GREEN SYNTHESIS OF SILVER NANOPARTICLES AND THEIR ANTIMICROBIAL ACTIVITY: A REVIEW

Khushdil Khan*, Tarun Gupta, Bhawna Dangi, Nitin Jain and Gaurav Sharma
Department of Biotechnology
Mohanlal Sukhadia University, Udaipur (Raj.),INDIA

Abstract:

Nanotechnology is a standout amongst the most dynamic of region examine in present day material science. Nanoparticles (NPs) as its name suggests is a 'Nano' or 'dwarf' particle with size ranges from 1nm to 100 nm.This field which is developing day by day is making an impact in spheres of humans' life and creating a growing excitement in the life science, specially biotechnology and biomedical science. Nanoparticles are manufactured worldwide in tremendous amount for use in an extensive variety of utilization. Plant-mediated synthesis of nanoparticles is a green chemistry approach that connects nanotechnology with plants. Green synthesis of silver nanoparticles using medicinal plants is eco-friendly approach and also cost effective in comparison with physical and chemical methods. Silver nanoparticles (AgNPs) are broadly utilized as a part of different research because of their unique physio-chemical properties. These unique characteristics make them useful in various applications like antimicrobial activities. It has been realize that nanoparticles and its compounds have solid inhibitory and antimicrobial activities for microorganisms, and parasites By this review study we will able to understand that how silver nanoparticles (AgNPs) is important for antimicrobial activity and its effectiveness against microorganisms.

Keywords: **Nanotechnology, silver nanoparticles, antimicrobial, nanomaterials**

INTRODUCTION

"Nanobiotechnology" means the application of nanotechnology to the life sciences including research relating to the characterization of nanomaterials for health and environmental safety implications. Bionanotechnology, Nano-biotechnology, and Nano-biology are terms that refer to the intersection of nanotechnology and biology. Nanoparticles are clusters of atoms in the range 1-100 nm. "Nano" is a Greek work synonymous to dwarf meaning extremely small (Krishnaveni and Priya, 2014). This discipline helps to indicate the merger of biological research with various fields of nanotechnology.

Biologically inspired nanotechnology uses biological systems as the inspirations for technologies not yet created. The most important objectives that are frequently found in nanobiotechnology involve applying nanotools to relevant medical/biological problems and refining these applications. This theoretical capability was envisioned as early as 1959 by physicist Richard Feynman. According to National science Foundation and NNI, Nanotechnology is the ability to understand, control and manipulate matter at the level of individual atoms and molecules. Nanocrystalline particles have found tremendous application in the field of high sensitivity biomolecular detection and diagnostics, therapeutics and anti-microbials (Sridhara *et al.,* 2012) catalysis and micro-electronics (Veera *et al.*, 2012).

Green chemistry is also known as environment friendly chemistry, or sustainable chemistry. Perhaps the most widely accepted definition of green chemistry is the one offered by chemists **Paul Anastas and John Warner**, who defined green chemistry as the ***design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.*** Green synthesis of nanoparticles had got valuable attention in past few years. A number of approaches are available for the synthesis of nanoparticles for example, reduction

in solution, photochemical and chemical reaction in reverse micelles thermal decomposition of nanoparticles compounds (Akl Awwad and Nida Salem, 2012), radiation assisted, electrochemical, microwave assisted process and recently via green chemistry route (Ravindra *et al.,* 2012).
Utilizing green substances has several advantages including low energy consumption and moderate operation conditions (*e.g.* pressure and temperature) without using any toxic chemicals (Mie *et al.*, 2014). Important member of the noble metal NPs are silver NPs (Ag NPs). They are also broadly applied in shampoos, soaps, detergents, cosmetics, toothpastes and medical and pharmaceutical products and are hence directly encountered by human systems (Bhattacharya and Mukherjee, 2008), (Bhumkar *et al*., 2007).
In the recent days, silver nanoparticles have been synthesized from the naturally occurring sources and their products like green tea (*Camellia sinensis)*, Neem (*Azadirachta indica)* , leguminous shrub (*Sesbania drummondii*) , various leaf broth, natural rubber, starch , *Aloe vera* plant extract , lemongrass leaves extract, etc (Vijayaraghavan *et al.*, 2012).
This current emerging field of nanobiotechnology is at the primary stage of development due to lack of implementation of innovative techniques in large industrial scale and yet has to be improved with the modern technologies. Hence, there is a need to design an economic, commercially feasible as well environmentally sustainable route of synthesis of Ag NPs in order to meet its growing demand in diverse sectors (Benerjee *et al.*, 2014).

