Volume - 13 | Issue - 01 | January - 2024 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

GREEN SYNTHESIS OF SILVER NANOPARTICLES AND ITS BIOMEDICAL APPLICATION

Chemistry

Sabina Yeasmin* PhD, University of Calcutta *Corresponding Author

Indrani Bhattacharya Professor, Calcutta National Medical College

ABSTRACT

Silver nanoparticle have versatile application. It can be synthesised by both chemical and green method. Here in our paper we focus on the synthesis of silver nanoparticle by green method. Fungi mediated, bacteria mediated, plant mediated synthesis were focused in this paper. This nanoparticles can be applied in the field of biology. Due to low toxicity it was used in different biological system. It was also used in the synthesis of pharmaceutical drugs, cosmetics, packets or food containers. Biomedical imaging part would be also discussed in this section. Metal oxide nanoparticles were also synthesised by using plant extract or microbes. Prepared silver nanoparticles were characterised by UV-Vis method, DLS method. Surface plasmon resonance indicates the formation of silver nanoparticles. Silver nanoparticle have strong antibacterial, antifungal, antidiabetes and anticancer activity.

KEYWORDS

Silver nanoparticle, biomedicine, fungi mediated synthesis, antidiabetes activity, nanomaterials

1. INTRODUCTION:

A new research area is nowadays open in the field of nanotechnology. Nanomaterials as well as nanoparticles have versatile application in the field of catalysis, electrochemistry, biomedicines, pharmaceuticals, sensors, food technology, cosmetics, etc [1-3]. Nanoparticles are found in nanometer range generally 1-100 nm range. Depending on their size and morphology nanoparticles have excellent physical properties. Among all others nanoparticles metal nanoparticles have excellent physical properties. They are highly dispersed in solution and have high surface to volume ratio [4,5,6,7]. Despite of all these properties nanoparticles have strong antimicrobial properties [8,9].

In cosmetics, electronics and textiles nanoparticles are widely used as a component. In case of antibiotic resistance among the patients nanoparticle is a strong alternative in medical fields. It may be used separately or conjugated with antibiotics in medical fields [10,11]. In case of biomedical imaging nanoparticles can be used to get relevant images for different diseases. For the diagnosis of tumor and atherosclerosis nanoparticle in combination with some contrast agents act as a strong biomedical imaging agents [12-14]. Furthermore, nanotherapeutic has been promoted everywhere throughout the world after the first FDA affirmed nanotherapeutic in 1990, to build up different nano-based drugs [15]. In early days different chemical methods were used for the synthesis of the nanoparticle [16]. But these methods are not eco-friendly, also cost effective and produces toxic by-products [17].To avoid chemical route nowadays researchers utilized aqueous plant extract and microbes, as they are environment-friendly, stable, clinically adaptable, biocompatible and cost-effective [16,17,18]. So nowadays scientists are focusing on the synthesis of metal and metal oxide nanoparticles using plant extract and microbes [19-22]. Owing to their wide availability, renewability and environment-friendly nature, in addition to their vast applications in the synthesis of NPs, plant biomass are also largely targeted by our group and others as a catalyst for chemical synthesis and biodiesel productions [23-26]. Among all the nanoparticles silver nanoparticles are widely used in microbiology, chemistry, food technology, cell biology, pharmacology and parasitology [27,28]. Basically, several techniques such as sol–gel method, hydrothermal method, chemical vapour deposition, thermal decomposition, microwave-assisted combustion method etc., have been utilized for the synthesis of silver NPs [29-31]. Scientists in their recent studies are busy in the synthesis of silver nanoparticles using plant extract and microbes as the reducing and stabilizing agents. These nanoparticles are widely used as an antimicrobial agents. Flavonoids, ketones, aldehydes, tannins, carboxylic acids, phenolic and the protein of the plant extracts are use for the reduction of silver nitrate to silver nanoparticle [32,33]. Silver nanoparticles formation can be studied by UV-Vis spectroscopic study. .Upon interaction with an electromagnetic field, the conducting electrons present in the outermost orbital of metal NPs collectively oscillate in resonance with certain wavelengths to exhibit a phenomenon called surface plasmon resonance (SPR). The color of the colloidal solution appear due to the SPR of AgNPs. The SPR peaks appear around 435 nm after complete reduction of silver nitrate to silver nanoparticles [34]. For spherical silver nanoparticles only one absorbance spectra whereas for two or more absorbance peak appear for different shape silver nanoparticles [35]. The aggregation in the silver nanoparticles can also be detected by SPR. Sometimes the absence of band between 335 and 560 nm indicates the absence of aggregation in AgNPs [32,36]. So this review is an example of biosynthesis of silver nanoparticle and its versatile application specially in the field of biology. We are going to discuss the synthesis of silver nanoparticles using different natural resources like plant extract and different microorganism. This review will also unlock ideas to utilize different paths for the production of silver nanoparticles, which can help human beings. We will discuss about the biogenic synthesis of silver nanoparticles and its biomedical application generally anticancer and antimicrobial activity. How the size, shape, concentration affect different cell line will also discuss here. How silver nanoparticles engulf by bacterial cell or it attack the cell wall of bacteria will also discuss here. In an attempt to synthesize metals NPs one has to bear in mind that the success of NPs depends not only on the size and shape but also on stability of NPs as they have the tendency to form large aggregates that lead to precipitation, thereby reducing their efficacy. So in this review we discuss about the green synthesis of silver nanoparticle and their biomedical application . The silver nanoparticle should be stable and they should have variable shape and size. So we should study their application in such a manner that we can discuss about the properties of a promising drug.

