or without stabilizing agents[2], thermal deposition in organic solvent[4], chemical reduction and photo-reduction in reveres micelles[4,5] microwave assisted process and radiation chemical reduction have been reported in the literature[6,7&8]. Most of these methods are extremely expensive and also involve the use of toxic, hazardous chemicals, which may pose potential environmental and biological risks. Since noble metal nanoparticles are widely applied to area of human contact[9], there is a growing need to develop environmentally friendly processes for nano-particle synthesis that do not use toxic chemicals. A quest for an environmentally sustainable synthesis process has lead to a few biomimetic approaches.

Biomimetic refers to applying biological principles in materials formation. Biological methods of nanoparticles synthesis using microorganism[10-14], enzymes[15, 16], fungus[17, 18 &19], and plant extracts [9, 20] have been suggested as possible eco-friendly alternatives. Green synthesis provides advancement over chemical and physical method as it is cost effective, environmentally friendly, easily scaled up for large scale synthesis and in this method there is no need to use high pressure, energy, temperature and toxic chemicals[21]. Sometimes the synthesis of nanoparticles using plants or parts of plant can prove advantageous over other biological processes by eliminating the elaborate processes of maintain microbial cultures[22]. The present Paper highlighted the current knowledge regarding the phyto-synthesis of nano-particles and try to find out the existing gaps that can be address in future research.

HABIT AND MODULES OF PHYTO-REDUCING AGENTS

There are broadly two nono-technological approaches associated with plants. These include phyto-synthesis of nanoparticles and nono coating of herbal drugs. Nearly 80 plants have been reported to have reducing properties for green synthesis of nanoparticles (Table 1). The habit analyses of these plants indicate that they belong to diverse groups such as herbs, vines, shrubs and trees. Among them, majority of these plants are Angiosperm and few are Gymnosperm. However, two mangroves like *Rhizophora mucronata* and *Sueada monoica*, succulents like *Aloe vera, Opuntia ficus* and one sea weed like *Padina tetrasfromatica* have also been reported for production of silver nanoparticles. Most of them have been distributed in tropical and subtropical countries. Among the plant parts majority of the experiments uses leaf as a reducing agent followed by seeds, root and fruit. Interestingly resin of *Commiphora weightii*, latex of *Calotropis procera*, bark of *Melia azadirachta* and flower of *Achillea wilhelmini* had also been used for synthesis of nanoparticles. Nanoparticles can be formed both inside the livening plants[23,24] and within the sundried biomass[25]. The basic mechanism in both these cases involves the accumulation of nanoparticles after the reduction of metal ions. This reduction process was mediated by some reducing agents or may involve some enzymes that were bound to the cell wall[24]. Chandran[20] have suggested that different bio-molecules like proteins were involved in this process. The effect of *Capsicum annum* proteins on the formation of silver nanoparticles indicated that amine group of proteins, played a reducing and controlling role during the formation of silver nanoparticles. Li[26] hypothesized that with *Ciinnamomum camphora* gold nano-triangles might grow by a process involving rapid reduction, assembly and room temperature sintering of spherical gold nanoparticles. Alfalfa roots (*Medicago sativa*) have capability for absorbing Ag (0) from agar medium and transferring them to shoot of the plant in the same oxidation state[27,28]. In the shoot, these Ag atoms arranged themselves to from nanoparticles by joining themselves to form larger arrangements. However, till now mechanistic aspects of nanoparticles formation in plants are not clear but according to some researchers it may be somewhat associated with the phyto- remediation concept in plants [23,24,29,30.] A generalized flow chart involving various steps related with phyto-synthesis is presented in figure 1.