WHY NANOPARTICLES?

Nanoparticles have one dimension that measures 100 nanometers or less. The properties of many conventional materials change when formed from nanoparticles. This is typically because nanoparticles have a greater surface area per weight than larger particles which causes them to be more reactive to some other molecules.
Due to their small dimensions, nanomaterials have extremely large surface area to volume ratio, which makes a large fraction of atoms of the materials to be the surface or interfacial atoms, resulting in more "surface" dependent material properties. When the size of materials is reduced to nanoscale, materials tend to be single crystals. It has been shown in case of metallic nanocrystalline materials that elastic modulii reduce dramatically. Even though some nanomaterials with slightly large number of atoms (>50-60 atoms) may acquire bulk crystalline materials, it is found that the lattice parameters may not be the same as in the bulk materials.The other physical properties of nanoparticles are:

- ✓ Color – Nanoparticles of yellow gold and gray silicon are red in color
- ✓ Silver nanoparticles melt at much lower temperatures (~115 °C for 2.5 nm size) than the silver slabs (1064 °C)
- ✓ Absorption of solar radiation in photovoltaic cells is much higher in nanoparticles than it is in thin films of continuous sheets of bulk material - since the particles are smaller, they absorb greater amount of solar radiation

SILVER NANOPARTICLES

Silver nanoparticles have unique optical, electrical, and thermal properties and are being incorporated into products that range from photovoltaic to biological and chemical sensors. Examples include conductive inks, pastes and fillers which utilize silver nanoparticles for their high electrical conductivity, stability, and low sintering temperatures.. The advancement of green synthesis of AgNPs is progressing as a key branch of nanotechnology; where the use of biological entities like micro-organisms, plant extract or plant biomass are being used for the production of AgNPs could be an alternative to chemical and physical methods in an eco-friendly manner (Pathak and Hendre, 2015). The synthesis of AgNPs is carried out by the use of various chemical and biological techniques, this will lead to obtain the size and shape of the silver nanoparticles.

Silver nanoparticles have attracted intensive research interest because of their important application in antimicrobial, catalysis, and surface-enhanced Raman scattering (Gokulkrishnan *et al.*, 2012). Nanoparticles are important scientific tools that have been and are being explored in various biotechnological, pharmacological and pure technological uses. They are a link between bulk materials and atomic or molecular structures. Nanoparticles are unique because of their large surface area and this dominates the contributions made by the small bulk of the material.

The synthesis of silver nanoparticles are being synthesized by two different approaches: (1)Top down procedure (2) Bottom's up procedure . In the top down procedure there will be reduction in the size of Ag metals to form the nanomaterials by various methods including lithography and laser ablation meanwhile the bottoms up procedure includes the dissolvation of silver metals in a solvent and ultimately forming the AgNPs by the reduction of silver particles by adding reducing agent in it to reduce the chances of accumulation of nanoparticles. Various methods like use of reducing agents, electrochemical techniques , physio-chemical reduction and radiolysis are extensively used for synthesis of AgNPs which is included in the chemical approaches.

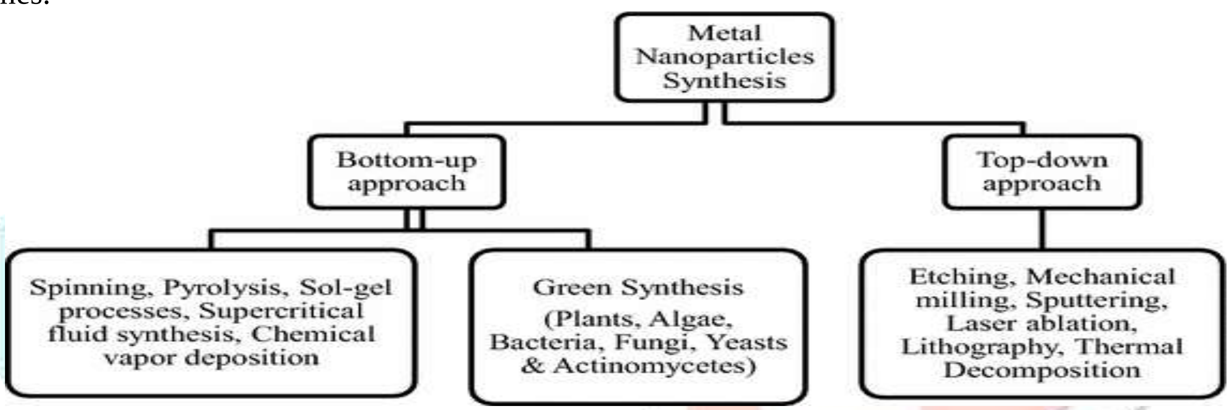

Fig1- Two different kind of approaches for synthesis of silver nanoparticles **(Liang Keat *et al.*, 2015)**

