

The Green route of Silver nanotechnology: Phytosynthesis and applications

Hilal Ahmad^{1,*}; Kalyanaraman Rajagopal¹; Ashiq Hussain Shah²

¹Department of Biotechnology, School of life sciences, Vels University (VISTAS) Chennai-600117 India

²CoET, Baba Ghulam Shah Badshah University, Rajouri, Jammu and Kashmir – 18513 India

Received 07 July 2015; revised 30 September 2015; accepted 05 October 2015; available online 02 May 2016

ABSTRACT: Silver nanoparticles (AgNPs) are amongst the most investigated materials in nanotechnology in view of their unique physio-chemical features and applications in restorative science. Their progressive usage in different fields of science and some predominant restrictions with conventional methods for their synthesis have demanded analysts to discover green courses for their creation. Biological methods are the preferred to combat with the issues concerned with the nanoparticle synthesis. Within this decade, thousands of plants have been screened to analyze the final impact on characterization and morphology of AgNPs compared to general modes of their synthesis. Phytosynthetic method is an eco-friendly route that can lead to an advanced production of silver nanoparticles with controlled morphology. We herein reviewed the present aspects of phytosynthesis of AgNPs and their importance in modern science. Moreover, overviews of proposed mechanisms in this technology have also been included, which ultimately provide some insights of their safe use and demand for further research.

Keywords: Ecofriendly; Green synthesis; Nanotechnology; Nanomaterials; Phytosynthesis; Plant extract; Silver nanoparticles

How to cite this article:

Ahmad H, Rajagopal K, Hussain Shah A. The green route of Silver nanotechnology; phytosynthesis and applications. *Int. J. Nano Dimens.* 2016; 7(2): 97-108. DOI: 10.7508/ijnd.2016.02.001

INTRODUCTION

Nanotechnology is the branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules. Nanomaterials often have a significant degree of difference in physico-chemical and biological properties when compared to their macroscale counterpart, in spite of the similar chemical compositions they possess [1].

Among the various inorganic metal nanoparticles, silver nanoparticles [AgNPs] have emerged as one of the most intensively studied areas in the field of nanotechnology due to their well-known effectiveness in various fields [2]. AgNPs applications in biomedical [3-5], drug delivery [6], food industries [7], agriculture [8], textile industries [9], water treatment [10],

catalysis and surface-enhanced Raman scattering [11] have been reviewed more. Thus, their applications in various fields have demanded researchers to create an ecofriendly route for their mass production [12, 13]. By way of green synthesis methodology, it is expected to develop and implement the nano products and processes to reduce or eliminate the use and generation of substances that are hazardous to human health and the environment.

Nevertheless, the use of plants for the synthesis of AgNPs is in focus of intensive research because of its eco-friendly nature. The use of plants boasts of several advantages such as elimination of elaborate processes of maintaining cell cultures, easy scale up for large-scale synthesis and cost-effectiveness. Moreover, plant extracts may act as both reducing agents and stabilizing agents in the synthesis of nanoparticles [14]. In this article, we aim to

✉ *Corresponding Author: Hilal Ahmad
Email: hhiillaallbiotech@gmail.com
Tel.: (+91) 9003926919; Fax: (+91) 9003926919

elaborate the different ways of how plants have been used to generate the silver nanoparticles.

Further, the article covers some important mechanisms proposed by different researchers that have been briefly explained here.

Phytosynthesis of silver nanoparticles

Compared to other green sources, plants are emerging as advantageous because the presence of broad and variable bio-molecules in plants can act as capping and reducing agents and thus increases the rate of reduction and stabilization of nanoparticles. Since plants differentiate in their concentrations and combinations of organic reducing agents, the source of the plant extract is known to influence the characteristics and morphology of the nanoparticles [14, 15].

Parameters of phytosynthesis of silver nanoparticles and their role

The reduction reaction, which brings about AgNPs development, is basically controlled by specific parameters, which impact the rate of synthesis and characterization of AgNPs. Researchers call them as altering factors in the nanoparticle formation and morphology, have revealed these parameters, which include reaction temperature, pH, substrate concentration, and exposure time to the substrate [16, 17]. The controlled production of some essential morphology like plates, discs, rods, wires and/or size, and size distribution of AgNPs heavily alters their application like electromagnetic field enhancement property. Thus, it became necessary to review the parameters which mainly influence the properties of nanoparticles.

I. Reaction temperature

As indicated by studies the reaction temperature can significantly impact response rate, and thus the particle qualities [18, 19 and 20]. The size of silver nanoparticles increases with temperature [17, 19 and 21]. The profile and growth trend of measurements of silver particles are apparently different at different temperatures. The higher the reaction temperature the faster the silver nanoparticles grow and with the temperatures increasing, the triangular silver nanoplates and spheres grow larger. This is because of the phenomenon of particle fusion mechanism [19, 22, and 23]. Moreover, a high temperature leads to reaction too faster because some of the reducing

agents of reaction mixture become more active at higher temperatures [17, 24 and 25]. Thus, in general, the variation in temperature of the reaction system heavily affects the reaction capability of components in reduction, surfactant adsorption/desorption, and complexation stability, the formation and growth rate, and hence the morphological distributions [19].

II. pH

Like temperature, pH is one of the most important factors for nanoparticle formation. There is a parallel relation of nanoparticle formation with increasing pH [17, 26 and 20]. The alkaline pH is seen to be favorable for the nanoparticle formation than the acidic pH. The possible reason may be because more precipitation or agglomeration occurs due to lack of stabilizing agents and may be due to the ionization of the phenol group present in the extract at neutral or alkaline pH. Thus, the rate of formation of AgNPs is high in basic pH than in acidic pH [27]. According to some studies, the formation of AgNPs occurs rapidly in neutral and basic pH, which is evident from observation, and this may be due to the ionization of the active groups present in the PE [27]. However, at acidic pH, the electrostatic repulsion of anions present in the solution may slow down the rate of formation and aggregation of AgNPs at this pH [28].

III. Substrate concentration

The effect of increasing molarities of AgNO_3 and plant extract broth concentration on the phytosynthesis and thus characterization of AgNPs has been revealed [17, 20 and 29]. The increase in concentration of AgNO_3 in the reaction mixture marks a gradual up of Surface Plasmon Resonance (SPR) bands [20, 30]. It was seen that the increase in metal concentration enlarges the AgNPs size while as with increase in PE quantity decreases the particle size of the AgNPs [20, 31].

IV. Role of Phytogenic source

Since the phyto-chemistry of plant kingdom is quiet large. This variation is seen among various species of same family to different parts of the same plant source [32]. Different authors have used separate plant parts for phytosynthesis showing a perfect result of AgNPs formation and it was seen that the specific plant part acts differently to reduce Ag to Ag^0 [33- 35]. With this phenomena it can be empathized that each plant part and /or plant source has a steady impact upon the amalgamation of AgNPs [Table 1.].