2. Advantages of green synthesis

Biosynthesis are better considered over chemical and physical method because:

1. High production, low cost, in the reduction it is large saving, and is higher in commercial viability while using biological nanoparticles [37].
2. The size of the particle in biosynthesis is lesser in size than the particles formed in both physical and chemical methods [38].
3. It is eco-friendly, clean and nontoxic.
4. High temperature and high pressure required for both physical and chemical methods and it is difficult to provide in this situation [39].

3. Plant extract

Various parts of the plant such as leaves, roots, flowers, fruits etc. have been successfully utilized for the synthesis of silver nanoparticles (AgNPs) [40-42]. Different parts of the plant are collected from different sources and washed properly to remove the impurity. Then the plant part were dried to make powder or to make extract. The powder sample then mixed and prepared solution in a deionized water. Silver nitrate solution is added to different concentration of plant extract at different pH and heated properly to prepare silver nanoparticles [43-45].This synthesis avoid the use of chemical substances as phytochemicals present in the extract use as reducing and stabilizing agents [46,47]. The change in color of the solution from colorless to yellowish brown color indicates the formation of silver nanoparticles. Formation of silver nanoparticles is also confirmed by SPR measurement by the use of UV-Vis spectroscopy [34]. After formation of silver nanoparticles it is centrifuged at high r.p.m and the precipitate then washed with double distilled water, purified, collected and stored in 4°C [48,49].

3.1. Leaf mediated nanoparticles
Leaf of Centella asiatica, Alternanthera sessilis, Murrraya koenigii, P.nigrum, Artemisia nilagirica were

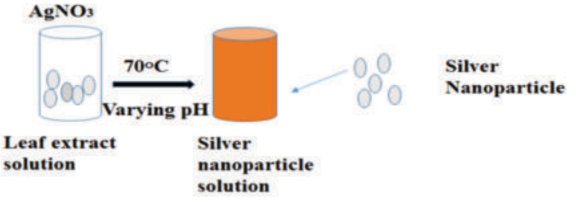

Figure 1: Synthesis of silver nanoparticle using different leaf extract

used for the synthesis of silver nanoparticles [50,51]. These silver nanoparticles have strong antimicrobial as well as anticancer effects.

3.2. Stem mediated nanoparticles
Methanolic extract of Callicarpa maingayi stem contains aldehyde group which plays a major role in reduction of silver ions to form silver nanoparticles. [Ag(Callicarpamaingayi)}+ complex. The

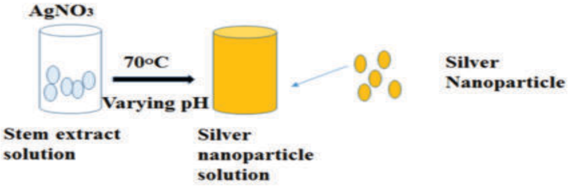

Figure 2: Synthesis of silver nanoparticle using stem extract

functional group such as –C=O, C=N indicates amide I, polypeptides play active role in metallic nanopartciles. Silver crystal molecule studies are complex when it is synthesized from plant and is not fully understood yet [52].

3.3. Fruit mediated nanoparticles
Tribulus terrestries fruit reduce silver nitrate and produces silver nanoparticles. This fruit extract on

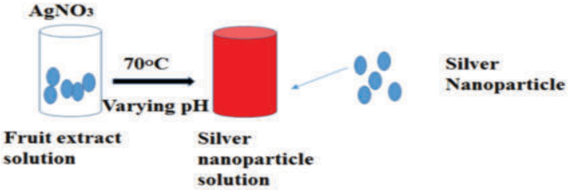

Figure 3: Fruit mediated synthesis of silver nanoparticle

reduction produces silver nanoparticles with good antimicrobial activity [53]. There is also a similar report on polyphenol from grapes palladium nanoparticles and is effective in activity [54].