The rapid breakdown of silver nanoparticles releases ionic silver that inactivates vital bacterial enzymes by interacting with essential thiol groups. Silver ions can inhibit bacterial DNA replication, damage bacterial cytoplasm membranes, depleting levels of intracellular adenosine triphosphate (ATP) and finally cause cell death (Parveen *et al.,* 2012). Silver nanoparticles resistance of bacteria to bacteriocides and antibiotics has increased due to the development of resistant strains. Some antimicrobial activity of agent are extremely toxic and irritant and much interest in finding ways to formulate new types of safe and cost-effective biocidal materials (Dhrutika *et al.,* 2013). Since reducing agents for silver nanoparticle synthesis are often considered toxic or hazardous, the use of green synthesis methods is becoming a priority (Panacek *et al.*, 2006).

Silver NPs have more important applications like it is utilized at the same time as discerning covering for lunar energy assimilation and the same as optical receptors intended for biolabeling. Bacterial cell membrane has abundance of sulfur containing proteins with which silver NPs react outside and inside the cell membrane and which affects the viability of bacterial cell leads to increased permeability of bacterial cell membrane (Sharma *et al.*, 2015).

NEED OF GREEN SYNTHESIS

Green synthesis is an environmental friendly approach where no toxic chemicals involved (Logeswari *et al.*, 2013). It is a revolutionary technique which leads to new era that unfolds potential of plants in synthesizing stable NPs, increase the life span of NPs synthesized and also overcome the limitations of chemical and physical methods (Kavitha *et al.,* 2013), (Malik *et al.,* 2014). It is faster and reliable technique comparative to conventional techniques which scale up the process of production of commercially applicable NPs with less or no toxicity. Plants therefore, used for NPs synthesis because they actively uptake and reduce metal ions in

bioremediation and thereby can form complex metal NPs (Singh *et al.*, 2014), (Gardea-Torresdey *et al.*, 2002). Green synthesis provides advancement over physical and chemical method as it is cost effective environment friendly, easily scaled up for large scale synthesis and in this method there is no need to use high pressure, temperature, energy and toxic chemical (Ravindra *et al.*, 2012).
Green synthesis of nanoparticles makes use of environmental friendly non-toxic and safe reagent. **Phytomining** is the uses of hyper accumulating plants to extract a metal from the biomass to return an economic profit (Lamb *et al.*, 2001). Green synthesis approaches include mixed-valence polyoxometalates, polysaccharides, Tollens, biological, and irradiation method which have advantages over conventional methods involving chemical agents associated with environmental toxicity.

PARTS OF THE PLANTS THAT CAN BE USED FOR THE SYNTHESIS OF NANOPARTICLES:

Recently the plant intervened nanomaterial has drawn more consideration because of its immense application in different fields due to their physicochemical properties. The different metallic nanoparticles such as gold, silver, platinum, zinc, copper, titanium oxide, magnetite and nickel were synthesized from natural resources and have been studied exclusively (Dhuper *et al.*, 2012). The different parts of plant such as stem, root, fruit, seed, callus, peel, leaves and flower are being used to syntheses of metallic nanoparticles in various shapes and sizes by biological approaches.