Table 1. Use of different plants for phytosynthesis of AgNPs and their characterization

Plant used	Reaction Temperature (°C)*	Size (nm)	Shape**	References
<i>Moringa oleifera</i>	RT	57	NA	[36]
<i>Trachyspermum ammi</i>	RT	87-99	Triangular	[37]
<i>Papaver somniferum</i>	25°C	3-8	Spherical	[38]
<i>Acalypha indica</i>	25°C	20-30	Spherical	[38]
<i>Terminalia chebula</i>	RT	25	Crystalline	[39]
<i>Sorbus aucuparia</i>	25°C	16-18	Spherical, Triangular and Hexagonal	[40]
<i>Boswellia serrata</i>	RT	7.5	Spherical	[41]
<i>Allium sativum</i>	RT	4-22	Spherical	[42]
<i>Datura metel</i>	RT	16-40	NA	[43]
<i>Coleus aromaticus</i>	RT	44	Spherical	[17]
<i>Aloe vera</i>	RT	50-350	Spherical, Triangular	[44]
<i>Pinus desiflora</i>	RT	15-500	Cubic	[25]
<i>Annona squamosa</i>	RT	20-100	Spherical	[84]
<i>Cissus quadrangularis</i>	70°C	37-44	Spherical, rod and Triangular	[17]
<i>Euphorbia hirta</i>	25°C	40-50	Spherical	[45]
<i>Desmodium triporum</i>	25°C	5-20	NA	[46]
<i>Anacardium occidentale</i>	27°C	6	NA	[47]
	100°C	17	NA	[47]
<i>Musa paradisiaca</i>	25°C	20	NA	[48]
<i>Desmodium triporu</i>	25°C	16-40	multistructural	[43]
<i>Ceratonia siliqua</i>	RT	5-40	Spherical	[49]
<i>Chenopodium album</i>	25°C	10-30	Quasi-Spherical	[50]
<i>Trachyspermum copticum</i>	RT	6-50	NA	[51]
<i>Artemisia nilagirica</i>	RT	70-90	Spherical, Triangular, Hexagonal	[51]
<i>Jatropha curcas</i>	RT	10-20	Crystalline	[33]
<i>Jatropha curcas</i>	RT	15-50	Spherical	[33]
<i>Argemone maxicana</i>	RT	30	Cubic, Hexagonal	[52]
<i>Syzygium cumini</i>	RT	29-92	Spherical	[53]
				[129]
<i>Acalypha indica</i>	RT	20-30	Crystalline	[38]
<i>Swietenia mahogani</i>	RT	20-100	NA	[54]
<i>Coscinium fenestratum</i>	RT	28.5-68.0	Rod shaped	[55]
<i>Rhododendron dauricum</i>	RT	25-30	Spherical	[56]
<i>Nelumbo nucifera</i>	RT	25-80	Spherical, Triangular	[57]
<i>Sesuvium portulacastrum</i>	RT	5-20	Spherical	[32]
<i>Rumex hymenosepalus</i>	RT	2-40	FCC, Hexagonal	[58]
<i>Mentha piperita</i>	RT	5-150	Spherical	[59]
<i>Ocimum tenuiflorum</i>	RT	25-40	Spherical	[60]
<i>Platanus orientalis</i>	RT	15-500	Cubic	[25]
<i>Ocimum sanctum</i>	RT	157.2	NA	[61]
<i>Ginkgo biloba</i>	RT	15-500	Cubic	[25]
<i>Mentha piperita</i>	28°C	90	Spherical	[62]
<i>Murraya keenigii</i>	RT	10	Crystalline, Spherical	[63]
<i>Pelargonium graveolens</i>	RT	16-40	Crystalline	[64]
	25°C	35		
<i>Citrus sinensis</i>	60°C	10	Spherical	[65]
<i>Memecylon edule</i>	25°C	20-50	Triangular, Circular,	[66]

Continued Table 1.

Plant used	Reaction Temperature (°C)*	Size (nm)	Shape**	References
<i>Rosa rugosa</i>	25°C	30-60	NA	[40]
<i>Piper pedicellatum</i>	RT	2.0-30	Spherical	[44]
<i>Catharanthus roseus</i>	25°C	48-67	NA	[67]
<i>Camelia sinensis</i>	25°C	30-40	NA	[68]
<i>Lawsonia inermis</i>)	25°C	7.5-65	Spherical, Triangular, quasiSpherical	[69]
<i>Gelidiella acerosa</i>	25°C	22	NA	[27]
<i>Solanum torvum</i>	RT	1-100	Spherical	[70]
<i>Eclipta prostrata</i>	RT	35-60	Triangular, Pentagonal, Hexagonal	[71]
<i>Cinamomum camphora</i>	RT	55-80	NA	[72]
<i>Euphorbiae latex</i>	RT	18	NA	[73]
<i>Garcinia mangostana</i>	RT	35	NA	[74]
<i>Solanum trilobatum</i>	RT	15-20	Cubic and Hexagonal	[75]
<i>Boswellia ovalifoliolata</i>	RT	30-40	NA	[76]
<i>Catharanthus roseus</i>	RT	48-67	Spherical	[15]
<i>Coleus aromaticus</i>	RT	44	NA	[77]
<i>Cassia auriculata</i>	RT	20-40	Spherical	[18]
<i>Trianthema decandra</i>	RT	17.9-59.6	Spherical	[79]
<i>Artocarpus heterophyllus</i>	121°C	10.78	Irregular	[41]
<i>Mangifera indica</i>	RT	20	Spherical, Triangular, Hexagonal	[80]
<i>Coleus amboinicus</i> Lour	RT	25	NA	[81]
<i>Azadirachta indica</i>	>100°C	20-50	Cubic	[82]
<i>Citrullus colocynthis</i>	RT	31	Spherical	[83]
<i>Zingiber officinale</i>	RT	6-20	Spherical	[34]
<i>Piper betle</i>	RT	3-37	Spherical	[84]
<i>Svensonia hyderabadensis</i>	RT	45	Spherical	[85]
<i>Moringa oleifera</i>	25°C	58	NA	[87]
<i>Pelargonium graveolens</i>	25°C	16-40	NA	[149]
<i>Carica papaya</i>	25°C	25-50	NA	[86]
<i>Nicotiana tobaccum</i>	RT	8	Crystalline	[87]

*Where RT is meant for room temperature and has been declared where some authors did not mention reaction temperature.

** NA is placed where authors have not mentioned the shape of AgNPs.

Proposed mechanism for Silver Nanoparticles phytosynthesis

I. Metal reduction by phytochemicals

It has been analyzed that phytochemicals are the key sources of nanoparticle synthesis. The reduction of Ag ions to Ag⁰ is likely dependent upon type of active compounds present in a plant extract.

Mostly the reduction occurred due to the presence of flavonoids [88], phenols [89, 39, 54], proteins, flavones and terpenoids [32], saponins [66], polyhydroxy limonoids [90], quinones [91] or other active ions like amine group [-NH₂], carbonyl group, -OH groups [92], polyol components [72], chlorophyll [63], in the respective plant extract solution. Thus, according to phytochemical reduction concept the synthesis of silver nanoparticles can be possibly

achieved by any plant extract owing to the presence of active components in the plant source under consideration [93, 64].

II. Concept of photosynthesis of AgNPs

According to some researchers, synthesis of silver nanoparticles is a photochemical reaction where green plant parts are used as photo centers. As in photosynthesis, here many chlorophyll pigments serve as an antenna, collecting light and transferring its energy to the reaction center. In the reaction center the silver ions, which entered in to the plant cell via the H⁺ ATPase protein embedded in the thylakoid membrane, is reduced to form silver nanoparticles by proteins embedded inside the plasma membrane. According to some authors [43], the following four

observations were recorded in the reaction system; a) Silver [Ag⁺] ions act as an electron donor molecule. b) Plastoquinone [PQ] acts as an electron acceptor molecule. c) Chlorophyll pigments act as a stabilizing agent by stabilizing reaction between electron donor and electron acceptor molecules. d) Plasto-hydroquinone or quinol [alcoholic agent] acts as a main reducing agent for reduction of silver ion to silver metal, both oxidation and reduction reactions carried out by different are reducing and oxidizing agent.

III. Metal reduction by reductases

In plant extracts, the NADH-dependent reductase can act as an electron carrier to transport electrons from NADH to metallic silver for their reduction. One such probable mechanism for AgNPs biosynthesis has been reported by Kalimuthu K et al. in 2008 and Ahmad K et al in 2010 [94, 95]. The biosynthesis of nanoparticles by reductases as reported earlier suggest that the nitrate reductase catalyzes the reduction of AgNO₃ to silver nanoparticles utilizing NADPH as reducing agent [38, 96 and 97].

Biological applications of Silver Nanoparticles

(a) Application in cancer therapy

The production of Silver nanoparticles through phytosynthesis has shown advanced cytotoxic effect against various cancer cell lines. This property of AgNPs has thus attracted oncologists for their use since it targets the mitochondrial system thereby limiting ATP and altering other biological mechanistic pathways for cell survival [98].

Different cell types investigated for their cytotoxicity using AgNPs including NIH 3T3 fibroblast cells [99], HeLa cells [100] and human glioblastoma cells [101]. The cytotoxic effect of AgNPs synthesized using *Piper longum* also had significant cytotoxic effect [94%-500ug/ml] against invasive cells of Hep-2 cell line [102].