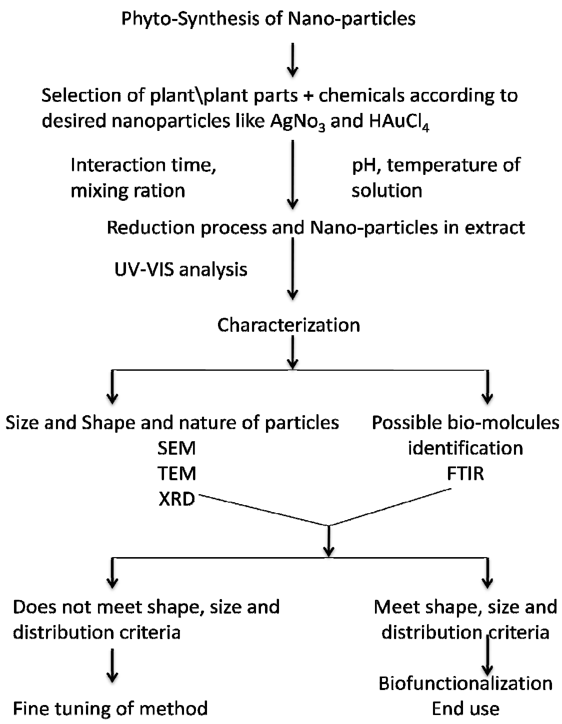

Figure 1. Generalized flow chart for phyto-synthesis of nanoparticles

SELECTION CRITERIA'S OF A PHYTO-REDUCING AGENT

The selection of a specific plant species was based on hit and trial method that further supported with different uses of a plant like medicinal, aromatic, spices and ornamental. Among them medicinal properties and its active ingredients were the major criteria for selecting them as a reducing agent. Maensiri[31] selected *Aloe vera* plant for production of titanium oxide nano-particle for removing problems associated with polymerization and highly polymeric resin for production of herbal products. *Catharanthus roseus* was evaluated for significance of vincristine and vinblastine in production of silver nanoparticles[32]. Both these important secondary metabolites were potential source of medicinal and nematicidal activities of this plant. *Dioscorea oppositifolia* have been selected with the hypothesis that silver ions required the NADPH- dependent nitrate reeducates enzyme for their reduction, and this was generally secreted by this plants in its extracellular environment[33].

Phyto-synthesis of nanoparticles not only provides an environmentally benign method but plants also serve as natural capping agents[34.]. Capping agents stabilizes the nanoparticles and prevents them from aggregation. For this latex of *Jatropha curcas* has efficiently utilized as reducing as well as capping agent for production of nanoparticles. Latex of *Jatropha curcas* possessed curcacycline A (a cyclic octapeptide) and curcacycline B (a cyclic nanopeptide) that serves as reducing property and enzyme cucain has stabilizing property[35]. With identification of the capping properties of plant latex *Alstonia scholaris, Calotropis gigantean, Ficus religiosa, Hevea brasiliensis, Musa paradisiaca* and *Achras sapota* have been selected for production of silver nanoparticles[36]. It was hypothesized that formation of gold nano-wires from sugar beet pulp, sugar acts as reducing agent while, proteins as stabilizing and/ or capping agent[37]. Zeta potential measurement commonly performed for direct comparison to conventional studies of nanoparticles stability. Understanding the nanoparticles stability at biological conditions and in biological media was an important aspect for application of different phyto-nanoparticles in biomedical field and commercial industry[38]. Zeta potential measurement of the garlic extract stabilized silver nanoparticles is consistent with other sugar-stabilized silver and gold nanoparticles including citrate, maltose, gum acacia, glucose and galactose[39]. In order to predict nano-particle behavior in the presence of large quantities of reactive oxygen species, *Allium sativum* nanoparticles oxidation resistance against H_2O_2[39]. Author have concluded that nano-particle oxidation resistance to H_2O_2 may be attributed to the phyto-chemical compound like allicin (diallyl-thiosulfinate) and other allyl sulfides.

CHARACTERIZATION

Various instruments like UV-Vis spectroscopy (for determining reduction of metal ions to nanoparticles), Fourier Transform Infrared Spectroscopy (to identify possible bio-molecules responsible for the reduction and stabilization of nanoparticles), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (for determining size and shape of nanoparticles). The X-ray diffraction (XRD) technique is used to establish the metallic nature of particles. The energetic X-ray can penetrate deep in the material and provide information about the bulk structure.