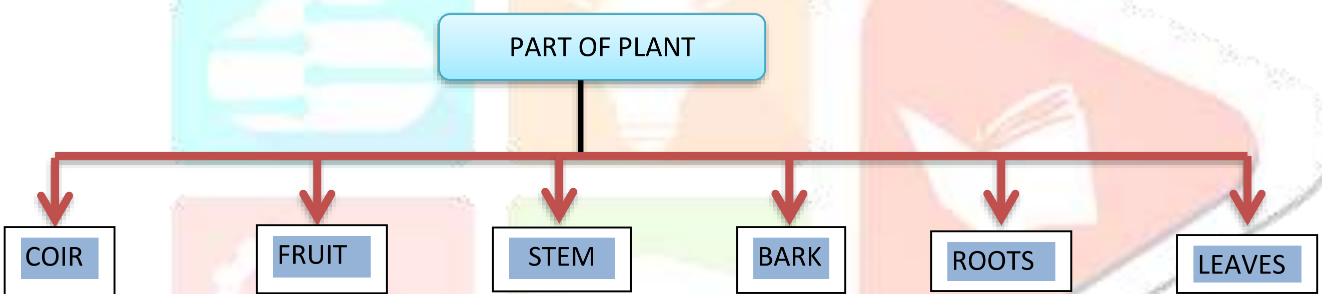

Table-1 Plant part used for synthesis of silver nanoparticles

S. No.	Natural Resource	Part used	Size [nm]	Shape	References
1	*Alternanthera sessilis*	Whole	40	Spherical	Niraimathi *et al.*, 2012
2	*Andrographis paniculata*	Leaves	67–88	Spherical	Suriyakalaa *et al.*, 2013
3.	*A. mexicana*	Leaves	20–50	Spherical	Singh *et al.*, 2010
4.	*Boswellia serrata*	Gum	7–10	Spherical	Kora *et al.*, 2012
5.	*Carica papaya*	Fruit	15	Spherical	Jain *et al.*, 2009
6.	*Cinnamon zeylanicum*	Leaves	45	Spherical	Sathishkumar *et al.*, 2009
7.	*Citrullus colocynthis*	Calli	5–70	Triangle	Satyavani *et al.*, 2011
8.	*Citrus sinensis*	Peel	35	Spherical	Kaviya *et al.*, 2011
9.	*Dillenia indica*	Fruit	11–24	Spherical	Singh *et al.*, 2013

10.	*Dioscorea bulbifera*	tuber	8–20	Rod, triangular	Ghosh *et al.*, 2012
11.	*Euphorbia prostrata*	Leaves	52	Rod, spherical	Zahir *and* Rahuman 2012
12.	*Gelsemium sempervirens*	whole	112	Spherical	Das *et al.*,2011
13	*H. canadensis*	Whole	113	Spherical	Das *et al.*,2011
14.	*Tinospora cordifolia*	Leaves	34	Spherical	Jayaseelan *et al.*, 2011
15.	*Calotropis gigantea*	Leaves	40-50	Spherical	Joshi *et al.*, 2017
16.	*Ocimum tenuiflorum*	Leaves	28	Irregular	Logeswari *et al.*, 2015
17.	*Azadirachta indica*	Leaves	34	Spherical	Ahmed *et al.*, 2015
18.	*Caesalpinia gilliesii*	Leaves	3-6	Spherical	Emam *et al.*, 2017
19.	*Citrullus lanatus*	Fruit Rind	17	Spherical	Ndikau *et al.*, 2017
20.	*Coriandrum sativum*	Leaves	6.45	Spherical	Khan *et al.*, 2018

ANTI-MICROBIAL PROPERTY OF SILVER NANOPARTICLES:

Silver metal has been utilized generally over the human advancements for various purposes. Numerous social orders utilize silver as gems, ornamentation and fine cutlery. Silver is a well-known antimicrobial agent against a wide range of over 650 microorganisms from different classes such as gram-negative and gram-positive bacteria, fungi or viruses. More recently the metal is finding use in the form of silver nanoparticles (Ahmed *et al.*, 2016). In ancient Indian medical system (called Ayurveda), silver has been described as therapeutic agent for many diseases.

The reciprocal action of nanoparticles subsequently breaks the cell membrane and disturbs the protein synthesis mechanism in the bacterial system (Sondi and Sondi, 2004). The increasing concentrations of silver nanoparticles have faster membrane permeability than the lower concentrations and consequently rupture the cell wall of bacteria (Kasthuri *et al.*, 2009)

The interactions of bacteria and the metallic silver and gold nanoparticles have been binding with active site of cell membrane to inhibit the cell cycle functions (Kim *et al.*, 2007). Silver is generally used in the nitrate form to induce antimicrobial effect but when silver nanoparticles are used, there is a huge increase in the surface area available for the microbes to be exposed to.

Silver nanoparticles have the ability to anchor to the bacterial cell wall and subsequently penetrate it, thereby causing structural changes in the cell membrane like the permeability of the cell membrane and death of the cell. There is formation of "pits" on the cell surface, and there is accumulation of the nanoparticles on the cell surface. There have been electron spin resonance spectroscopy studies that suggested that there is formation of free radicals by the silver nanoparticles when in contact with the bacteria, and these free radicals have the ability to damage the cell membrane and make it porous which can ultimately lead to cell death (Danilcauk *et al.*, 2006). It has also been proposed that there can be release of silver ions by the nanoparticles (Feng *et al.*, 2008). The action of these nanoparticles on the cell can cause the reaction to take place and subsequently lead to cell death. Another fact is that the DNA has sulfur and phosphorus as its major components; the nanoparticles can act on these soft bases and destroy the DNA which would definitely lead to cell death (Morones *et al.*, 2005). It was found that the nanoparticles dephosphorylate the peptide substrates on tyrosine residues, which leads to signal transduction inhibition and thus the stoppage of growth. It is however necessary to understand that further research is required on the topic to thoroughly establish the claims (Hatchell and Henry, 1996)