3.4. Seed mediated nanoparticles
In fenugreek seed extract flavonoids and bioactive products such as vitamins, lignin, chloroauric acid and saponin are present. Chloroauric acid act as a strong reducing agents. There are presents of C=N, COO- group (carboxylic) and C=C functional group present in seed extract. The silver nanoparticles

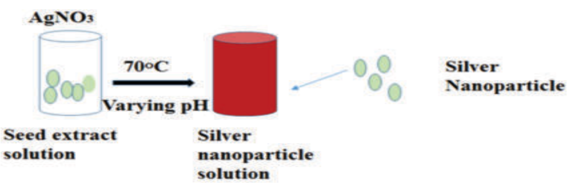

Figure 4: Seed mediated synthesis of silver nanoparticle

produced by fenugreek seed extract use as an antibacterial and antifungal agents [55]. The xyloglucan of TKP is composed of D-glucose, D-xylose and Dgalactose. The hydroxyl group present in the xyloglucan help in the reduction of silver nitrate to silver nanoparticles [56].

3.5. Flower mediated nanoparticles
Flower extract of *Aerva lanata* help in the synthesis of silver nanoparticle. The silver nanoparticle

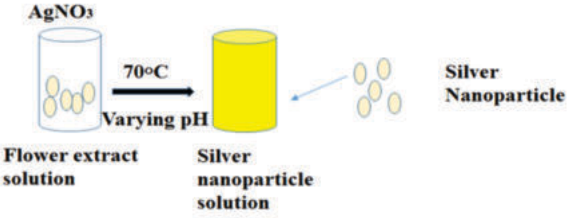

Figure 5: Reduction of silver nitrate using flower extract

produce have strong biomedical application [57, 58]. Green synthesis of silver nanoparticles using flower extract of *Abelmoschus esculentus* is also have strong antimicrobial and cytotoxicity activity [59].

3.6. Gum mediated nanoparticles
Guar gum is use in the synthesis of silver nanoparticles. The hydroxyl group present in the guar gum reduce silver nitrate to silver nanoparticle. Guar gum here act as reducing and stabilizing agents [60].

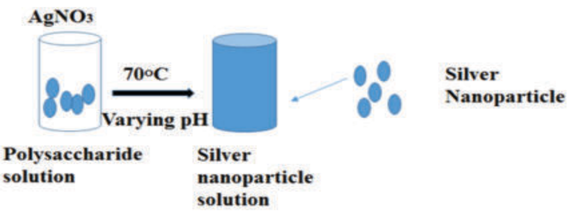

Figure 6: Polysaccharide gum mediated synthesis of silver nanoparticle

The gum present in *Acacia nilotica* help in the reduction of silver nitrate to silver nanoparticle. On reduction it produces spherical silver nanoparticle. It show cytotoxicity against Hela, A 549, Raw 264.7 and Wi 38 cell line [61]. Gum present in *Astragalus gummifer* also reduces and stabilizes silver nitrate and produces silver nanoparticle [62].

4. Synthesis from bacteria
Nanoparticle synthesis using bacteria is an easy and eco-friendly process. But it faces challenges for contamination and lengthy procedures. It also have less control over nanoparticle size [63]. The bacteria become as a promising agent for the reduction of heavy metals and synthesis of nanoparticles. Studies have reported that some bacteria species like Pseudomonas stutzeri and Pseudomonas aeruginosa have a developing ability to resort to specific defense mechanisms to overcome stresses like toxicity of heavy

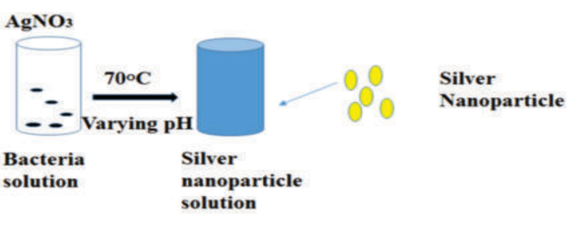

Figure 7: Synthesis of silver nanoparticle using bacteria solution

metal ions or metals and even survive and grow despite high metal ion concentrations [64]. Pseudomonas stutzeri strain mediated synthesis result in a well defined shapes and compositions of silver nanoparticles [65]. Using the culture of psychrophilic bacteria Shivaji et al. produces silver nanoparticles [66,67]. Nanda et al. reported the synthesis of silver nanoparticles using Staphylococcus aureus. Biomass of Bacillus licheniformis can also produces silver nanoparticle in 40-50 nm range according to Kalimuthu and his friends [68].

5. Synthesis of Silver Nanoparticles Using Fungi

Silver nitrate can also be reduced and the silver nanoparticles produced are stabilized by fungi.