Most of the researches were put their efforts for production of silver nanoparticles followed by gold, titanium oxide and only one effort has been made for production of zinc nanoparticles (Table 1). The synthesis of these nanoparticles has been confirmed with production of specific colour within plant extract. Generally silver nanoparticles produces yellowish brown colour, while gold nanoparticles produces ruby red colour. Time taken for the production of such specific colour was ranges between 10 minutes (*Cymbopogan citrates, Mucuna pruriens* and *Eclipta alba*) and 11 hours (*Ocimum sanctum*). Such colour productions were carried out due to surface plasmon resonance process. It is physical process that can occur when plane polarized light hits a metal film under total reflection conditions. This process gives different UV-Vis absorption peak for different size of nano particles of different solgel medium. The plasmon resonances in silver nanoparticles depend on two components, absorption and a near field component that evolves into radioactive far-field scattering. The relative contribution of these two components is related to nano-particle size. In the case of small nanoparticles (<30nm), the absorption generally dominants the extinction spectrum. For larger nanoparticles (>50nm), the scattering component dominates the plasmon resonance extinction spectrum. UV absorption peak of different plant extract are presented in table 1 and it was ranges between 251 nm (*Saccharum officinarum, sorghum bicolor*) and 580 nm (*Phyllanthus amarus*).

FACTORS AFFECTING THE SYNTHESIS OF NANOPARTICLES

Several factors influences the reduction process of metal ions into metal nanoparticles like temperature, pH etc[24]. Temperature has a profound effect on the nanoparticles formation. It has been observed that gold nanoparticles formation was kinetically controlled and was highly favored at the low temperature range[40.] Further temperature also plays an important role for controlling the aspect ratio and relative amounts of gold nanoparticles and spherical silver nanoparticles[41]. In *Dioscorea bulbifera* rapid gold biosynthesis depends on plant concentration (1mM) and high temperature (50^0C). In *Momordica charantia* at 30^0 C, more than 24 hours were required for the complete reduction; whereas at 100^0 C the colour appeared in less than 5 second. Further concentration of nitrate reductase and protein concentration negatively associated with gold nano-particle formation[42]. 2012). In *Murraya koenigii* high concentration of carbazoles responsible for the reduction of metal ions[43]. It had been demonstrated that when the solution of Au^{3+} with the oat biomass were reacted for one hour in a pH range 2-6, that Au^{3+} ions were bound to oat biomass in a pH- dependent manner, with highest absorption at pH 3[44]. Moreover, it was also observed that presence of some ions like chloride, bromide and iodide etc. also affects the nanoparticles formation in the plants. Presence of chloride ions during synthesis promotes the growth of nano-triangles, whereas presence of iodide ions distorts the nano-triangles morphology and induces the formation of aggregated spherical nanoparticles[41,24].

SIZE AND SHAPE OF PHYTO - SYNTHETIC NANOPARTICLES

Size and shape analysis of reviewed plants revealed that both were varied with species to species. In our present review the minimum size (12.5) of nanoparticles was observed with *Mucuna pruriens* while the largest size (150nm) with *Nyctanthes arbor-tristis* (Titanium oxide) and *Eucalyptus hybrid* (Silver). Among shape, majority of the nanoparticles were recorded as spherical in nature (Table 1), cubical and triangle were recorded with *Cymbopogan citrates.* In *Cymbopogon flexuosus* (Lemongrass) size of gold nanoparticles controlled by varying the concentration of lemongrass extract. With increase the amount of extract, average size of the triangular and hexagonal particles decreases, while the ratio of number of spherical nanoparticles to triangular\hexagonal particles increases. By varying the temperature of the reaction conditions, the shape, size and optical properties of the anisotropic nanoparticles can be finely tuned[4]. The synthesis of silver nanoparticles from weeds namely, *Ipmomea aquatica, Enhydra fluctuans* and *Ludwigia adscendens*[45]. They have reported the average size of nanoparticles produced by these plant ranges from 100-400nm with inter-particle distance, where as the shapes were spherical and cubic in *I.* aquatic but only spherical in *E. fluctuans* and *L. adscendens*. Moreover pH of the medium also influences a lot the size of nanoparticles. In *Avena sativa*, it was observed that size of the gold nanoparticles can be controlled by altering the pH of medium[44.] A rapid biosynthesis of well-dispersed silver nanoparticles by aqueous *Mangifera indica* leaf extract was reported by Philips[46]. At a pH of 8, the colloid consists of well dispersed triangular, hexagonal and nearly spherical nanoparticles having size of~ 20 nm. In plant-mediated synthesis, the control of the size of silver nano-particles has been proposed to be time –reaction dependent[47]. Basically, the longer the reaction time, the larger the sizes and the nanoparticles change from polycrystalline to single crystalline. Starnes[48] have studied the temporal effects on the formation and size distribution of nanoparticles in *Medicago sativa*, he found synthesis of nano-gold particles as early as 6h following $KAuCl_4$ treatment and the sizes of approximately 65% of these nanoparticles formed were range from 11-20 nm. Further Starnes[48] found that higher pH (7.8) tends to push the sizes of nano-gold particles formed into the 11-20 nm range. Whereas, at pH 3.8 and pH 5.8 the particles revealed more of a bell curved distribution across size classes ranging from 1-10nm to 41-50nm.