The multifunctional AgNPs have a promising activity against spore producing fungus and effectively destroy the fungal growth. The fungal cell membrane structure significant changes were observed by treating it with metallic nanoparticles (Gardea-Terresdey *et al.*, 2002)

The antimicrobial properties of silver nanoparticles depend on:

1. Size and environmental conditions (size, pH, ionic strength)
2. Capping agent

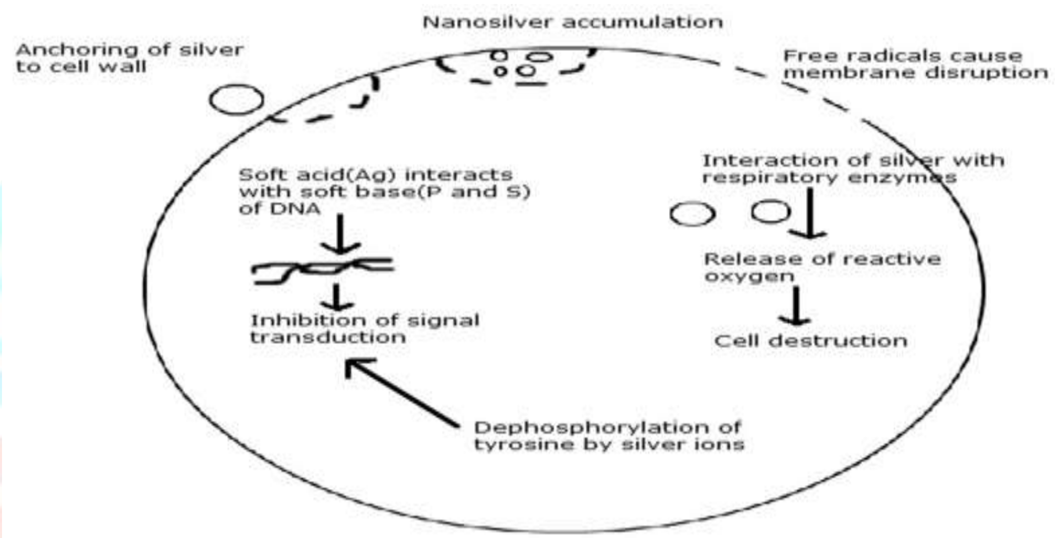

Fig 2- Various modes of action of silver nanoparticles on bacteria (Sukumaran and Poulose, 2012)

CONCLUSIONS:

- ✓ The nanomaterials are of very small dimensions
- ✓ These nanoparticles can be of different kind on the basis of synthesis process and by its property
- ✓ The use of nanomaterials is expanded in many field viz. electronics, biological and in many more fields.
- ✓ Reason for choosing the nanomaterials is larger surface are and less dimensions.
- ✓ Nanoparticles especially the silver nanoparticle (AgNPs) have a vast variety of the property and applications.
- ✓ Silver nanoparticle (AgNPs) can be synthesized by various ways i.e. top down and bottom's up approaches.
- ✓ Green synthesis is required due to its effective properties e.g its cheap cost etc.
- ✓ Green synthesis s that procedure by which the non toxic part of nanomaterials will produced,

- ✓ Different different parts of plant can be used for synthesis.
- ✓ AgNPs have the anti-microbial activity
- ✓ It will affect its physical character as well as its chemical characters i.e either cell wall or signal transduction.
- ✓ Destruction of cell wall will be occurred in case of AgNPs.
- ✓ The AgNPs will stop the signalling of the cells so death will become easier

References:

Ahmed, S., Ahmad, S.M., Swami, B.L. and Ikram, S. 2015. Green synthesis of silver nanoparticles using *Azadirachta indica* aqueous leaf extract. Journal of Radiation Research and Applied sciences. 1-7

Akl Awwad, M. and Nida Salem, M. 2012. Green synthesis of silver nanoparticles by mulberry leaves extract. Journal of Nanoscience and Nanotechnology. 2 (4): 125-128.

Ahmed, S., Ahmad, M., Swami, B.L. and Ikram, S. 2016. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise. *Journal of Advanced Research* 7:17–28.