The AgNPs synthesized using *Annona squamosa* [27], *Coscinium fenestratum* [55], *Melia azedarach* [103], *Piper longum* [104], *Eucalyptus chapmaniana* [105] and *Albizia adianthifolia* [106] had some advanced results against HEP-2, MCF-7 [human breast cancer], HeLa [cervical cancer], HEP-2, HL-60 [human acute promyelocytic leukemia] and A549 [lung cancer] cancer cell lines, respectively. These results clarify that AgNPs generally show cytotoxicity to carcinoma cells when compared with normal cell

lines. Mechanism of action: MTT and LDH assays are the mostly used techniques to determine cytotoxicity of AgNPs. The mechanisms for AgNP-induced toxicity may be related to mitochondrial damage, oxidative stress, DNA damage and induction of apoptosis [102]. It is also proposed that the cytotoxic effect of AgNPs is due to the physicochemical interaction of silver atoms with the functional groups of intracellular proteins, as well as with the nitrogen bases and phosphate groups in DNA [83, 107].

(b) Application in anti-microbial activity

Antibacterial activity: Bio-synthesized silver nanoparticles exhibited better antibacterial activity against most human pathogens [108]. Antimicrobial activity of silver nanoparticles synthesized by specific commercial plant extracts has been investigated against various pathogenic organisms. Extracts of *C. sinensis* and *C. asiatica* were used to study the effect of AgNPs against *Streptococcus aureus*, *P. aeruginosa*, *E. coli* and *K. pneumoniae* [109]. AgNPs synthesized from *Trianthema decandra* were more pronounced in Gram-negative bacteria than Gram-positive ones [110]. The AgNPs synthesized using extract of *Ocimum sanctum* were effective against a resistant of *Streptococcus aureus* and *B. megaterium* being resistant against Ampicillin, Penicillin, Cloxacillin, Ceftazidime, Methicillin and Ceftazidime and Cloxacillin, respectively [61]. The AgNPs synthesized using *Ocimum sanctum* leaf extracts had significant antimicrobial activity against both Gram-negative [*E. coli*] and Gram-positive [*Streptococcus aureus*] microorganisms [111] which corresponds with that of *Ocimum tenuiflorum* being active against Gram-negative and Gram-positive bacteria [60]. Moreover the antibacterial activity against ampicillin-resistant *Escherichia coli* and multi-drug resistant *E. coli*, *S. aureus*, and *Salmonella typhi* strains was also investigated [112]. About 10-35 nm size AgNPs synthesized using peel extract of *Citrus sinensis* reported a broad spectrum antibacterial activity [65].

Anti-fungal activity of AgNPs: The anti-fungal activity of AgNPs has been reported against both human and some phytopathogens. Padma S. et al evaluated AgNPs against some crop pathogens like *Fusarium oxysporum* and *Alternaria brassicicola* using agar diffusion method [113]. The disease incidence of powdery mildew in cucumbers and pumpkins was efficiently controlled by AgNPs both *in vitro* and in field conditions when compared to commercial

fungicides [114]. Some other findings also support the effectivity of AgNPs against phytopathogens [115-119]. However, some studies support cytotoxicity and genotoxicity effects of AgNPs on the plant anatomy [120-128]. On the other hand, substantial inhibition of fungal species was obtained in terms of zone of inhibition in the plate against human pathogens namely *Candida albicans* [79,129], *Candida lipolytica* [48], *Candida parapsilosis* [79, 130 and 75]. In addition it was also demonstrated that these nanoparticles [from *Solanum trilobatum*] when mixed with shampoo enhance the anti-dandruff effect against dandruff causing fungal pathogens namely *Pityrosporum ovale* and *Pityrosporum folliculitis* [131].

Anti-plasmodial activity of AgNPs: According to some studies, AgNPs synthesized using *Ammannia baccifera* show significant toxic effects against fourth instar larvae of two mosquito species, *Anopheles subpictus* and *Culex quinquefasciatus*. The larvae were exposed to varying concentrations of AgNPs for 24 h to analyze the larvicidal effect. The AgNPs were toxic against the larvae of *A. subpictus* with an LC50 = 29.54 ppm and against the larvae of *C. quinquefasciatus* with LC50 = 22.32 ppm [132]. The larvicidal activity of AgNPs against ulariasis and malaria vectors was also reported using *Eclipta prostrate* as biogenic agent [133].

Mechanism of antimicrobial action of AgNPs

The exact mechanism for the growth inhibition by Ag nanoparticles has not yet been elucidated, but many possible mechanisms have been proposed. The effect of silver ions on microbe can be observed by

the structural and morphological changes. Some of the researchers have tried to generate the mechanism of AgNPs upon targeting microbes, which can be explained under two broad concepts (Fig. 1).

Extra-cytol aberration concept

According to this concept, AgNPs get attached to the surface of bacterial membrane thus disturbing its permeability (Fig. 2). This also interferes with the respiration ability of a cell during their interaction [134]. This concept is widely accepted while researchers propose that AgNPs has a higher tendency to react with phosphorus and sulfur compounds present in the membrane of bacterial cells, which readily causes the bacteria to lose its ability to replicate [135]. The electrostatic attraction in the cell wall membrane with negatively charged and silver nanoparticles with positive charge makes them to interact and get attached [136-38]. After attachment, the silver nanoparticles associated with thiol groups of cell wall result in generation of reactive oxygen species and disrupt the cell [139- 143] or AgNPs may form 'pits' in the cell wall after attachment and finally affects the permeability, and cause cell death [144]. Moreover, the attachment ruptures the cell wall, which leads to denaturation of proteins and finally leading to cell death [145]. It may also cause accumulation of envelope protein precursors or affect the function of membrane-bound enzymes on the cell wall, which results in dissipation of the proton motive force.

This leads to destabilization of the outer membrane after which it ruptures and finally causes depletion of intracellular ATP [36, 144, 146 and 147].

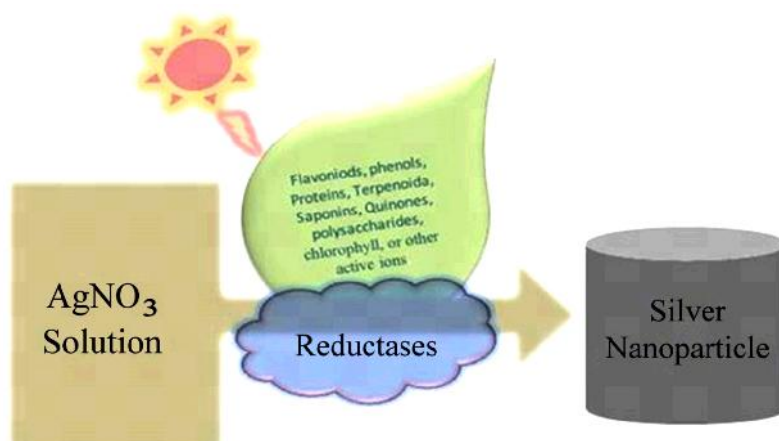


Fig. 1: Mechanism of AgNP Phytosynthesis by using concepts of Metal reduction, AgNP phytosynthesis and Reduction by Reductases.

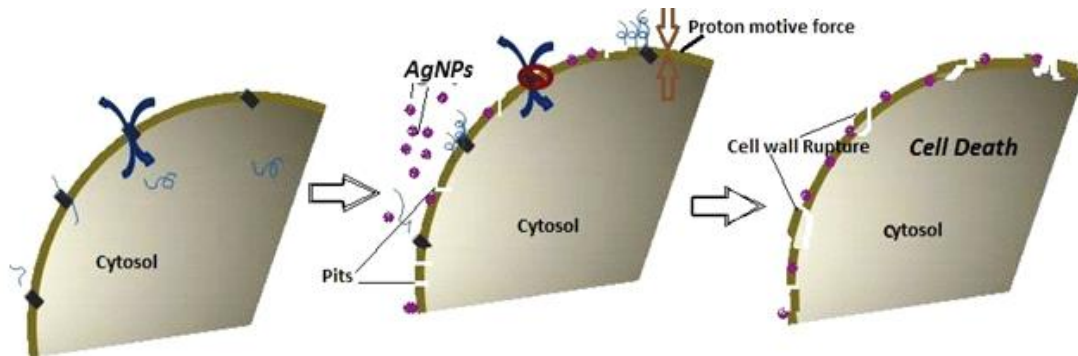


Fig. 2: Extra-cytol aberration of microbial cell by AgNPs.