In S*esbania drummondii*, *Medicago sativa*, *Brassica Juncea* and in *Chiopsis linearis* different growth variables likes' temperature, pH and light conditions influence shapes of nano-gold. At low pH (3.8) 8 % of total nano-gold particles were found triangle in nature, however, at pH (7.8) hexagonal particles was recorded[48]. It was reported that acidic conditions of sugar beet pulp medium favors production of polynomial nano- particles while basic conditions favors nano-wires[37]. In *Allium sativum* reaction temperature and concentration of extract were major controlling factors for size, polydispersity and reaction kinetic[39] (White *et al.,* 2012). At 60^0 C and 1.5mL concentration of extract nanoparticles were synthesized within 15 minutes compare to 2 h. at 25^0C.

BIO-MOLECULES ASSOCIATED WITH REDUCTION AND STABILIZATION OF NANOPARTICLES

Several parameters together determine the nano-particles synthesis including plant source, the organic compound in the crude extract, the concentration of chemical that act as reducing agent, temperature and pigments of plant modules[49]. From plant, extracellular synthesis of silver and gold nano-particles, biomolucules acts as reducing agents and the heterocyclic compound act as capping agents for the nanoparticles. Different mechanism for the production of silver nanoparticles in xerophytes, mesophytes and in hydrophytes have been proposed[50]. In xerophytes like *Bryophyllum* sp. Phosphenol pyurvate and anthraquinone undergoes tautomerization that leads to reduction of silver ion[51]. In mesophytes like *Cyprus* sp. benzoquionens like cyperquinone (type I), ditechequinone (type II) and remirin (type III) were reported to undergo radial tautomerization for reduction of silver ions. In hydrophytes like *Potamageton* and *Hydrilla* sp. Catechol oxidizes to protactechuic acid through protoacatechaldehyde, presumably with hydrogen participation in the reduction of silver ions and synthesis of silver nano-particles. Flavonoids and terpenoid components of *Azadirachta indica* and *Psidium gaujava leaf* broth being predicted to stabilize nanoparticles[52]. Poly-components and water soluble heterocyclic component of leaf extract of *Helianthus annus, Basella alba* and *Saccharum officiannum* were recognized as a crucial factor for reduction of silver as well as stabilization of nanoparticles[53]. ATR- FTIR analysis of garlic extract revealed that –OH- and –CH were the major stretches and these are the characteristics of sugar. It was stated that sucrose and fructose can function as reducing agent for the synthesis of aqueous dispersion of silver nanoparticles as well as stabilizing ligands for other nanoparticles[39]. It is observed that carbonyl and amide are two important groups involved in the biosynthesis of gold nano-wires from pulp of sugar beet[37]. Similar functional groups were also identified with *Polylthia longifolia* silver nanoparticles[54], while in *Achillea wilhelmsii* flower heterocyclic compound like alkaloid and flavones were major functional groups. The literature describes polyol component and the water-soluble heterocyclic components were mainly responsible for the reduction of silver ions and the stabilization of the nanoparticles, respectively. Thus various primary and secondary metabolites have profound effect on synthesis of nanoparticles.