Bhattacharya, R. and Murkherjee, P. 2008. Biological properties of “naked” metal Nano-particles. Advance Drug Delivery Review 60:1289–1306

Bhumkar, D.R., Joshi, H.M., Sastry, M. and Pokharkar, V.B. 2007. Chitosan reduced gold nanoparticles as novel carriers for transmucosal delivery of insulin. Pharmaceutical Research 24:1415–1426.

Banerjee, P., Satapathy, M., Mukhopahayay, A. and Das, P. 2014. Leaf extract mediated green synthesis of silver nanoparticles from widely available Indian plants: synthesis, characterization, antimicrobial property and toxicity analysis. Bio resources and Bioprocessing. 1(3):1-10

Dhuper, S., Panda, D. and Nayak, P. L. 2012. Green synthesis and characterization of zero valent iron nanoparticles from the leaf extract of *Mangifera indica*. Nano Trends: Journal of Nanotechnology Application. 13(2):16–22.

Dhrutika, P., Miral, P. and Krishnamurthy, R..2013. Silver nanoparticles biosynthesis and its antimicrobial activity. Cibtech Journal of Bio-protocol. 2 (1): 50-57.

Das, R.K., Gogoi, N. and Bora, U. 2011. Green synthesis of gold nanoparticles using *Nyctanthes arbortristis* flower extract. Bioprocess Biosysystem Engineering 34:615–619.

Danilcauk, M., Lund, A, Saldo, J., Yamada, H. and Michalik, J.2006. "Conduction electron spin resonance of small silver particles". Spectrochimaca. Acta. Part A., 63:189-191.

Emam, M., El Raey, M.A., Eisa, W.H., Wl-Haddad, A.E., Osman, S.M., El-Ansari, M.A. and Rabie, A.G. 2017. Green synthesis of silver nanoparticles from *Caesalpinia gilliesii* (Hook) leaves: antimicrobial activity and in vitro cytotoxic effect against BJ-1 and MCF-7 cells. Journal of Applied Pharmaceutical Sciences. 7(8):226-233.

Feng, Q., Wu, J., Chen, G.Q., Cui, F.Z., Kim, T.N. and Kim, J.O. 2008. "A mechanistic study of the antibacterial effect of silver ions on Escherichia coli and Staphylococcus aureus". Journal of Biomedical Material Research.52:662-668.

Gardea-Torresdey, J.L., Parson, J.G., Gomez, E., Peralta-Videa, J., Troiani, H.E., Santiago, P. and Yacaman, M.J. 2002. Formation and growth of Au nanoparticles inside live alfalfa plants. *Nano Letters*. 2:397–401.

Ghosh, S., Patil, S., Ahire, M., Kitture, R., Kale, S., Pardesi, K., Cameotra, S.S., Bellare, J., Dhavale, D.D., Jabgunde, A. and Chopad, B.A. 2012. Synthesis of silver nanoparticles using *Dioscorea bulbifera* tuber extract and evaluation of its synergistic potential in combination with antimicrobial agents. International Journal of Nanomedicine. 7:483–496.

Gardea-Torresdey, J. L., Parsons J. G., Gomez, E., Peralta-Videa, J., Troiani, H. E., Santiago P. and Yacaman, M. J. 2002. Formation and growth of Au nanoparticles inside live alfalfa plants. Nano letters, 2(4): 397-401.

Gokulakrishnan, R., Ravikumar, S. and Raj, J.A. 2012. In vitro antibacterial potential of metaloxide nanoparticles against antibiotic resistant bacteria pathogens. Asian Pacific Journal of Tropical Disease. 2(5): 411-413.

Hatchett, D. and Henry, S. 1996. "Electrochemistry of sulfur adlayers on low-index faces of silver". Journal of Phyical Chemistry. 100(23):9854-9859.

Jain, D., Daima, H.K., Kachhwaha, S. and Kothari, S.L. 2009. Synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their anti-microbial activities. Digest *Journal of Nanomaterials* & Biostructures.4:557–563.

Jayaseelan, C., Rahuman, A.A., Rajakumar, G., Kirthi, A.V., Santhoshkumar, T. and Marimuthu, S. 2011. Synthesis of pediculocidal and larvicidal silver nanoparticles by leaf extract from heart leaf moon seed plant *Tinospora cordifolia* Miers. Parasitology. Research. 109:185–194.