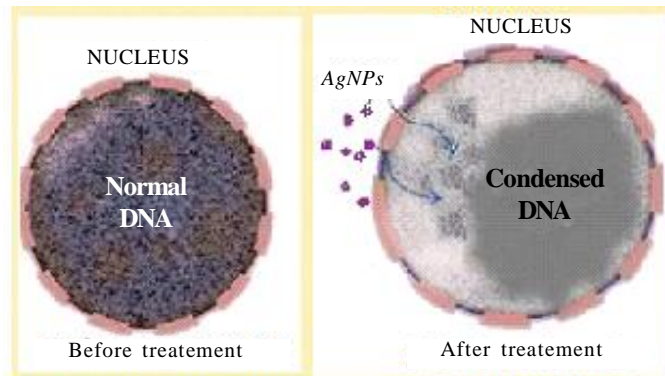


Fig. 3: Intra-cytol aberration of microbial cell by AgNPs.

Intra-cytol aberration concept

This concept takes into account the interference of AgNPs with the macro molecules like proteins, DNA and RNA. It is assumed that the DNA loses its replication ability in condensed form, which can be achieved by it when the silver ions penetrate inside the microbial cell (Fig. 3). This condensation inhibits the replication ability of DNA, which ultimately leads to cell death [148]. The malfunction of the bacterial replication system can also happen when Ag ions released from AgNP normally penetrate into bacterial cell and cause damage on its main components such as the peptidoglycan, DNA, and proteins [3 and 112].

CONCLUSION

Silver products have a long history for their solid inhibitory and bactericidal impacts, and in addition an expansive range of antimicrobial exercises. They have been used from centuries to prevent and treat various diseases, particularly infections [149]. The

performance of AgNPs in biomedical science has pulled researchers to adapt the phytogenic way for their synthesis. According to reports, the phytogenic resource and reaction parameters do impact upon the characterization and thus the affectivity of AgNPs. The phytosynthetic approach provides an eco-friendly platform to generate AgNPs with controlled growth and development. Since the reaction proceeds easily within minutes and at room temperature, there is no much energy loss by the reaction system. Consequently, with a specific end goal to accomplish better results in a controlled way, a considerable measure of examination is in need to figure out the real component of their synthesis and method of activity.

REFERENCES

1. Heidarpour F, Ghani W. A., Ahmadun F. R., Sobri S., Zargar M., Mozafari M. R., (2010), Nano silver-coated polypropylene water filter: I. Manufacture by electron beam gun using a

- modified balzers 760 machine. *Dig. J. Nanomater. Biostruct.* 5: 787-796.
2. Kvitek L., Panacek A., Soukupova J., Kolar M., Vecerova R., Prucek R., Holecova M., Zboril R., (2008), Effect of surfactants and polymers on stability and antibacterial activity of silver nanoparticles Nps.. *J. Phys. Chem.* 112: 5825-5834.
 3. Chaloupka K., Malam Y., Seifalian A. M., (2010), Nanosilver as a new generation of nanopropduct in biomedical applications. *Trends Biotechnol.* 128: 580-588.
 4. Rai M., Yadav A., Gade A., (2009), Silver nanoparticles as a new generation of antimicrobials. *Biotechnol. Adv.* 27: 76-83.
 5. Krutyakov Y. A., Kudrinskiy A. A., Olenin A.Y., Lisichkin G.V., (2008), Synthesis and properties of silver nanoparticles: advances and prospects. *Russ. Chem. Rev.* 77: 233-236.
 6. Prow T.W., Grice J. E., Lin L. L., Faye R., Butler M., Becker W., Wurm E. M. T., Yoong C., Robertson T. A., Soyer H. P., Roberts M. S., (2011), Nanoparticles and microparticles for skin drug delivery. *Adv. Drug Deliv. Rev.* 63: 470-491.
 7. Chaudhry Q., Castle L., (2011), Food applications of nanotechnologies: an overview of opportunities and challenges for developing countries. *Trends Food Sci. Tech.* 22: 595-598.
 8. Nair R., Varghese S. H., Nair B. G., Maekawa T., Yoshida Y., Sakthi Kumar D., (2010), Nanoparticulate material delivery to plants. *Plant Sci.* 179: 154-163.
 9. Kelly E. M., Johnston J. H., (2011), Colored and functional silver nanoparticle wool fiber composites. *ACS Appl. Mater. Interfaces.* 3: 1083-1092.
 10. Dankovich T. A., Gray D. G., (2011), Bactericidal paper impregnated with silver nanoparticles for point-of-use water treatment. *Environ. Sci. Technol.* 45: 1992-1998.
 11. Sharma V. K., Yngard R. A., Lin Y., (2009), Silver nanoparticles: Green synthesis and their microbial activities. *Adv. Colloid and Interface Sci.* 145: 83-96.
 12. Abdel-Halim E. S., Al-Deyab S. S., (2011), Utilization of hydroxypropyl cellulose for green and efficient synthesis of silver nanoparticles. *Carbohydr. Polym.* 86: 1615-1622.
 13. Singh M., Sinha I., Mandal R. K. (2009), Role of pH in the green synthesis of silver nanoparticles. *Mater. Let.* 63, 425-427.
 14. Kumar V., Yadav S. K., (2009), Plant mediated synthesis of silver and gold nanoparticles and their applications. *J. Chem. Technol. Biotechnol.* 84: 151-157.
 15. Mukunthan K., Balaji S., (2012), Cashew apple juice *Anacardium occidentale L.* speeds up the synthesis of silver nanoparticles. *Int. J. Green Nanotechnol.* 4: 71-79.
 16. Gericke M., Pinches A., (2006), Microbial production of gold nanoparticles. *Gold Bull.* 39: 22-28.
 17. Mahendran V., Gurusamy A., (2013), *Coleus aromaticus* leaf extract mediated synthesis of silver nanoparticles and its bactericidal activity. *Appl. Nanosci.* 3: 217-223.
 18. Jiang X. C., Zeng Q. H., Yu A. B., (2009), Silver nanoplates: synthesis, growth mechanism and functional properties. *In New Nanotech. Develop.* 17: 145-182.
 19. Jiang X. C., Chen W. M., Chen C. Y., Xiong S. X., Yu A. B., (2011), Role of Temperature in the Growth of Silver Nanoparticles Through a Synergetic Reduction Approach. *Nanoscale Res. Lett.* 6: 32-36.
 20. Shashi P. D., Manu L., Heikki S., Mika S., (2010), Bioprospective of *Sorbus aucuparia* leaf extract in development of silver and gold nanocolloids. *Colloids and Surfaces B: Biointerfaces.* 80: 26-33.
 21. Jin R., Cao Y., Metraux G. S., Schatz G. C., Mirkin C. A., (2003), Controlling anisotropic nanoparticle growth through plasmon excitation. *Nature.* 425: 487-490.
 22. Tang Z., Kotov N. A., Giersig M., (2002), Spontaneous organization of single CdTe nanoparticles into luminescent nanowires. *Science.* 297: 237-240.
 23. Penn R. L., Banfield J. F., (1998), Imperfect oriented attachment: a mechanism for dislocation generation in defect-free nanocrystals. *Science.* 281: 969-971.
 24. Pillai Z. S., Kamat P. V., (2004), What Factors Control the Size and Shape of Silver Nanoparticles in the Citrate Ion Reduction Method. *J. Phys. Chem. B.* 108: 945-951.
 25. Song J. Y., Kim B. S., (2009), Rapid biological synthesis of silver nanoparticles using plant leaf extracts. *Bioprocess Biosyst. Eng.* 32: 79-84.
 26. Maidul Islam A. K. M., Mukherjee M., (2011), Effect of temperature in synthesis of silver nanoparticles in triblock copolymer micellar solution. *J. Experim. Nanosci.* 6: 596-611.
 27. Vivek M., Senthil K. P., Ste S., Sudha S., (2011), Biogenic silver nanoparticles by *Gelidiella acerosa* extract and their antifungal effects. *Avecenna J. Medical Biotech.* 3: 143-148.
 28. Tripathy A., Raichur A. M., Chandrasekaran N., Prathna T. C., Mukherjee A., (2010), Process variables in biomimetic synthesis of silver nanoparticles by aqueous extract of *Azadirachta indica* *Neem*. *leave. J. Nanopart. Res.* 12: 237-46.
 29. Jagtap U. B., Bapat V. A., (2013), Green synthesis of silver nanoparticles using *Artocarpus heterophyllus* *Lam.* Seed extract and its antibacterial activity. *Ind. Crops and Prod.* 46: 132-137.
 30. Paulraj K., Seung T. L., (2013), Synthesis and characterization of pullulan-mediated silver nanoparticles and its antimicrobial activities. *Carbohydr. Polym.* 97: 421-428.
 31. Mock J. J., Barbic M., Smith D. R., Schultz D. A., Schultz S., (2002), Shape effects in plasmon resonance of individual colloidal silver nanoparticles. *J. Chem. Phys.* 116: 6755-6758.
 32. Nabikhan A., Kandasamy K., Raj A., Alikunhi N. M., (2010), Synthesis of antimicrobial silver nanoparticles by callus and leaf extracts from saltmarsh plant, *Sesuvium portulacastrum L.* *Colloids Surf. B. Biointerf.* 79: 488-493.
 33. Bar H., Bhui D. K., Sahoo G. P., Sarkar P., De S. P., Misra A., (2009), Green synthesis of silver nanoparticles using latex of *Jatropha curcas*. *Colloids Surf. A. Physicochem. Eng. Asp.* 339: 134-139.
 34. Kumar K. P., Paul W., Sharma C. P., (2012), Green synthesis of silver nanoparticles with zingiber officinale extract and study of its blood compatibility. *Bio. Nano. Sci.* 2: 144-152.
 35. Roopan S. M., Bharathi A., Prabhakaran A., Rahuman A. A., Velayutham K., Rajakumar G., Padmaja R. D., Lekshmi M., Madhumitha G., (2012), Efficient phyto-synthesis and