ANTIMICROBIAL ACTIVITIES OF NANOPARTICLES

Present analysis revealed that most of the phyto-chemically synthesized nanoparticles possessed antibacterial (*Staphylococcus. aureus, E. coli, Corynebaterium diphtheriae, Micrococcus spp., Candida albicans*), antifungal (*Rhizactonia solani, Macrophomina phaseolina, Alternaria alternata, Fusarium oxysporum, Sclerotium rolfsi, Aspergillus niger*) activities. Silver nanoparticles from *Catharanthus roseus* and *Euphorbia prostrate* can control *Plasmodium falciparum* and *Sitophilus oryzae* respectively, while leaf of *Rhizophora mucronata* was larvicidal. Silver nanoparticles an effective germ fighter were wider recognized as being especially effective because of their enormously high surface area[36]. Within bacteria nanoparticles interact with phosphorus and sulphur containing compounds like DNA[54]. It has been concluded that all bacteria use an enzyme (protein) as a form of chemical lung in order to metabolize the oxygen[55]. Silver ions cripple the enzyme and stop the take up of oxygen. This effectively suffocates any bacteria, killing it within 6 minutes and leaving surrounding tissue or material unaffected. Silver inactivates enzymes by reacting with the sulfhydryl groups to form silver sulfides. Silver also reacts with the amino-carboxyl, phosphate and limidazole-group and diminished and activates lactate dehydrogenase and glutathione peroxidase. It has been also reported that DNA loses its replication ability once the bacteria have been treated with silver[56]. It also concluded that silver nano-particles from leaf extract exhibited higher toxicity than that of bark extract[57]. The reason could be that the leaf extract synthesized higher concentration of silver nano-particle because they are site of photosynthesis and availability of more H^+ ions to reduce the silver nitrate into silver nanoparticles. It have proved that antibacterial activities are probably derived through the electrostatic attraction between negative charged cell membrane of microorganism and positively charged nanoparticles[54,57].

NANOPARTICLES AND HERBAL DRUGS

Nano-coating of active components of herbal formulation was effective in protecting the active drug molecule from oxidative, hydrolytic and environmental degradation processes and hence enhances the shelf-life of the herbal products. In phyto-formulation research, developing nano dosage forms [polymeric nanoparticles (nano-spheres and nano-capsules), liposomes (protection from enzymatic degradations), proliposomes, solid lipid nanoparticles, nano-emulsion, etc. has a large number of advantages for herbal drugs, including enhancement of solubility and bioavailability, protection from toxicity, enhancement of pharmacological activity and stability[58] . Liquid dosage compositions of stable nano-particulate drugs have improved stability than the conventional dosage forms. Eleven different nano-coating herbal formulations are presented in table 2. Traditional forms of these herbal products possessed many drawbacks like lower aqueous solubility, stability and lesser targeted activities. Nono-coating of these herbal products provides higher solubility and enhances their delivery system. For production of such smart drugs, various non-green techniques like micro-emulsion, ionic gelation, dialysis, self assembly, nano suspension and rotary-evaporated film-ultra-sonication methods were utilized[59].

GAPS

Following gaps were identified with relation to various aspects of phyto-synthesis of nanoparticles,

1. Studied revealed that most of the biomimetic efforts were carried out for production of silver and gold nano-particle. In order to enhance the agricultural production now it is essential that efforts must be carried out for the synthesis of important nutrients (like phosphorus, zinc, magnesium, iron etc.) in a nano-particle forms so that their availability and targeted distribution may be achieved.
2. There is a need to evaluate role of these green nanoparticles for treatment of disorders related with different corporeal system. Efforts have been carried out to analysis of gold nanoparticles derived from stem bark of *Cassia fistula* for controlling diabetes mellitus[60].
3. Biological distribution of phyto-synthetic nanoparticles need to be addressed. Such studies are very important for smart drug delivery system. Tissue bio-distribution of gold nanoparticles was size dependent and 15 to 50 nm gold nanoparticles able to pass blood-brain barrier. Some of the disease like Alzmier and Parkinson need very target oriented drug that can worked on specific groups of neuron[61].
4. Different primary and secondary metabolites reported an important role for the reduction of metal ion to nano-particles; however, within plant temporal variation in concentration of these metabolites persist. Thus correlation studies between temporal variation in concentration of metabolites and rate, size, shape of nanoparticles need to establish.
5. Size and shape of botanical nanoparticles are well studied but information regarding the yield of these nanoparticles need to measures.
6. Identification of different biological\environmental friendly and cost effective methods for production of nano-coated herbal products.

