CHAPTER 11

# RESEARCH PROGRESS AND NEW INSIGHTS IN BIOSYNTHESIS OF SILVER NANOPARTICLES WITH PARTICULAR APPLICATIONS

DEBARSHI KAR MAHAPATRA[1,*] and SANJAY KUMAR BHARTI[2]

[1]*Department of Pharmaceutical Chemistry, Dadasaheb Balpande College of Pharmacy, Nagpur 440037, Maharashtra, India*

[2]*Institute of Pharmaceutical Sciences, Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur 495009, Chhattisgarh, India*

[*]*Corresponding author. E-mail: mahapatradebarshi@gmail.com*

**ABSTRACT**

The plant mediated biosynthesis of silver nanoparticles (AgNPs) is an attractive method for commercial fabrication of nanomaterials with indispensable environment protection attributes. The central theme of this article is to provide an approach for replacing the influence of certain harmful chemicals like sodium borohydride, dimethyl formamide, hydrazine hydrate, ethylene glycol, etc. in the fabrication of AgNPs, with plant extracts for overcoming the drawbacks. The present chapter comprehensively focuses on the common techniques and principles for the fabrication of AgNPs by the utilization of some common plant biomass. The content focuses on the information of specific plant species, plant part employed, size of produced nanoparticles, etc. In addition to it, the nanomedicinal applications of AgNPs as anti-cancer (in vivo and cell-line), anti-diabetic, anti-parasite (malaria, dengue, and filariasis), anti-inflammatory, anti-platelet, theranostic utility, and anti-microbial (bacteria and fungi) as

well as their impact on environment have been highlighted exclusively. The probable mechanisms of actions of AgNP-based products (Acti-coat®, SilvaSorb®, Silverline®, ON-Q-SilverSoaker®) exerted via various biochemical pathways as well as the plausible mechanism of formation of reduced silver forms from plant extracts are also shown exhaustively.

## 11.1 INTRODUCTION

The nanotechnology in biomedical research and clinical practice emerged as nanomedicine that could potentially make a major impact on human health.[213] Nanotechnology has revolutionized all fields across the globe and opened up several frontiers in nanobiotechnology,[348] nanopharmaco-therapeutics,[178] and material and applied sciences.[257] The role of silver (Ag) materials as bactericidal agents is known for ages and many archives have highlighted the role and utilization of Ag-fabricated products in their daily life. The synthesis of silver nanoparticles (AgNPs) is a dynamic field in academics and applied research. AgNPs are increasingly used in therapy, diagnostics, imaging, and targeted drug delivery due to their specific function at the cellular, atomic and molecular levels.[212] Recently, AgNPs gained key importance in biomedical sciences,[433] drug delivery,[369] catalysis,[269] optics,[133] and photoelectrochemistry.[367] Nanomedicine has potential to integrate diagnostics/imaging with therapeutics and facilitates the development of theranostics for personalized medicine.[283] Generally, the processes employed for the synthesis of nanoparticles are broadly classified into two types: the "top-down" process and "bottom-up" process (Fig. 11.1). In "top-down" approach, the bulk material breaks down into particles at the nanoscale with various lithographic procedures like grinding, milling, etc., whereas in "bottom-up" approach, the atoms bring together to form a nucleus which grows eventually into a particle of nanosize.[397]

A variety of chemical and physical processes have been reported for the synthesis of metallic nanoparticles. The use of biological resources in synthesis of nanomaterials is rapidly developing due to their growing success, ease of formation of nanoparticles, economic, and ecofriendly in nature.[196] Typically, a plant-mediated bioreduction process occurs when the aqueous extract of plant reacts with an aqueous solution of the metal salt (here, $AgNO_3$) (Fig. 11.2). The complete reaction occurs at room temperature within a few minutes. Due to presence of a wide variety of chemicals, the bioreduction process is relatively complex. Biological