- structural characterization of rutile TiO₂ nanoparticles using Annona squamosa peel extract. *Spectrochim. Acta A: Mol. Biomol. Spectrosc.* 98: 86-90.
36. Prasad T. N. V. K. V., Elumalai E., (2011), Biofabrication of Ag nanoparticles using Moringa oleifera leaf extract and their antimicrobial activity. *Asian Pac. J. Trop. Biomed.* 1: 439-42.
37. Vijayaraghavan K., Nalini S., Prakash N. U., Madhankumar D., (2012), One step green synthesis of silver nano/microparticles using extracts of Trachyspermum ammi and Papaver somniferum. *Colloids Surf. B. Biointerf.* 94: 114-117.
38. Krishnaraj C., Jagan E., Rajasekar S., Selvakumar P., Kalachelvan P., Mohan N., (2010), Synthesis of silver nanoparticles using *Acalypha indica* leaf extracts and its antibacterial activity against water borne pathogens. *Colloids Surf. B. Biointerf.* 76: 50-56.
39. Edison T. J. I., Sethuraman M. G., (2012), Instant green synthesis of silver nanoparticles using *Terminalia chebula* fruit extract and evaluation of their catalytic activity on reduction of methylene blue. *Process Biochem.* 47: 1351-1357.
40. Dubey S. P., Lahtinen M., Sillanpaa M., (2010), Green synthesis and characterizations of silver and gold nanoparticles using leaf extract of *Rosa rugosa*. *Colloids Surf. A.* 605: 34-41.
41. Aruna J. K., Sashidhar R. B., Arunachalam J., (2012), Aqueous extract of gum olibanum *Boswellia serrata*: A reductant and stabilizer for the biosynthesis of antibacterial silver nanoparticles. *Process Biochem.* 47: 1516-1520.
42. Ahamed M., Khan M., Siddiqui M., AlSalhi M. S., Alrokayan S. A., (2011), Green synthesis, characterization and evaluation of biocompatibility of silver nanoparticles. *Physica E. Low Dimens. Sys. Nanostruct.* 43: 1266-1271.
43. Kesharwani J., Yoon K. Y., Hwang J., Rai M., (2009), Phytosynthesis of silver nanoparticles by leaf extract of *Datura metel*: hypothetical mechanism involved in synthesis. *J. Bionanosci.* 3: 39-44.
44. Chandran S. P., Chaudhary M., Pasricha R., Ahmad A., Sastry M., (2006), Synthesis of gold nanotriangles and silver nanoparticles using *Aloe vera* plant extract. *Biotechnol. Prog.* 22: 577-583.
45. Elumalai E., Prasad T., Hemachandran J., Therasa S. V., Thirumalai T., David E., (2010), Extracellular synthesis of silver nanoparticles using leaves of *Euphorbia hirta* and their antibacterial activities. *J. Pharm. Sci. Res.* 2: 549-554.
46. Ahmad N., Sharma S., Singh V., Shamsi S., Fatma A., Mehta B., (2010), Biosynthesis of silver nanoparticles from *Desmodium triuorum*: A novel approach towards weed utilization. *Biotechnol. Res. Int.* 2: 44-50.
47. Sheny D., Mathew J., Phillip D., (2011), Phytosynthesis of Au, Ag and Au-Ag bimetallic nanoparticles using aqueous extract and dried leaf of *Anacardium occidentale*. *Spectrochim. Acta A. Mol. Biomol. Spec.* 79: 254-262.
48. Bankar A., Joshi B., Kumar A. R., Zinjarde S., (2010), Banana peel extract mediated novel route for the synthesis of silver nanoparticles. *Colloids Surf. A.* 368: 58-63.
49. Akl M. A., Nidá M. S., Amany O. A., (2013), Green synthesis of silver nanoparticles using carob leaf extract and its antibacterial activity. *Int. J. Indus. Chem.* 4: 29-35.
50. Dwivedi A. D., Gopal K., (2010), Biosynthesis of silver and gold nanoparticles using *Chenopodium album* leaf extract. *Colloids Surf. A.* 369: 27-33.
51. Vijayakumar M., Priya K., Nancy F. T., Noorlidah A., Ahmed A. B. A., (2013), Biosynthesis, characterisation and antibacterial effect of plant-mediated silver nanoparticles using *Artemisia nilagirica*. *Indus. Crops and Produc.* 41: 235-240.
52. Singh A., Jain D., Upadhyay M. K., Khandelwal N., Verma, H. N., (2010), Green synthesis of silver nanoparticles using *Argemone Mexicana* leaf extract and evaluation of their antimicrobial activity. *Dig. J. Nanomater. Biostruct.* 5: 483-489.
53. Banerjee J., Narendhirakannan R., (2011), Biosynthesis of silver nanoparticles from *Syzygium cumini* L. seed extract and evaluation of their in vitro antioxidant activities. *Dig. J. Nanomater. Biostruct.* 6: 961-968.
54. Mondal S., Roy N., Laskar R. A., Sk I., Basu S., Mandal D., (2011), Biogenic synthesis of Ag, Au and bi-metallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (*Swietenia mahogani* JACQ) leaves. *Colloids Surf. B: Biointerf.* 82: 497-504.
55. Jacob S. J. P., Mohammed H., Murali K., Kamarudeen M., (2012), Synthesis of silver nanorods using *Coscinium fenestratum* extracts and its cytotoxic activity against Hep-2 cell line. *Colloids and Surf. B: Biointerf.* 98: 7-11.
56. Mittal A. K., Kaler A., Banerjee U. C., (2012), Free radical scavenging and antioxidant activity of silver nanoparticles synthesized from flower extract of *Rhododendron dauricum*. *Nano Bio. Med. Eng.* 4: 118-124.
57. Santhoshkumar T., Rahuman A. A., Rajakumar G., Marimuthu S., Bagavan A., Jayaseelan C., (2011), Synthesis of silver nanoparticles using *Nelumbo nucifera* leaf extract and its larvicidal activity against malaria and ulariasis vectors. *Parasitol Res.* 108: 693-702.
58. Ericka R. L., Ramón I. P., Rosa E. N., Ronaldo H. U., Judith T., Claudia I. P., Amir M., (2013), Synthesis of silver nanoparticles using reducing agents obtained from natural sources (*Rumex hymenosepalus* extracts). *Nanoscale Res. Lett.* 8: 318-322.
59. Parashar U. K., Saxena P., Srivastava A., (2009), Bioinspired synthesis of silver nanoparticles. *Dig. J. Nanomater. Biostruct.* 4: 159-166.
60. Patil R., Kokate M., Kolekar S., (2012), Bioinspired synthesis of highly stabilized silver nanoparticles using *Ocimum tenuiflorum* leaf extract and their antibacterial activity. *Spectrochim Acta A: Mol. Biomol. Spectrosc.* 91: 234-238.
61. Debajit B., Priyadarshini D., Piyalee B., Anupam C., Yadav R. N. S., (2013), *Ocimum sanctum* mediated silver nanoparticles showed better antimicrobial activities compared to citrate stabilized silver nanoparticles against multidrug resistant bacteria. *J. Pharm. Res.* 7: 478-482.
62. MubarakAli D., Thajuddin N., Jeganathan K., Gunasekaran M., (2011), Plant extract mediated synthesis of silver and gold nanoparticles and its antibacterial activity against clinically isolated pathogens. *Colloids and Surf. B: Biointerf.* 85: 360-365.