S. No	***Plant Name***	**Plant Part use**	**Agent**	**Time duration of changes in colour**	**Absorption peak**	**Size (nm)**	**Shape**	**Effective Against**	**Reference**
1	*Achillea wilhelmsii*	Flower	Hydrogen tetra chloraurate	-	540nm	70	Spherical	-	62
2	*Acorus calamus*	Rhizome	Silver nitrate	8h.	425nm	18.6-37.9	Spherical	Anti-bacterial and anti-fungal	63
3	*Allium cepa*	Bulb	Silver nitrate	2h.	413nm	40	Spherical	Anti-bacteiral	55
4	*Allium sativum*	Chopped garlic	Silver nitrate	-	404nm	133 nm	Spherical	Anti-bacteiral and anti-fungal	39
5	*Aloe vera*	Leaves	Indium (III) acetylacetonate	2 h.	288nm	30-50	Spherical	-	31
6	*Aloe vera*	Leaves	Hydrogen tetra chloraurate	5h.	455nm	54-80	Triangle	Anti-bacteiral and antifungal	20
7	*Andropogon muricatus*	Root	Silver nitrate	8h.	501nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
8	*Azadirachta indica*	Leaf	Hydrogen tetra chloraurate	15 min	550 nm	50-100	Spherical	-	49 &64
9	*Basella alba*	Leaf	Silver nitrate	-	431nm	-	-	-	64
10	*Berberis aristata*	Wood	Silver nitrate	8h.	453nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
11	*Boswellia ovalifolialata*	Stem bark	Silver nitrate	2h.	430nm	30-40	Spherical	-	65
12	*Calotropis procera*	Latex	Zinc acetate dehydrate, sodium hydroxide	-	368nm	5-40	Spherical and granular	-	66
13	*Camellia sinensis*	Leaves	Silver nitrate	-	-	50-150	Triangle	-	1
14	*Carica papaya*	Fruit	Silver nitrate	4 h.	450 nm	25-50	Cubic	Anti-bacteiral	1
15	*Cassia fistula*	Stem bark	Hydrogen tetra chloraurate	-	529nm	55.2-98.4	-	Hypoglycemic activities in rats	60
16	*Catharanthtus roseus*	Leaf	Silver nitrate	6 h.	-	35-55	Cubical	Plasmodium falciparum	32
17	*Cedrus deodara*	Wood	Silver nitrate	2h.	429.2nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63

18	*Celastrus paniculata*	Seed	Silver nitrate	8h.	425.2nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
19	*Cinnammum canphora*	Sun dried leaf	Hydrogen tetra chloraurate	-	454nm	50-85	Triangle	Anti-bacterial and anti-fungal	25
20	*Citrus limon*	Leaves	Silver nitrate	2.5 h.	557nm	8-12	Variable shape	Ant-fungal	67
21	*Cleome viscose*	Leaf	Silver nitrate	2 h.	455nm	7-50	Spherical	-	68
22	*Commiphra weightii*	Resin	Silver nitrate	6h.	428nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
23	*Coriandrum sativum*	Fruit	Silver nitrate	8h.	432nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
24	*Cuminum cyminum*	Fruit	Silver nitrate	4h	466nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
25	*Cycas*	Leaf	Silver nitrate	-	-	-	Spherical	-	51
26	*Cymbopogan citrates*	Leaf	Silver nitrate	10 min.	430 nm	32	Spherical	Anti-bacterial and anti-fungal	69
27	*Cymbopogan citrates*	Leaf	Hydrogen tetra chloraurate	-	450 nm	35	Triangle	-	44
28	*Cynodon dactylon*	Entire plant	Silver nitrate	-	420 nm	25	Spherical	Anti-bacteiral	70
29	*Dioscorea bulbifera*	Tuber	Hydrogen tetra chloraurate	90 min	300 nm	9-12	Spherical	-	71
30	*Dioscorea oppositifolia*	Rhizome	Silver nitrate	-	409nm	14	Spherical	Anti-bacterial and anti-fungal	33
31	*Eclipta alba*	Leaf	Silver nitrate	10 min	445nm	40	Spherical	Anti-bacterial and anti-fungal	72
32	*Elettaria cadamomom*	Seed	Silver nitrate	4 h.	440-480nm	40-70	Spherical	Klebsiella planticolla (MTCC 2277), Bacillus subtilis (MTCC 3053)	73
33	*Embelia ribes*	Fruit	Silver nitrate	8h.	459nm	100	Spherical	Anti-bacterial and anti-fungal	63
34	*Enhydra fluctuans*	Leaf	Silver nitrate	-	-	100nm	Spherical	-	45
35	*Eucalyptus hybrid*	Methanolic extract of leaf	Silver nitrate	3 h.	412 nm	50-150	Cubical	-	74
36	*Euphrbia hirta*	Leaf	Silver nitrate	-	430 nm	40-50	Spherical	Anti-fungal	75