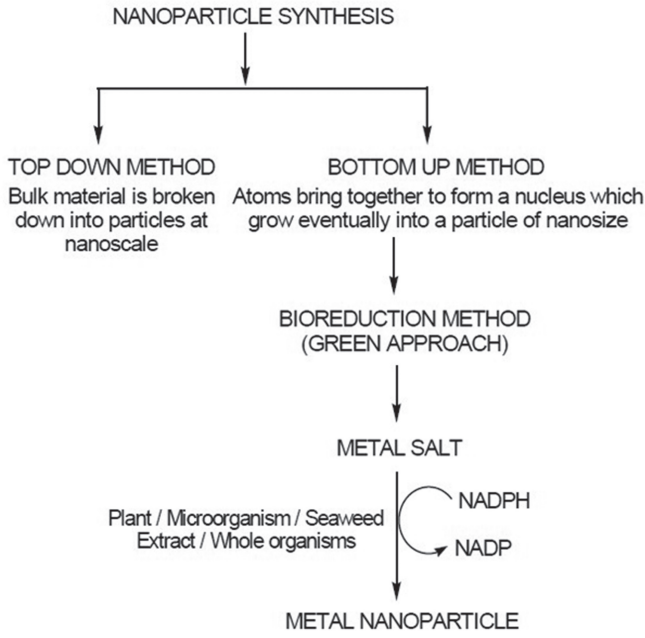


**FIGURE 11.1** Top-down and bottom-up methods for AgNP fabrication.

synthesis of nanoparticles using plant extracts are relatively scalable and less expensive compared with microbial processes.[235] The source of the plant extract also influences the characteristics of nanoparticles because of varying concentrations and combinations of organic reducing agents.[92] Thus, there is a need to explore ecofriendly green synthetic protocols for the synthesis of AgNPs.

## 11.2 NANOMEDICINE PERSPECTIVES OF AgNPs

### *11.2.1 AgNPs AS ANTI-DIABETIC AGENTS*

Silver nanomaterials obtained from the *Tephrosia tinctoria* aqueous extract demonstrated increased glucose uptake in muscular cells and noteworthy α-amylase and α-glucosidase inhibitory potential with inhibition percentages of 94.76 and 83.52, respectively. The mediated pharmacological activity may be due to the antioxidant potential of the AgNPs.[308]

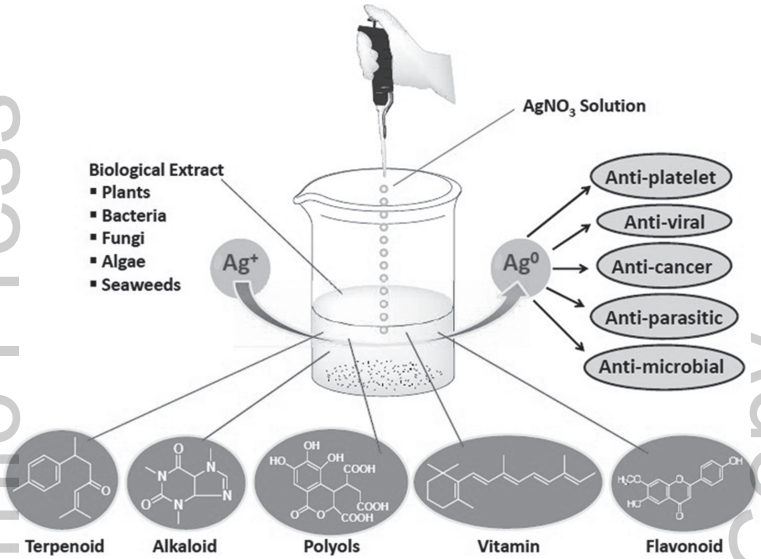


**FIGURE 11.2** Diagrammatic representation of common technique for the fabrication of AgNPs.

### *11.2.2 AgNPs AS THERANOSTIC AGENT*

Although at present in a very stage for use in mammals, the biosynthesized AgNPs find applications as a future generation nanomedicine for the advances in cancer theranostic agents (imaging, sensing, and therapy) owing to their physicochemical attributes. The safety and effectiveness of fabricated AgNPs have not yet established very well. The translation process of the existing knowledge and the emerging technologies into a few application-oriented commercial products for the simultaneous imaging and pharmacotherapeutics by overcoming the main challenges and issues will be the future perspective.[246,283]

### *11.2.3 AgNPs AS ANTI-INFLAMMATORY AGENTS*

Noteworthy, anti-inflammatory perspective has been demonstrated by the biosynthesized AgNPs without any specific toxic effects. The in vivo experimental findings revealed that the AgNPs expressed a significant

decrease in inflammatory responses in the peritoneal adhesions and their clinical application provides directions toward the postoperative adhesion prevention. The study presented substantiation for comprehending the mechanism of anti-inflammatory action(s).[438]