63. Philip D., Unni C., Aromal S. A., Vidhu V. K., (2011), *Murraya koenigii* leaf-assisted rapid green synthesis of silver and gold nanoparticles. *Spectrochim. Acta Part A*. 78: 899-904.
64. Shankar S. S., Ahmad A., Sastry M., (2003), Geranium leaf assisted biosynthesis of silver nanoparticles. *Biotechnol Prog* 19:1627-31.
65. Kaviya S., Santhanalakshmi J., Viswanathan B., Muthumary J., Srinivasan K., (2011), Biosynthesis of silver nanoparticles using *Citrus sinensis* peel extract and its antibacterial activity. *Spec. Acta A. Mol. Biomol. Spec.* 79: 594-598.
66. Elavazhagan T., Arunachalam K. D., (2011), *Memecylon edule* leaf extract mediated green synthesis of silver and gold nanoparticles. *Int. J. Nanomedicine*. 6: 1265-1278.
67. Ponarulselvam S., Panneerselvam C., Murugan K., Aarthi N., Kalimuthu K., Thangamani S., (2012), Synthesis of silver nanoparticles using leaves of *Catharanthus roseus* Linn. G. Don and their antiplasmodial activities. *Asian Pac. J. Trop. Biomed.* 2: 574-580.
68. Vilchis-Nestor A. R., Sánchez-Mendieta V., Camacho-López M. A., Gómez-Espinosa R. M., Arenas-Alatorre J. A., (2008), Solventless synthesis and optical properties of Au and Ag nanoparticles using *Camellia sinensis* extract. *Mater. Lett.* 62: 3103-3105.
69. Kasthuri J., Veerapandian S., Rajendiran N., (2009), Biological synthesis of silver and gold nanoparticles using apiin as reducing agent. *Colloids Surf. B: Biointerf.* 68: 55-60.
70. Ramamurthy C. H., Padma M., Daisy I., Mareeswaran R., Suyavaran A., Suresh Kumar M., Premkumar K., Thirunavukkarasu C., (2013), The extra cellular synthesis of gold and silver nanoparticles and their free radical scavenging and antibacterial properties. *Colloids and Surf. B: Biointerf.* 102: 808-811.
71. Rajakumar G., Abdul Rahuman A., (2011), Larvicidal activity of synthesized silver nanoparticles using *Eclipta prostrata* leaf extract against ulariasis and malaria vectors. *Acta Trop.* 118: 196-203.
72. Huang J., Li Q., Sun D., Lu Y., Su Y., Yang X., Wang H., Wang Y., Shao W., He N., Hong J., Chen C., (2007), Biosynthesis of silver and gold nanoparticles by novel sundried *Cinnamomum camphora* leaf. *Nanotechnology*. 18: 105104-105114.
73. Patil S. V., Borase H. P., Patil C. D., Salunke B. K., (2012), Biosynthesis of silver nanoparticles using latex from few euphorbian plants and their antimicrobial potential. *Appl. Biochem. Biotechnol.* 167: 776-790.
74. Veerasamy R., Xin T. Z., Gunasagaran S., Xiang T. F. W., Yang E. F. C., Jeyakumar N., (2010), Biosynthesis of silver nanoparticles using mangosteen leaf extract and evaluation of their antimicrobial activities. *J. Saudi. Chem. Soc.* 15: 113-120.
75. Gaurav P., Nitesh N., Gyana Prasuna R., (2013), Enhancement of antidandruff activity of shampoo by biosynthesized silver nanoparticles from *Solanum trilobatum* plant leaf. *Appl. Nanosci.* 3: 431-436.
76. Ankanna S., Prasad T. N. V. K. V., Elumalai E. K., Savithramma N., (2010), Production of biogenic silver nanoparticles using *Boswellia ovalifoliolata* stem bark. *Dig. J. Nanomater. Biostruct.* 5: 369-372.
77. Vanaja M., Annadurai G., (2012), *Coleus aromaticus* leaf extract mediated synthesis of silver nanoparticles and its bactericidal activity. *Appl. Nanosci.* 3: 217-223.
78. Udayasoorian C., Kumar K. V., Jayabalakrishnan R. M., (2011), Extracellular synthesis of silver nanoparticles using leaf extracts of *Cassia auriculata*. *J. Nanomater. Biostruct.* 6: 279-283.
79. Geethalakshmi R., Sarada D. V. L., (2013), Characterization and antimicrobial activity of gold and silver nanoparticles synthesized using saponin isolated from *Trianthemadecandra* L. *Ind. Crops Prod.* 51: 107-115.
80. Phillip D., (2011), *Mangifera indica* leaf-assisted biosynthesis of well dispersed silver nanoparticles. *Spectrochim. Acta., Part A*. 78: 327-332.
81. Subramanian V., (2012), Green synthesis of silver nanoparticles using *Coleus amboinicus* lour, antioxidant activity and invitro cytotoxicity against Ehrlich's Ascite carcinoma. *J. Pharm. Res.* 5: 1268-1272.
82. Zaheer K., Javed I. H., Athar A. H., (2012), Shape-directing role of cetyltrimethylammonium bromide in the green synthesis of Ag-nanoparticles using Neem *Azadirachta indica*. leaf extract. *Coll. and Surf. B: Biointerf.* 95: 229-234.
83. Satyavani K., Ramanathan T., Gurudeekan S., (2011), Green synthesis of silver nanoparticles using stem dried callus extract of bitter apple *Citrullus colocynthis*. *Dig. J. Nanomater. Biostruct.* 6: 1019-1024.
84. Mallikarjuna K., Dillip G. R., Narasimha G., Sushma N. J., Raju B. D. P., (2012), Phytofabrication and characterization of silver nanoparticles from Piper betle broth. *Res. J. Nanosci. Nanotechnol.* 2: 17-23.
85. Rao M. L., Savithramma N., (2011), Biological synthesis of silver nanoparticles using *Svensonia Hyderabadensis* leaf extract and evaluation of their antimicrobial efficacy. *J. Pharm. Sci. Res.* 3: 1117-1121.
86. Jain D., Daima H. K., Kachhwaha S., Kothari S. L., (2009), Synthesis of plant mediated silver nanoparticles using papaya fruit extract and evaluation of their anti microbial activities. *Digest. J. Nanomater. Biostruc.* 4: 557-563.
87. Prasad K. S., Pathak D., Patel A., Dalwadi P., Prasad R., Patel P., Selvaraj K., (2011), Biogenic synthesis of silver nanoparticles using *Nicotiana tobaccum* leaf extract and study of their antibacterial effect. *Afr. J. Biotechnol.* 10: 8122-8130.
88. Deshpande R., Bedre D. M., Basavaraja S., Sawle B., Manjunath S. Y., Venkataraman A., (2010), Rapid biosynthesis of irregular shaped gold nanoparticles from macerated aqueous extracellular dried clove buds (*Syzygium aromaticum*) solution. *Colloids Surf. B: Biointerf.* 79: 235-240.
89. Rajesh S., Raja D. P., Rathi J. M., Sahayaraj K., (2012), Biosynthesis of silver nanoparticles using *Ulva fasciata* Delile. ethylacetate extract and its activity against *Xanthomonas campestris* Pv. *malvacearum*. *J. Biopest.* 5: 119-128.
90. Mondal S., Roy N., Laskar R. A., Sk I., Basu S., Mandal D., (2011), Biogenic synthesis of Ag, Au and bi-metallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (*Swietenia mahogani* JACQ) leaves. *Colloids Surf. B: Biointerf.* 82: 497-504.