37	*Euphrbia prostrate*	Leaves	Silver nitrate	-	420nm	52.4	Spherical	Sitophilus oryzae	76
38	*Glycyrrhiza glabra*	Root	Silver nitrate	-	430 nm	20	Spherical	-	77
39	*Helianthus annus*	Leaf	Silver nitrate	-	440nm	-	-	-	49
40	*Hemisesmus indicus*	Root	Silver nitrate	8h.	444.6nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
41	*Holarrhena antidysenterica*	Seed	Silver nitrate	2h.	455nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
42	*Ipomora aquatic*	Leaf	Silver nitrate	-	-	150nm	Spherical and cubic	-	45
43	*Lantana camara*	Leaf	Silver nitrate	-	430 nm	40	Spherical	-	78
44	*Ludwigia adscendens*	Leaf	Silver nitrate	-	400nm	400nm	Spherical	-	45
45	*Melia azadirachta*	Bark	Silver nitrate	6h.	439.8nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
46	*Mirabilis jalapa*	Flower	Hydrogen tetra chloraurate	2 h.	570nm	60-70	Spherical	-	79
47	*Momordica charantia*	Fruit	Hydrogen tetra chloraurate	-	536nm	30-40	Cubical	-	42
48	*Morinda pubescens*	Leaves	Silver nitrate	-	430nm	15	Spherical	-	80
49	*Moringa oleifera*	Leaf	Silver nitrate	1 h.	430-440nm	57	Spherical	Anti-bacterial and anti-fungal	81
50	*Mucuna pruriens*	Seed	Chloroauric acid	10 min	537 nm	12.5	Spherical	-	82
51	*Murraya koenigii*	Leaves	Silver nitrate	2 h.	435nm	19-Feb	Spherical and ellipsoidal	-	43
52	*Negella sativa*	Seed	Silver nitrate	4h.	442nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
53	*Nerium oleander*	Leaves	Silver nitrate	-	-	48-67	Cubical	Anti-fungal	83
54	*Nyctanthes arbor-tristis*	Ethanolic leaf extract	Titanium tetraisoproxide	-	-	100-150	Spherical	-	84
55	*Ocimum sanctum*	Leaf	Silver nitrate	2 h.	-	Jan-00	Spherical	Anti-bacterial and anti-fungal	85
56	*Ocimum sanctum*	Root and stem	Silver nitrate	11 h.	442nm	-	Cubic	Anti-bacterial and anti-fungal	86

57	*Opuntia ficus*	Cladoddes	Silver nitrate	-	398nm	8-50nm	Spherical	-	47
58	*Oryza sativa*	Leaf	Silver nitrate	-	269nm	-	-	-	49
59	*Padina ttrasformatica*	Leaf	Silver nitrate	-	426nm	20nm	-	-	87
60	*Parthenium hysterophorus*	Leaves	Silver nitrate	-	-	40-50	Irregular	-	1
61	*Phyllanthus amarus*	Leaf	Silver nitrate	-	420 nm	32-53	Spherical	-	63
62	*Phyllanthus amarus*	Leaf	Hydrogen tetra chloraurate	-	580 nm	65-99	Cubic	-	88
63	*Plumbugo rosea*	Root	Silver nitrate	6 h.	519.6	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
64	*Polyalthia longifolia*	Leaf	Silver nitrate	1 h.	435 nm	15-20	Spherical	Anti-bacterial and anti-fungal	54
65	*Pomegranate*	Seed	Silver nitrate	4 h.	430 nm	30	Spherical	-	89
66	*Pongamia pinnata*	Leaf	Silver nitrate	-	-	20-50	Spherical	Anti-bacterial and anti-fungal	45
67	*Psoralea corylifolia*	Seed	Silver nitrate	2h.	429.8nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
68	*Putranjiva roxburghii*	Leaf	Hydrogen tetra chloraurate	15 min	544nm	24-38	-	-	90
69	*Rhizophora mucronata*	Leaf	Silver nitrate	-	420nm	60-95	-	Larvicidal against mosquito	91
70	*Saccharum officinarum*	Leaf	Silver nitrate	-	251nm	-	-	-	49
71	*Salvia officinalis*	Leaves and Flower	Hydrogen tetra chloraurate	-	440 nm	-	-	-	92
72	*Seena saimea*	Leaf	Silver nitrate	5 h.	470nm	-	-	Anti-bacterial and anti-fungal	93
73	*Shorea tumbuggaia*	Stem bark	Silver nitrate	15 min	350nm	-	Spherical	Anti-bacterial and anti-fungal	57
74	*Smilax china*	Root	Silver nitrate	4h.	467.8	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
75	*Sorghum bicolor*	Leaf	Silver nitrate	-	251nm	-	-	-	49
76	*Sueada monoica*	Leaf	Silver nitrate	5 h.	430nm	31	Spherical	-	94
77	*Svensona hyderobadensis*	Leaves	Silver nitrate	15 min	300-400nm	-	Spherical	Anti-bacterial and anti-fungal	57