### 11.2.4 AgNPs AS ANTI-PLATELET AGENTS

Considerable in vitro integrin-mediated platelet responses suppression has been exhibited by the plant extract-mediated synthesized AgNPs of size 15–30 nm in a dose-dependent manner. On focusing the mechanism of action of the AgNPs, it was seen that the compound accrues inside the platelet and diminishes the interplatelet proximity. AgNPs do not have any lytic effect on the human platelets which opens new avenues of new-generation antithrombotic agents.[368] In a similar manner, AgNPs of size range 10–50 nm procured from *Brevibacterium casei* have remarkable anticoagulant potentials where AgNPs adheres with the immobilized collagen, thereby, preventing the platelet aggregation and formation of fibrin clot along with inhibiting the integrin-mediated platelet function in a dose-dependent manner. The nanoparticles are fabricated from the proteins present in the bacterium which acts as possible bioreductants and capping agent, thereby marked stability to the nanoparticles.[163]

### 11.2.5 AgNPs AS ANTI-MICROBIAL AGENTS

Nanoparticles of Ag find importance as bactericidal from millenniums. Even in the old literature, Ag in ionic form or in any other forms has received adequate attention. At present, AgNPs have been reported to exert bactericidal effect on a large number of severely pathogenic bacterial species such as *Aeromonas hydrophilla*, *Bacillus cereus*, *Corney bacterium*, *Enterobacter cloacae*, *Escherichia coli*, *Klebsiella pneumoniae*, *Micrococcus Luteus*, *Proteus mirabilis*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Salmonella enterica*, *Salmonella paratyphi*, *Shigella dysenteriae*, *Shigella sonnei*, *Staphylococcus aureus*, *Streptococcus pyogens*, *Staphylococcus saprophyticus*, and *Vibrio cholera*.[102] The ionized Ag forms distinctly interact with the thiol part of proteins, bacterial plasmid, DNA bases, peptidoglycan structures, plasma membrane, release lipid peroxide, and bacterial protein assembly (ribosomes) that cause inactivation of the

cellular enzymes, generate reactive oxygen species (by strongly reacting with the electron-donating groups), increase permeation of the cell membrane and mitochondrial systems, ceases DNA replication process, detaches respiratory electron transport from the oxidative phosphorylation, protein synthesis inhibition, causes DNA condensation, alters membrane permeability, deformation of microcellular constitution, therefore, ultimately leading to complete bacterial growth inhibition and inactivation.[65] The bactericidal mechanism in *E. coli* by AgNPs was comprehensively studied by Li et al.[205] where the nanomaterial at concentration of 100 mg/mL forms a pit in the cell membrane causing oozing of the proteins and reducing sugars from the cytoplasm (Fig. 11.3).