Joshi, P.S., Ramesh, G., Packiyam, J.E. and Jayanna, S. K. 2017. Green synthesis and evaluation of silver nanoparticles using leaf extract from *Calotropis gigantea*. International Journal of Current Biotechnology. 5(3): 1-5.

Kasthuri, J., Kathiravan, K. and Rajendiran, N., 2009. Phyllanthin assisted biosynthesis of silver and gold nanoparticles: a novel biological approach. Journal of Nanoparticles. Research.11:1075- 1085.

Kavitha, K. S., Syed, B., Rakshith, D., Kavitha, H U., Yashwantha, R H C., Harini, B. P. and Satish, S. 2013. Plants as green source towards synthesis of nanoparticles. International Research Journal Biological Science. *2*(6): 66- 76.

Kaviya, S., Santhanalakshmi, J., Viswanathan, B., Muthumary, J. and Srinivasan, K. 2011.Biosynthesis of silver nanoparticles using Citrus sinensis peel extract and its antibacterial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy.79(3):594-8.

Khan, M.Z.H., Tareq, F.K., Hossen, M.A. and Roki, M.N.A.M. 2018. Green synthesis and characterization of silver nanoparticles using *Coriandrum sativum* leaf extract. Journal of Engineering Science and Technology. 13(1): 158-166.

Kim, J.S., Kuk, E., Yu, K.N., Jong-Ho, K., Park, S.J., Lee, H.J. and Kim, S.H. 2007. Antimicrobial effects of silver nanoparticles. Nano medicine 3:95–101.

Kora, A.J., Sashidhar, R.B. and Arunachalam, J. 2012. Aqueous extract of gum olibanum (*Boswellia serrata*): A reductant and stabilizer for the biosynthesis of antibacterial silver nanoparticles. Process Biochemistry. 47:1516–1520.

Krishnaveni, B. and Priya, P. 2014. Green Synthesis and antimicrobial activity of silver nanoparticles from *Calotropis gigantean, Catharanthus roseus,* Chitin and Chitosan. Intenational Journal of Chemical Studies.1(6):10-20.

Kuppusamy, P., Mashitah, M., Yusoff, Gaanty Pragas Maniam., Govindan, N. 2016. Biosynthesis of metallic nanoparticles using plant derivatives and their new avenues in pharmacological applications – An updated report. Saudi Pharmaceutical Journal 24: 473–484.

Lamb, A. E., Anderson, C. W. N. and Haverkamp, R. G. 2001. The extraction of gold from plants and its application to phytomining. Chemistry of New Zealand.65: 31-33.

Liang Keat, C., Aziz, A., M Eid, A. and Nagib A. Elmarzugi. 2015. Biosynthesis of nanoparticles and silver nanoparticles. Bioresources and Bioprocessing 2:47

Logeswari, P., Silambarasan, S. and Abraham, J. 2013. Ecofriendly synthesis of silver nanoparticles from commercially available plant powders and their antibacterial properties. Scientia Iranica, 20(3): 1049-1054.

Logeswari, P., Silambarasan, S. and Abraham, J. 2015. Synthesis of silver nanoparticles using plants extract and analysis of their antimicrobial property. Journal of Saudi Chemical Society.19:311-317.

Malik, P., Shankar, R., Malik, V., Sharma, N. and Mukherjee, T. K. 2014. Green chemistry based benign routes for nanoparticle synthesis. Journal of Nanoparticles. 1-14.

Mie, R., Samsudin, M. W., Din, L. B., Ahmad, A., Ibrahim, N. and Adnan, S. N. A. 2014. Synthesis of silver nanoparticles with antibacterial activity using the lichen *Parmotrema* praesorediosum. International Journal of Nanomedicine 9: 121-127.

Morones, J., Elechiguerra, J.L., Camacho, A., Holt, K., Kouri, J.B., Ramirez, J.T. and Yacaman, M.J.2005. "The bactericidal effect of silver nanoparticles". Nanotechnology. 16:2346-2353.

Ndikau, M., Noah, N.M., Andala, D.M. and masika, E. 2017. Green synthesis and characterization of silver nanoparticles using *Citrullus lanatus* fruit rind extract. International Journal of Analytical Chemistry. 1-9.

Niraimathi, K.L., Sudha, V., Lavanya, R. and Brindha, P. 2012. Biosynthesis of silver nanoparticles using *Alternanthera sessilis* (Linn.) extract and their antimicrobial, antioxidant activities. Colloids Surf B Biointerfaces.102:288-291

Panacek, A., Kvitek, L., Prucek, R., Kolar, M., Vecerova, R., Pizurova, N., Sharma, V., Nevecna. T. and Zboril, R. 2006. Silver colloid nanoparticles: synthesis, characterization, and their antibacterial activity. Journal of Physical Chemistry B 110:16248– 16253.