78	*Trianthema decandra*	Root	Silver nitrate	5 h.	450nm	15	Cubic and Hexagonal	Anti-bacterial and anti-fungal	21
79	*Tribulus terrestris*	Fruit	Silver nitrate	-	-	16-28	Spherical	Anti-bacterial and anti-fungal	95
80	*Tridax procumbens*	Leaf	Silver nitrate	-	460 nm	-	-	Anti-bacterial and anti-fungal	96
81	*Trigonella foenum-graceum*	Seed	Silver nitrate	2h.	435nm	33-45.9	Spherical	Anti-bacterial and anti-fungal	63
82	*Vitex negundo*	Leaf	Silver nitrate	4 h.	-	-	-	Anti-bacterial and anti-fungal	97
83	*Zea mays*	Leaf	Silver nitrate	-	255nm	-	-	-	49

Table 2. Nano-particle containing herbal drugs

Name of Bioactive component	Botanical sources	botanical sources uses as	Drawback associated with botanical sources	Application of bioactive component with nano-particles	References
Paclitaxel	Pacific yew tree (*Taxus brevifolia)*	Anticancer	Lesser uptake of crude drug, environmentally not friendly	Paclitaxelnanoparticles having short-term stability, drug entrapment efficiency and high blood- brain permeability.	98 &99
Curcumin	*Curcuma longa*	Anticaner	Poor aqueous solubility	Increase solubility, enhance antioxidant and atihepatoma activities	100 &101
Dodder	*Cuscuta Chinensis*	Liver and Kidney tonic	Poor aqueous solubility	Increase solubility and enhance its hepat-otixicity at lower concentration	102
Triptolide	*Tripterygium wilfordii*	Use as anti-inflammatory, anti-fertility, anti-neoplastic	Poor aqueous solubility and undesirable toxic effects	Higher anti-inflammatory activites and increase solubility	103
Danshen	*Salvia miltiorrhiza*	Promotes blood circulation, antioxidant	Slow pharmacological action	Decrease duration of drug action	104
Zedoary turmeric oil	Turmeric	Anticancer agent	Hydrophobic properties, poor stability and low bioavailability	Increased stability and drug loading	105 &106

Quercetin	Quercetin is an important flavonoidal antioxidant and it can be found in fairly large amounts in fruits, vegetable oils, red wine and tea	Antioxidant property and is effective against neurodegenerative diseases	Slow drug release	Increased drug release and its antioxidant activities	107
Silybinin	*Carduus marianus*	Hepatoprotective	Lower solubility and bioavailability	Increase bioavailability due to increase in circulation time and solubility	108
Camptothecin	*Camptotheca acuminata*	Anti-cancer	Hydrophobic properties, lower physiological stability	Increase aqueous solubility	109
Glycyrrhizic acid	Glycyrrhiza glabra	Anti-inflammatory and antihypertensive	Lower stability	Enhance physiological stability	110
Res-Q	Poly Herbal drug containing *Abies wabbiana, Aadhatoda vasica, Glycyrrhiza glabra, Pistacia intergerrima, Ricinus communis, Zingiber offieinale,Cinnamomum zeylanicum, piper langum),*	Useful in respiratory disorders	Lesser targeted drug and slow in action	Mouth dissolving drug reached the blood directly	111

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