91. Newman D. K., Kolter R., (2000), Nature A role for excreted quinones in extracellular electron transfer. *Nature*. 405: 94-97.
92. Noruzi M., Zare D., Khoshnevisan K., Davoodi D., (2011), Rapid green synthesis of gold nanoparticles using *Rosa hybrida* petal extract at room temperature. *Spectrochim. Acta A: Mol. Biomol. Spectrosc.* 79: 1461-1465.
93. Kavitha K. S., Syed B., Rakshith D., Kavitha H. U., Yashwantha R. H. C., Harini B. P. Satish S., (2013), Plants as Green Source towards Synthesis of Nanoparticles. *Int. Res. J. Biological. Sci.* 2: 66-76.
94. Kalimuthu K., Babu R. S., Venkataraman D., Bilal M., Gurunathan S., (2008), Biosynthesis of silver nanocrystals by *Bacillus licheniformis*. *Colloids Surf. B: Biointerf.* 65: 150-153.
95. Ahmad N., Sharma S., Singh V., Shamsi S., Fatma A., Mehta B., (2010), Biosynthesis of silver nanoparticles from *Desmodium triuorum*: a novel approach towards weed utilization. *Biotechnol. Res. Int.* 2: 24-29.
96. Duran N., Marcato P. D., Alves O. L., De Souza G. H., Esposito E., (2005), Mechanistic aspects of biosynthesis of silver nanoparticles by several *Fusarium oxysporum* strains *J. Nanobiotechnol.* 3: 8-13.
97. Shahverdi A., Minaeian S., Shahverdi H. R., Jamalifar H., Nohi A. A., (2007), Rapid synthesis of silver nanoparticles using culture supernatants of Enterobacteria: a novel biological approach. *Process Biochem.* 42: 919-923.
98. Gengana R. M., Ananda K., Phulukdareeb A., Chuturgoon A., (2013), A549 lung cell line activity of biosynthesized silver nanoparticles using *Albizia adianthifolia* leaf. *Colloids Surf. B: Biointerf.* 105: 87-91.
99. Miura N., Shinohara Y., (2009), Cytotoxic effect and apoptosis induction by silver nanoparticles in HeLa cells. *Biochem. Biophys. Res. Commun.* 390: 733-737.
100. Hsin Y. H., Chen C. F., Huang S., Shih T. S., Lai P. S., Chueh P. J., (2008), The apoptotic effect of nanosilver is mediated by a ROS- and JNK-dependent mechanism involving the mitochondrial pathway in NIH3T3 cells. *Toxicol. Lett.* 179: 130-139.
101. Asha R. P. V., Low K. M. G., Hande M. P., Valiyaveetil S., (2009), Cytotoxicity and genotoxicity of silver nanoparticles in human cells. *ACS Nano* 3: 279-290.
102. Sukirtha R., Priyanka K., Antony J. J., Kamalakkannan S., Thangam R., Gunasekaran P., (2012a), Cytotoxic effect of Green synthesized silver nanoparticles using *Melia azedaracha* against in vitro HeLa cell lines and lymphoma mice model. *Process. Biochem.* 47: 273-279.
103. Sukirtha R., Priyanka K., Antony J. J., Kamalakkannan S., Thangam R., Gunasekaran P., (2012b), Cytotoxic effect of Green synthesized silver nanoparticles using *Melia azedaracha* against in vitro HeLa cell lines and lymphoma mice model. *Process. Biochem.* 47: 273-279.
104. Jacob S., Finub J., Narayanan A., (2011), Synthesis of silver nanoparticles using *Piper longum* leaf extracts and its cytotoxic activity against Hep-2 cell line. *Colloids Surf. B: Biointerf.* 91: 212-214.
105. Ghassan M. S., Wasnaa H. M., Thorria R. M., Ahmed A. A., Abdul A. H. K., Abu B. M., (2013), Green synthesis, antimicrobial and cytotoxic effects of silver nanoparticles using *Eucalyptus chapmaniana* leaves extract. *Asian Pac. J. Trop. Biomed.* 3: 58-63.
106. Gengana R. M., Ananda K., Phulukdareeb A., Chuturgoon A., (2013), A549 lung cell line activity of biosynthesized silver nanoparticles using *Albizia adianthifolia* leaf. *Colloids Surf. B: Biointerf.* 105: 87-91.
107. Moaddab S., Ahari H., Shahbazzadeh D., Motallebi A. A., Anvar A. A., Rahman-Nya J., Shokrgozar M. R., (2011), Toxicity study of nanosilver Nanocid. on osteoblast cancer cell line. *Int. Nano Lett.* 1: 11-16.
108. Dipankar C., Murugan S., (2012), The green synthesis, characterization and evaluation of the biological activities of silver nanoparticles synthesized from *Iresine herbstii* leaf aqueous extracts. *Colloids Surf. B: Biointerf.* 98: 112-119.
109. Logeswari P., Silambarasan S., Abraham J., (2013), Ecofriendly synthesis of silver nanoparticles from commercially available plant powders and their antibacterial properties. *Scientia Iranica, Transactions F: Nanotech.* 20: 1049-1054.
110. Geethalakshmi R., Sarada D. V. L., (2013), Characterization and antimicrobial activity of gold and silver nanoparticles synthesized using saponin isolated from *Trianthemadecandra* L. *Ind. Crops and Products.* 51: 107-115.
111. Debajit B., Priyadarshini D., Piyalee B., Anupam C., Yadav R. N. S., (2012), *Ocimum sanctum* mediated silver nano particles showed better antimicrobial activities compared to citrate stabilized silver nano particles against multidrug resistant bacteria. *J. Pharm. Res.* 7: 478-482.
112. Shrivastava S., Bera T., Roy A., Singh G., Ramachandrarao P., Dash D., (2007), Characterization of enhanced antibacterial effect of novel silver nanoparticles. *Nanotechnology* 18: 225103-225107.
113. Padma S., Vankar D. S., (2012), Biosynthesis of silver nanoparticles using lemon leaves extract and its application for antimicrobial finish on fabric. *Appl. Nanosci.* 2: 163-168.
114. Lamsal K., Kim S. W., Jung J. H., Kim Y. S., (2011), Inhibition Effects of Silver Nanoparticles against Powdery Mildews on Cucumber and Pumpkin. *Mycobiology* 39: 26-32.
115. Jo Y. K., Kim B. H., (2009), Antifungal activity of silver ions and nanoparticles on phytopathogen fungi. *Plant Dis.* 93: 1037-1043.
116. Park H. J., Kim S. H., Kim H. J., Choi S. H., (2006), A new composition of nanosized silica-silver for control of various plant diseases. *Plant Pathol. J.* 22: 295-302.
117. Min J. S., Kim S. U., Kim S. W., Jung J. H., Lamsal K., Kim S. B., Jung M., Lee Y. S., (2009), Effects of colloidal silver nanoparticles on sclerotium-forming phytopathogenic fungi. *Plant Pathol. J.* 25: 376-380.
118. Kim S. W., Kim K. S., Lamsal K., Kim Y. J., Kim S. B., Jung M., Sim S. J., Kim H. S., Chang S. J., Kim J. K., (2009), An *in vitro* study of the antifungal effect of silver nanoparticles on oak wilt pathogen *Raffaelea* sp. *J Microbiol. Biotechnol.* 19: 760-764.
119. Jaidev L. R., Narasimha G., (2010), Fungal mediated biosynthesis of silver nanoparticles, characterization and antimicrobial activity. *Colloids Surf. B.* 81: 430-433.
120. Gri tt R. J., Luo J., Gao J., Bonzongo J. C., Barber D. S., (2008), Effects of particle composition and species on toxicity of metallic nanomaterials in aquatic organisms. *Environ. Toxicol. Chem.* 27: 1972-1978.