The fungi mediated synthesis of silver nanoparticles has attracted more attention because of its ability to produce commercial quantities of silver nanoparticles with controlled size, morphology, and low toxicity of residues [69]. In the synthesis of silver nanoparticles using microorganisms, fungi strains are

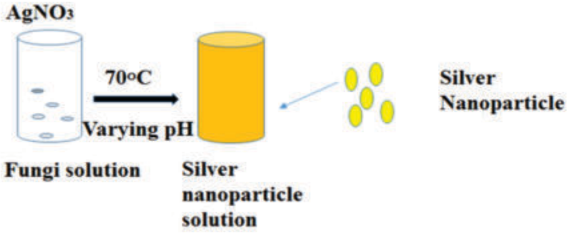

Figure 8: Synthesis of silver nanoparticle using fungi solution

preferred over bacteria species due to metal accumulation properties and better tolerance of the fungi [70,71]. Using fungi nanoparticles can be synthesised by both intracellular and extracellular method. In case of intracellular synthesis metal solution can be added to the bacterial culture. The nanoparticles produced are separated from bacterial biomass by centrifugation, washed properly and stored with double distilled water [72]. In extracellular synthesis methods, the metal precursor is added to the aqueous filtrate that is made up of only the fungal biomass biomolecules, thereafter resulting in the formation of free nanoparticles. This method does not require any protocols to release the nanoparticles from the cells and is the most widely used method [73]. Balaji and his colleagues synthesized silver nanoparticles by using Cladosporium cladosporioides [74]. The synthesized silver nanoparticles showed average sizes that range between 10–100 nm. Aspergillus terreus synthesized silver nanoparticles in 1-20 nm size range [75]. Fungus Verticillium synthesized mono-dispersed silver nanoparticles as described by Mukherjee et al [76].

4. Biomedical Application

(a) Antibacterial Activity

Silver nanoparticle have strong antibacterial activity. Both chemical and green route produces silver nanoparticle. Green synthesis using natural gum produces silver nanoparticle. Tamarind kernel powder and gum acacia produces silver nanoparticle within the size range of 5 to 50 nm. These nanoparticle have strong antibacterial activity against both gram negative E. coli and gram positive S. aureus. Ampicillin resistant E. coli and cefoxitim resistant S. aureus were isolated from UTI infected patient. From ZOI study it is clear that E.coli was more sensitive in silver nanoparticle than S.aureus [77]. Monodispersed silver nanoparticle prepared by guar gum and poly vinyl alcohol show strong antibacterial activity. Here also antibacterial study was done by ZOI study [78].

(b) Antifungal Activity

Antifungal effect of silver nanoparticles studied on Candida albicans and Saccharomyces cerevisiae. Fungicidal activity were compared against Amphotericin B and Fluconazole. Their membrane disruption were studied using SEM images [79].

(c) Antioxidant Activity

Cumin oil used in the synthesis of silver nanoparticle. It assess strong antioxidant activity. Both DPPH assay and BHT assay used to detect antioxidant activity. Antioxidant activity measured with respect to free radical scavenging activity. Phenolics compound present in the cumin have strong antioxidant activity. The antioxidant activity of the silver nanoparticle acquired by the phenolic compound present in the cumin [80].

(d) Anticancer Activity

In some literature it was shown that silver nanoparticle have anticancerous property. Poly vinyl alcohol and tamarind kernel powder produces silver nanoparticle. Among this different shape silver nanoparticle round shaped silver nanoparticle have good anticancer activity [81]. Round shaped silver nanoparticles also produced by using tamarind kernel powder and gum acacia. Silver nanoparticle produced within the size range of 10 nm to 78 nm. In vitro anticancer activity was done against different cancer cell line Hela, A549 and Raw 264.7 cell line [63].

(e) Antidiabetes Activity

Allium Cepa reduces metallic silver and produces silver nanoparticle. This silver nanoparticle were characterized by using different characterization method. The silver nanoparticle synthesized were spherical in shape. These particle inhibit higher level of α-amylase and α-glucosidase activity. It was used as antidiabetic medicine [82].

5. CONCLUSION

Silver nanoparticle were highly focused in this review. It will be strongly used in the field of medical microbiology. Natural gum and different plant extract were used in this synthesis process. Fungi and bacteria were also be used in this synthesis process. This silver nanoparticle were perfect for biological system. Different type of application have been focused in this review paper.