Parveen, A., Ashish, S. R. and Srinath, R. 2012. Biosynthesis and characterization of silver nanoparticles from *Cassia auriculata* leaf extract and in-vitro evaluation of anti-microbial activity. International Journal of Applied Biology and Pharmaceutical Technology. 3 (2): 222-228.

Pathak, S. R. and Hendre, S. A. 2015 Sunlight induced green synthesis of silver nanoparticles using sundried leaves extract of *Kalanchoepinnata* and evaluation of its photocatalytic potential. Der Pharmacia Lettre, 7 (5): 313-324.

Ravindra, B. M., Seema, L. N., Neelambika, T. M., Gangadhar, S. M., Nataraja, K. and Vijaya, K. S. 2012 Silver nanoparticles synthesized by in-vitro derived plants and *Callus* culture of *Clitoriaternatea*; evaluation of antimicrobial activity. Research in Biotechnology. 3 (5): 26-38.

Satyavani, K., Gurudeeban, S., Ramanathan, T. and Balasubramanian, T. 2011. Biomedical potential of silver nanoparticles synthesized from calli cells of Citrullus colocynthis (L.)Schrad. Journal of Nanobiotechnology. 9:43–51.

Sathishkumar, M., Sneha, K., Won, S.W., Cho, C.W., Kim, S. and Yun, Y.S., 2009. *Cinnamon zeylanicum* bark extract and powder mediated green synthesis of nano-crystalline silver particles and its bactericidal activity. Colloids Surf B Biointerfaces.73: 332–338.

Sharma, C. K., Sharma, M., Verma., O. and Sharma, V. 2015.Green synthesis of different nanoparticles and their potential applications in different fields. A critical review. International Journal of Pharma and Bio Sciences 6(3): 555 – 567.

Singh, A., Singh, S. and Singh, N. 2014. Green Chemistry; Sustainablity an Innovative.Approach. Journal of Applied Chemistry. 2(2): 77-82.

Singh, C., Sharma, V., Naik, P.K., Khandelwal, V. and Singh, H. 2010. A green biogenic approach for synthesis of gold and silver nanoparticles using *zingiber officinale*. Digest *Journal of Nanomaterials* & Biostructures.. 6:535–542.

Singh, S., Saikia, J.P. and Buragohain, A.K. 2013. A novel 'green' synthesis of colloidal silver nanoparticles (SNP) using *Dillenia indica* fruit extract. Colloids Surf B Biointerfaces 102: 83–85.

Sondi, I. and Salopek-Sondi, B. 2004. Silver nanoparticles as antimicrobial agent: a case study on *E. coli* as a model for Gram-negative bacteria. Journal of Colloid and Interface Science. 275:177–182.

Sridhara, V., Ali, B., Shaziya, K., Satapathy, L.N. and Khandelwal, P. 2012. Biosynthesis and antibacterial activity of silver nanoparticles. Research Journal of Biotechnology. 8 (1): 11-17.

Sukumaran P. and Poulose, E.K. 2012. Silver nanoparticles: mechanism of antimicrobial action, synthesis, medical applications, and toxicity effects. International Nano Letters 2:32,1-10

Suriyakalaa, U., Antony, J.J., Suganya, S., Siva, D., Sukirtha, R., Kamalakkannan, S., Pichiah, P.B.T. and Achiraman, S. 2013. Hepatocurative activity of biosynthesized silver nanoparticles fabricated using *Andrographis paniculata*. Colloids Surf B Biointerfaces.102:189–194.

Veera, B. N., Jahnavi, A., Rama, K., Manisha, R. D., Rajkiran, B. and Pratap, R. M. P. 2012. Green synthesis of plant mediated silver nanoparticles using *Withania somnifera* leaf extract and evaluation of their antimicrobial activity. Asian Pacific Journal of Tropical Biomedicine. 1-5.

Vijayaraghavan, K., Kamala Nalini, S.P., Udaya Prakash, N. and Madhan kumar, D. 2012. Biomimetic synthesis of silver nanoparticles by aqueous extract of *Syzygium aromat- icum.*75:33-35.

Zahir, A.A. and Rahuman, A.A., 2012. Evaluation of different extracts and synthesized silver nanoparticles from leaves of Euphorbia prostrate against the plant *Haemaphysalis bispinosa* and *Hippobosca maculate*. Veterinary Parasitology. 187:511–520.