121. Gri tt R. J., Hyndman K., Denslow N. D., Barber D. S., (2009), Comparison of molecular and histological changes in zebrafish gills exposed to metallic nanoparticles. *Toxicol. Sci.* 107: 404-415.
122. Wise Sr J. P., Goodale B. C., Wise S. S., Craig G. A., Pongan A. F., Walter R. B., Thompson D., Ng A. K., Aboueissa A. M., Mitani H., Spalding M. J., Mason M. D., (2010), Silver nanospheres are cytotoxic and genotoxic to fish cells. *Aquat. Toxicol.* 97: 34-41.
123. Park B. S. Y., Choi J., (2010), Geno- and ecotoxicity evaluation of silver nanoparticles in freshwater crustacean *Daphnia magna*. *Environ. Eng. Res.* 15: 23-27.
124. Park A. E. J., Yi J., Kim Y., Choi K., Park K., (2010), Silver nanoparticles induce cytotoxicity by a Trojan-horse typemechanism. *Toxicol. In Vitro* 24: 872-878.
125. Nair P. M. G., Park S. Y., Lee S. W., Choi J., (2011), Differential expression of ribosomal protein gene, gonadotrophin releasing hormone gene and Balbiani ring protein gene in silver nanoparticles exposed *Chironomus riparius*. *Aquat. Toxicol.* 101: 31-37.
126. Anita K. P., Ashley B., La B. M., Paul B. T., (2012), Genotoxicity of Silver Nanoparticles in *Vicia faba*: A Pilot Study on the Environmental Monitoring of Nanoparticles. *Int. J. Environ. Res. Public Health.* 9: 1649-1662.
127. Kumari M., Mukherjee A., Chandrasekaran N., (2009), Genotoxicity of silver nanoparticles in *Allium cepa*. *Sci. Total Environ.* 407: 5243-5246.
128. Stampoulis D., Sinha S. K., White J. C., (2009), Assay-dependent phytotoxicity of nanoparticles to plants, *Environ. Sci. Technol.* 43: 9473-9479.
129. Bankar A., Joshi B., Kumar A. R., Zinjarde S., (2010), Banana peel extract mediated novel route for the synthesis of silver nanoparticles. *Colloids Surf. A.* 368: 58-63.
130. Shahjahan M., Vani G., Shyamaladevi C. S., (2005), Effect of *Solanum trilobatum* on the antioxidant status during diethyl nitrosamine induced and phenobarbital promoted hepatocarcinogenesis in rat. *Chem. Biol. Interact.* 156: 113-123.
131. Gaurav P., Nitesh N., Gyana Prasuna R., (2013), Enhancement of antidandruff activity of shampoo by biosynthesized silver nanoparticles from *Solanum trilobatum* plant leaf. *Appl. Nanosci.* 3: 431-436.
132. Suman T. Y., Elumalai D., Kaleena P. K., Radhika Rajasree S. R., (2012), GC-MS analysis of bioactive components and synthesis of silver nanoparticle using *Ammannia baccifera* aerial extract and its larvicidal activity against malaria and filariasis vectors. *Ind. Crops and Prod.* 47: 239-245.
133. Rajakumar G., Abdul Rahuman A., (2011), Larvicidal activity of synthesized silver nanoparticles using *Eclipta prostrata* leaf extract against ulariasis and malaria vectors. *Acta Trop.* 118: 196-203.
134. Hui M. N., Hong N. L., Rahman J., (2006), Silver colloid nanoparticles: Synthesis, characterization, and their antibacterial activity. *J. Phys. Chem. B.* 110: 16248-16253.
135. Morones J. R., Elechiguerra J. L., Camacho A., Ramirez J. T., (2005), The bactericidal effect of silver nanoparticles. *Nanotech.* 16: 2346-2353.
136. Dragieva I., Stoeva S., Stoimenov P., Pavlikianov E., Klabunde K., (1999), Complex formation in solutions for chemical synthesis of nanoscaled particles prepared by borohydride reduction process. *Nanostruc. Mater.* 12: 267-270.
137. Hamouda T., Myc A., Donovan B., Shih A., Reuter J. D., Baker J. R., (2001), A novel surfactant nanoemulsion with a unique non-irritant topical antimicrobial activity against bacteria, enveloped viruses and fungi. *Microbiolog. Res.* 156: 1-7.
138. Dibrov P., Dzioba J., Gosink K. K., Hase C. C., (2002), Chemiosmotic mechanism of antimicrobial activity of Ag⁺ in *Vibrio cholerae*. *Antimicrob. Agents. Chemother.* 46: 2668-2670.
139. Lara H. H., Ayala-Nuarez N. V., Ixtapan-Turrent L., Rodriguez-Padilla C., (2010), Bactericidal effect of silver nanoparticles against multidrug-resistant bacteria. *World J. Microbiol. Biotechnol.* 26: 615-621.
140. Kumar V. S., Nagaraja B. M., Shashikala V., Padmasri A. H., Madhavendra S. S., Raju B. D., (2004), Highly efficient Ag/C catalyst prepared by electro-chemical deposition method in controlling microorganisms in water. *J. Mol. Catal. A.* 223: 313-319.
141. Feng Q. L., Wu J., Chen G. Q., Cui F. Z., Kim T. N., Kim J. O., (2000), A mechanistic study of the antibacterial effect of silver ions on *Escherichia coli* and *Staphylococcus aureus*. *J. Biomed. Mater. Res.* 52: 662-668.
142. Holt B., Bard A. J., (2005), Interaction of silver I. ions with the respiratory chain of *Escherichia coli*: an electrochemical and scanning electrochemical microscopy study of the antimicrobial mechanism of micromolar Ag⁺. *Biochemistry* 44: 13214-13222.
143. McDonnell G., Russell A. D., (2009), Antiseptics and Disinfectants: Activity, Action, and Resistance *Clin. Microbiol. Rev.* 12: 147-179.
144. Sondi I., Salopek-Sondi B., (2012), Silver nanoparticles as antimicrobial agent: a case study on *E. coli* as a model for Gram-negative bacteria. *J. Colloid. Interf. Sci.* 275: 177-182.
145. Lin Y. E., Vidic R. D., Stout J. E., McCartney C. A., Yu V. L., (1998), Inactivation of *Mycobacterium avium* by copper and silver ions. *Water Res.* 32: 1997-2000.
146. Lok C., (2006), Proteomic analysis of the mode of antibacterial action of silver nanoparticles. *J. Proteome Res.* 5: 916-924.
147. Holt B., Bard A. J., (2005), Interaction of silver I. ions with the respiratory chain of *Escherichia coli*: Asn electrochemical and scanning electrochemical microscopy study of the antimicrobial mechanism of micromolar Ag⁺. *Biochemistry.* 44: 13214-13222.
148. Liao S. Y., Read D. C., Pugh W. J., Furr J. R., Russell A. D., (1997), Interaction of silver nitrate with readily identifiable groups: relationship to the antibacterial action of silver ions. *Let. Appl. Microbiol.* 25: 279-283.
149. Shankar S. S., Rai A., Ankamwar B., Singh A., Ahmad A., Sastry M., (2004), Biological synthesis of triangular gold nanoprisms. *Nat. Mater.* 3: 482-488.