REFERENCES:

1. E. Kianfar. Catalytic Properties of Nanomaterials and Factors Affecting it. Iran. MedDocs Publishers LLC; 2020.
2. I. Rezic. Nanoparticles for Biomedical Application and Their Synthesis. Basel. Polymers (Basel). MDPI; 2022.
3. C. Sharma, R. Dhiman, N. Rokana. Nanotechnology: An Untapped Resource for Food Packaging. Front. Microbiol. Frontiers Media S.A; 2017.
4. F. Tosan, N. Rahnama, D. Sakhaei. Effects of doping metal nanoparticles in hydroxyapatite in Improving the physical and chemical properties of dental implants. Nanomed. Res. J. IJFMR; 2021.
5. A. Gade, A. Ingle, C. Whiteley. Mycogenic metal nanoparticles: progress and applications. Biotechnology Letters. Springer Science; 2010.
6. P. Kattan. Ratio of Surface Area to Volume in Nanotechnology and Nanioscience. Peter Books; 2011.
7. V.V. Mody, R. Siwale. Introduction to metallic nanoparticles. J. Pharm. Bioallied Science. Medknow; 2010.
8. C.T. Handoko, A. Huda, F. Gulo. Synthesis Pathway and Powerful Antimicrobial Properties of Silver Nanoparticle: A Critical Review. Asian Journal Of Scientific Research; 2019.
9. M.M.K. Peiris, S.S.N. Fernando. Comparison of Antimicrobial Properties of Silver Nanoparticles Synthesized from Selected Bacteria. Indian Journal Microbiol. Springer; 2018.
10. M.A. Dar, A. Ingle. Enhanced antimicrobial activity of silver nanoparticles synthesized by *Cryphonectria* sp. evaluated singly and in combination with antibiotics. Nanomedicine: Nanotechnology, Biology and Medicine. Elsevier; 2013.
11. M. Rai, A. Yadav. Silver nanoparticles as a new generation of antimicrobials. Biotechnology Advances. Elsevier; 2009.
12. X. Han, K. Xu, O. Taratula, K. Farsad. Applications of Nanoparticles in Biomedical Imaging. Nanoscale. The Royal Society of Chemistry; 2019.
13. A. Ray, A. Mukundan, Z. Xie, L. Karamchand. Highly stable polymer coated nano-clustered silver plates: A multimodal optical contrast agent for biomedical imaging. Nanotechnology. IOP; 2014.
14. J.M. Harner, D.A. Hoagland. Thermoreversible Gelation of an ionic liquid by crystallization of a dissolved polymer. Macromolecules, Soft Matter. Royal Society of Chemistry; 2010.
15. A. C. Burdusel, O. Gherasim, A. Fecai. Biomedical Applications of Silver Nanoparticles: An Up-to-Date Overview. Nanomaterials, MDPI; 2018.
16. S. Iravani, H. Korbekandi, B. Zolfaghari. Synthesis of silver nanoparticles: chemical, physical and biological methods. Res Pharm Sci., Wolters Kluwer Medknow Publications; 2014.
17. K. J. Lee, B. H. Jun, J. Choi, Y. S. Oh. Environmentally friendly synthesis of organic-soluble silver nanoparticles for printed electronics. Nanotechnology, IOP Science; 2007.
18. S.B. Maddinedi, B.K. Mondal, K.K. Anna. Environment friendly approach for size controllable synthesis of biocompatible Silver nanoparticles using diastase. Environmental Toxicology and Pharmacology; 2016.
19. M. S. H. Bhuiyan, M.Y. Miah, S.C. Paul, Md. Ashaduzzaman. Green synthesis of iron oxide nanoparticle using *Carica papaya* leaf extract: application for photocatalytic degradation of remazol yellow RR dye and antibacterial activity. Heliyon, Cell Press; 2020.
20. S. Lakshminarayanan, M. F. Shereen, A. Arumugam. One-pot green synthesis of iron oxide nanoparticles from *Bauhinia tomentosa*: Characterization and application towards synthesis of 1, 3 diolein. Nature, Nature; 2021.
21. J. Jeevanandam, S. F. Kiew, S. B. Ansah, J. Rodrigues. Green approaches for the synthesis of metal and metal oxide nanoparticles using microbial and plant extracts. Nanoscale, Royal Society of Chemistry; 2022.
22. J. Jeevananandam, Y. S. Chan, M.K. Danquah. Biosynthesis of Metal and Metal Oxide Nanoparticles. Chem. Bio. Eng. Rev, Wiley; 2016.
23. K. W. Koladka, D. Malina, Z. Wzorek. Bio-Based Synthesis of Silver Nanoparticles from Waste Agricultural Biomass and Its Antimicrobial Activity. Processes, MDPI; 2022.
24. EK Elumalai, J. Hemachandran, T. Thirumalai, E. David. Extracellular synthesis of silver nanoparticles using leaves of Euphorbia hirta and their antibacterial activities. J. Pharm. Sci. & Res., Scimago; 2010.
25. R. A. Voloshin, M.V. Radionova, T.N. Veziroglu. Biofuel production from plant and algal biomass. International Journal of Hydrogen Energy, Elsevier; 2016.
26. M. V. Radionova, R.S. Poudyal, I. Tiwari, S.I. Allakhverdiev. Biofuel production: Challenges and oppurtunities. International Journal of Hydrogen Energy, Elsevier; 2016.
27. I. Z. Pena, C. Cueva, M.V. Moreno-Arribus. Silver Nanoparticles against Foodborne Bacteria. Effects at Intestinal Level and Health Limitations. Microorganisms, MDPI; 2020.
28. P. Mathur, S. Jha, N. K. Jain. Pharmaceutical aspects of silver nanoparticles. Artif Cells Nanomed Biotechnol, PubMed; 2018.
29. P. Piszczek, A. Radtke. Silver Nanoparticles Fabricated Using Chemical Vapor Deposition and Atomic Layer Deposition Techniques: Properties, Applications and Perspectives: Review. Noble and precious metals; 2017.
30. T. Wu, H. Shen, J. Shen. Facile Synthesis of Ag Interlayer Doped Graphene by Chemical Vapor Deposition Using Polystyrene As Solid Carbon Source. *ACS Appl. Mater. Interfaces. ACS Publications; 2012.*
31. M. J. McNally, G. Galinis, O. Youle, K. V. Haeften. Silver nanoparticles by atomic

vapour deposition on an alcohol micro-jet. Nanoscale Advances, Royal Scociety of Chemistry; 2019.
32. N. Sahu, D. Soni, R. A. Pandey. Synthesis of silver nanoparticles using flavonoids: hesperidin, naringin and diosmin. International Nano Letters, Springer; 2016.
33. M. Hussain, N. I. Raja, S. Aslam. Applications of Plant Flavonoids in the Green Synthesis of Colloidal Silver Nanoparticles and Impacts on Human Health. Iran J Sci Technol Trans Sci, Iran; 2017.
34. S. B. Aziz, R. T. Abdulwahid, H.M. Ahmed. Polymer Blending as a Novel Approach for Tuning the SPR Peaks of Silver Nanoparticles. Polymers. MDPI; 2017.
35. J. Helmlinger, C. Sengstock, M. Koller, M. Epple. Silver nanoparticles with different size and shape: equal cytotoxicity, but different antibacterial effects. RSc Advances, Royal Society of Chemistry; 2016.
36. J. Hajtuch, N. Hante, I. I. Stepniak. Effects of functionalized silver nanoparticles on aggregation of human blood platelets. Int. J. Nanomedicine, Dove Medical Press; 2019.
37. S. Stanley. Biological nanoparticles and their influence on organisms. Current Opinion In Biotechnology. Elsevier; 2014.
38. P. Belteky, A. Ronavari, Z. Konya. Are Smaller Nanoparticles Always Better? Understanding the Biological Effect of Size-Dependent Silver Nanoparticle Aggregation Under Biorelevant Conditions. International Journal of Nanomedicine, Dovepress; 2021.
39. S. Iravani, H. Korbekandi. Synthesis of silver nanoparticles: Chemical, physical and biological methods. Research In Pharmaceutical Sciences, RPS; 2014.
40. A. Verma, M. S. Mehata. Controllable synthesis of silver nanoparticles using Neem leaves and their antimicrobial activity. Journal of Radiation Research and Applied Sciences, Elsevier; 2016.
41. L. N. Khanal, K. R. Sharma, H. Paudyal, S. K. Kalauni. Green Synthesis of Silver Nanoparticles from Root Extracts of *Rubus ellipticus* Sm. and Comparison of Antioxidant and Antibacterial Activity. Journal of Nanomaterials, Hindawi; 2022.
42. M. C. D. Niluxsshun, K. Masilamani, U. Mathiventhan. Green Synthesis of Silver Nanoparticles from the Extracts of Fruit Peel of *Citrus tangerina*, *Citrus sinensis*, and *Citrus limon* for Antibacterial Activities. Bioinorganic Chemistry And Applications, Hindawi; 2021.
43. N. M. Muchanyereyi, C. Gusha, S. Nyoni. Synthesis of silver nanoparticles using plant extracts from *Erythrina abyssinica* aerial parts and assessment of their anti-bacterial and anti-oxidant activities. Results In Chemistry. Elsevier; 2022.
44. N. Krithiga, A. Jayachitra. Green Synthesis of Silver Nanoparticles Using Leaf Extracts of *Clitoria ternatea* and *Solanum nigrum* and Study of Its Antibacterial Effect against Common Nosocomial Pathogens. Journal of Nanoscience, Hindawi; 2015.
45. M. Aslam, F. Fozia, H. Hussain. Phyto-Extract-Mediated Synthesis of Silver Nanoparticles Using Aqueous Extract of *Sanvitalia procumbens*, and Characterization, Optimization and Photocatalytic Degradation of Azo Dyes Orange G and Direct Blue-15. Molecules, MDPI; 2021.
46. Md. M. R. Mollick, D. Rana, S. K. Dash, D. Chattopadhyay. Studies on green synthesized silver nanoparticles using *Abelmoschus esculentus* (L.) pulp extract having anticancer (*in vitro*) and antimicrobial applications. Arabian Journal of Chemistry, Elsevier; 2019.
47. Li Xu, Yi Yi Wang, Hui Xie. Silver nanoparticles: Synthesis, medical applications and biosafety. Theranostics, Ivyspring International Publisher; 2020.
48. S. T. Galatage, A.S. Hebalkar, S. V. Dhobale, S. G. Killedar. Silver Nanoparticles: Properties, Synthesis, Characterization, Applications and Future Trends. Silver Micro Nanoparticles, Intech Open; 2021.
49. Hemlata, P. R. Meena, A. P. Singh, K. K. Tejavath. Biosynthesis of Silver Nanoparticles Using *Cucumis prophetarum* Aqueous Leaf Extract and Their Antibacterial and Antiproliferative Activity Against Cancer Cell Lines. ACS Omega, ACS Publications; 2020.
50. J. Zhang, IS. Zhao, M. Ml. The Antibacterial Mechanism of Silver Nanoparticles and Its Application in Dentistry. International Journal of Nanomedicine, Dovepress; 2020.
51. T. Rasheed, M. Bilal, H. M. N. Iqbal, C. Li. Green biosynthesis of silver nanoparticles using leaves extract of Artemisia vulgaris and their potential biomedical applications. Colloids Surf B Biointerfaces, Elsevier; 2017.
52. J. Y. Song, B. S. Kim. Rapid biological synthesis of silver nanoparticle using plant leaf extracts. Bioprocess Biosyst Eng, Springer Verlag; 2009.
53. V. Gopinath, D. M. Ali, P. Velusamy. Biosynthesis of silver nanoparticles from Tribulus terrestris and its antimicrobial activity: a novel biological approach. Colloids Surf B Biointerfaces, Elsevier; 2012.
54. A. Singh, P. K. Gautam, A. Verma, V. Singh, A. K. Sahoo. Green synthesis of metallic nanoparticles as effective alternatives to treat antibiotics resistant bacterial infections: A review. Biotechnology Reports, Elsevier; 2020.
55. R. M. Ahmed, N. K. Alshafei, H. A. Mohamed. Green method of synthesis silver nanoparticles as using fenugreek seeds extract (Trigonella foenum-graecum) and its application as antibacterial agent. University of Bahri Journal of Veterinary Sciences, Sudan; 2022.
56. C. Vanlalveni, S. Lallianrawna, A. Biswas, S. L. Rokhum. Green synthesis of silver nanoparticles using plant extracts and their antimicrobial activities: a review of recent literature. RSC Advances, Royal Society of Chemistry; 2021.
57. S. Palithya, S. A. Gaddam, V. S. Kotakadi, S.B.N Krishna. Green synthesis of silver nanoparticles using flower extracts of *Aerva lanata* and their biomedical applications. Particulate Science and Technology, Taylor & Francis Online; 2022.
58. P. Kanniah, J. Radhamani, P. Chelliah, J. R. Thangapandi. Green Synthesis of Multifaceted Silver Nanoparticles Using the Flower Extract of *Aerva lanata* and Evaluation of Its Biological and Environmental Applications. Chemistry Europe, European Chemical Societies Publishing; 2020.
59. S. Devanesan, M.S.A. Salhi. Green Synthesis of Silver Nanoparticles Using the Flower Extract of *Abelmoschus esculentus* for Cytotoxicity and Antimicrobial Studies. Int J Nanomedicine, Dovepress; 2021.
60. T. Das, S. Yeasmin, S. Khatua, K. Acharya, A. Bandyopadhyay. Influence of a blend of guar gum and poly(vinyl alcohol) on long term stability, and antibacterial and antioxidant efficacies of silver nanoparticles. RSC Advances. Royal Society of Chemistry. 2015.
61. S. Yeasmin, H.K. Datta, S. Chaudhuri, D. Malik, A. Bandyopadhyay. In-vitro anti-cancer activity of shape controlled silver nanoparticles (AgNPs) in various organ specific cell lines. Journal of Molecular Liquids. Elsevier; 2017.
62. A. S. Yaglioglu, R. Erenler, E. N. Gecer, N. Genc. Biosynthesis of Silver Nanoparticles Using *Astragalus flavesces* Leaf: Identification, Antioxidant Activity, and Catalytic Degradation of Methylene Blue. Journal of Inorganic and Organometallic Polymers and Materials, Springer; 2022.
63. N. Duran, P. D. Marcato, M. Brocchi. Potential use of silver nanoparticles on pathogenic bacteria, their toxicity and possible mechanisms of action. J. Braz. Chem. Soc., Brazil; 2010.
64. R. M. Sterritt, J.N. Lester. Interactions of heavy metals with bacteria. Science of The Total Environment, Elsevier; 1980.
65. N. Rajora, S. Kaushik, A. Jyoti, S. L. Kothari. Rapid synthesis of silver nanoparticles by *Pseudomonas stutzeri* isolated from textile soil under optimised conditions and evaluation of their antimicrobial and cytotoxicity properties. IET Nanobiotechnol, Wiley Online Library; 2016.
66. M. Mohamed, A. Mohamed, A. E. R. Hallol. Studies on Bacterial Synthesis of Silver Nanoparticles Using Gamma Radiation and Their Activity against Some Pathogenic Microbes. Cairo University; 2009.
67. S. Shivaji, S. Madhu, S. Singh. Extracellular synthesis of antibacterial silver nanoparticles using psychrophilic bacteria. Process Biochemistry. Elsevier; 2011.
68. L. V. Tan, T. Tran, V.D. Thi. Biosynthesis of Silver Nanoparticles from Bacillus licheniformis TT01 Isolated from Quail Manure Collected in Vietnam. Processes. MDPI; 2021.
69. M. G. Casagrande, R. D. Lima. Synthesis of Silver Nanoparticles Mediated by Fungi: A Review. Front. Bioeng. Biotechnol, Frontiers; 2019.
70. M. Gajbhiye, J. Kesharwani, A. Ingle. M. Rai. Fungus-mediated synthesis of silver nanoparticles and their activity against pathogenic fungi in combination with fluconazole. Nanomedicine: Nanotechnology, Biology and Medicine, Elsevier; 2009.
71. P. Mukherjee, A. Ahmad, D. Mandal, R. Kumar, M. Sastry. Fungus-Mediated Synthesis of Silver Nanoparticles and Their Immobilization in the Mycelial Matrix: A Novel Biological Approach to Nanoparticle Synthesis. Nano Letters, ACS; 2001.
72. S. Behzadi, V. Serpooshan, W. Tao, M. Mahmoudi. Cellular Uptake of Nanoparticles: Journey Inside the Cell. Chem. Soc. Rev., Royal Society of Chemistry; 2017.
73. T. L. Moore, D. A. Urban, L.R. Lorenzo, A. P. Fink. Nanoparticle administration method in cell culture alters particle-cell interaction. Scientific Reports, Nature; 2019.
74. D. Popli, V. Anil, A. B. Subramanyam, S. N. Rao. Endophyte fungi, *Cladosporium* species-mediated synthesis of silver nanoparticles possessing *in vitro* antioxidant, anti-diabetic and anti-Alzheimer activity. Artificial cells, Nanomedicine, and Biotechnology, Taylor & Francis online; 2018.
75. R. Raliya, J. C Tarafdar. Novel Approach for Silver Nanoparticle Synthesis Using Aspergillus terreus CZR-1: Mechanism Perspective. Journal of Bionanoscience, American Scientific Publishers; 2012.
76. P. Mukherjee, A. Ahmad, R. Kumar, M. Sastry. Fungus-Mediated Synthesis of Silver Nanoparticles and Their Immobilization in the Mycelial Matrix: A Novel Biological Approach to Nanoparticle Synthesis. Nano Letters, ACS Publications; 2001.
77. S. Yeasmin, I. Bhattacharya. SIZE-CONTROLLED SILVER NANOPARTICLES SYNTHESIZED OVER THE RANGE 5–50 NM AND THEIR ANTIBACTERIAL EFFICACY STUDY ON BACTERIA ISOLATED FROM UTI INFECTION. International Journal of Scientific Research, 2023.
78. T. Das, S. Yeasmin, S. Khatua, K. Acharya, A. Bandyopadhyay. Influence of a blend of guar gum and poly (vinyl alcohol) on long term stability, antibacterial and antioxidant efficacies of silver nanoparticles. RSC Advances, Royal Society of Chemistry; 2015.
79. A. Nasrollahi, K. Pourshamsian, P. Mansourkiaee. Antifungal activity of silver nanoparticles on some of fungi. International Journal of Nano Dimension, Islamic Azad University; 2011.
80. N. Keerthiga, R. Anitha, S. Rajeshkumar, T. Lakshmi. Antioxidant Activity of Cumin Oil Mediated Silver Nanoparticles. Pharmacogn., J. Pharmacognosy Journal; 2019.
81. S. Yeasmin, D. Malik, T. Das, A. Bandyopadhyay. Green synthesis of silver nano/micro particles using TKP and PVA and their anticancer activity. RSC Advances, Royal Society of Chemistry; 2015.
82. D. Jini, S. Sharmila. Green synthesis of silver nanoparticles from *Allium cepa* and its *in vitro* antidiabetic activity. Materialstoday: 2020.