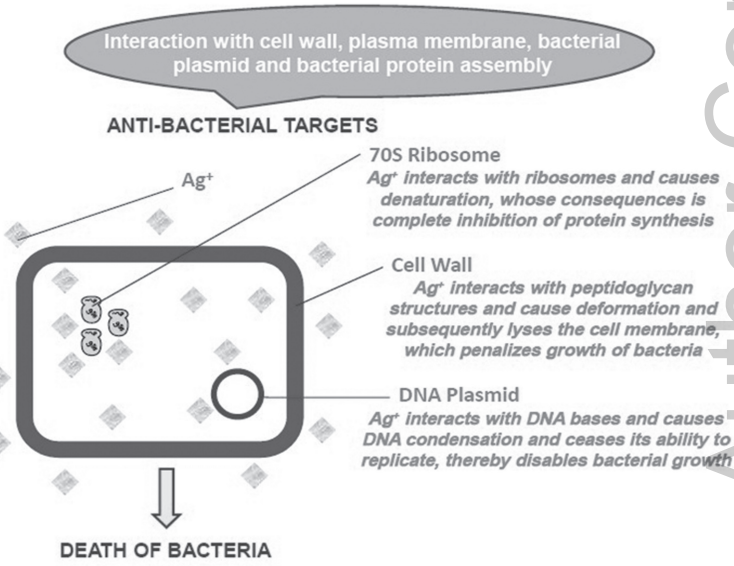


**FIGURE 11.3** Anti-bacterial mechanism of action(s) of AgNPs.

### *11.2.6 AgNPs AS ANTIPARASITIC AGENTS*

The plant extract-mediated AgNPs have been reported to exhibit noteworthy larvicidal and pupicidal activity. Malaria, dengue, and filariasis are the chief diseases transmitted by the malaria vector (by bite of infected mosquitoes) in the tropical and subtropical regions like Africa.[437] Biomass-mediated synthesized AgNPs play pivotal activity against *Aedes aegypti*, *Anopheles stephensi*, *Anopheles subpictus*, *Culex gelidus*, *Culex*

*quinquefasciatus*, *Culex tritaeniorhynchus*, *Haemaphysalis bispinosa*, *Hippobosca maculate*, *Hyalomma anatolicumanatolicum*, *Hyalomma marginatumisaaci*, *Pediculus humanus capitis*, etc.

AgNPs synthesized from the leaf extract of *Andrographis paniculata* have been reported to express antiplasmodial activity against *Plasmodium falciparum* with $IC_{50}$ values of 83% at 100 µg/mL.[273] A significant *Anopheles* larvicidal activity has been displayed by the AgNPs produced from the plant biomass. The larvicidal activity of *Gmelina asiatica* aqueous leaf extract,[251] aqueous leaf extracts of *Nelumbo nucifera*,[346] leaf extract of *Euphorbia hirta*,[301] floral extract-mediated biosynthesized AgNPs from *Chrysanthemum indicum* ,[22] aqueous leaf extracts of *Musa paradisiaca* L.,[151] and biosynthesized AgNPs using *Murraya koenigii* leaf extract[384] against late third instar larvae of *Anopheles stephensi*. Considerable larvicidal activity against *Aedes aegypti* have been observed by biosynthesized AgNPs from aqueous extract from *Eclipta prostrate*,[306] plant latex of *Plumeria rubra*,[281] and leaf extract of *Mukia maderaspatana*.[68] Remarkable larvicidal potentials of plant extract-mediated AgNPs have been noticed extensively. Bark aqueous extract of *Ficus racemosa*,[420] *Couroupita guianensis* leaf and fruit extracts[429] against *Culex quinquefasciatus* and *Culex gelidus*.

Similarly, authors also reported the pediculocidal and larvicidal activities of biosynthesized AgNPs from aqueous leaf extract of *Tinospora cordifolia* against the head louse *Pediculus humanus capitis* and fourth instar larvae of malaria vector, *Anopheles subpictus* and filariasis vector, *Culex quinquefasciatus*.[150] Aqueous leaf extract of *Ocimum canum* mediated synthesis have shown antiparasitic activities against the larvae of *Hyalomma anatolicum* (a.) *anatolicum* and *Hyalomma marginatum* (m.) *isaaci*.[151]

Plant-mediated synthesized AgNPs of size 70–140 nm using aqueous leaf extract of *Manilkara zapota* to control *Rhipicephalus (Boophilus) microplus* was reported with $LC_{50}$ values of 16.72 and 3.44 mg/L, respectively.[306]

### 11.2.7 AgNPs AS ANTICANCER AGENTS

Cytotoxicity and genotoxicity remained the mainstream biological activity of the biofabricated AgNPs. At low concentration, AgNPs on contact with the lysosome under acidic environment exert pronounced cytotoxicity by directly liberating reactive oxygen species (ROS) production.[449] The ionized Ag escapes from the lysosomes and supplementary tempt for the intensification of the intracellular ROS (like hydroxyl radicals, superoxide

anions, and hydrogen peroxide) and subsequently diffuse into the nucleus via nuclear pore complexes causing chromosomal abnormalities and produce DNA damage.[24] The ionized Ag interacts with the cellular components and release lipid peroxide which leads to cytoplasmic contents leakage, resulting in the rupture of lysosomal membranes, activation of lysosome-mediated apoptosis, mitochondria injury which often give rise to necrosis and impairs electron transfer system (Fig. 11.4). In addition to it, in vivo $Ag^+$ release occur in contact with $H_2O_2$ which results in metabolism upregulation and activation of genes essentially linked with the oxidative stress, thus, greatly elevates the ROS production.[435]

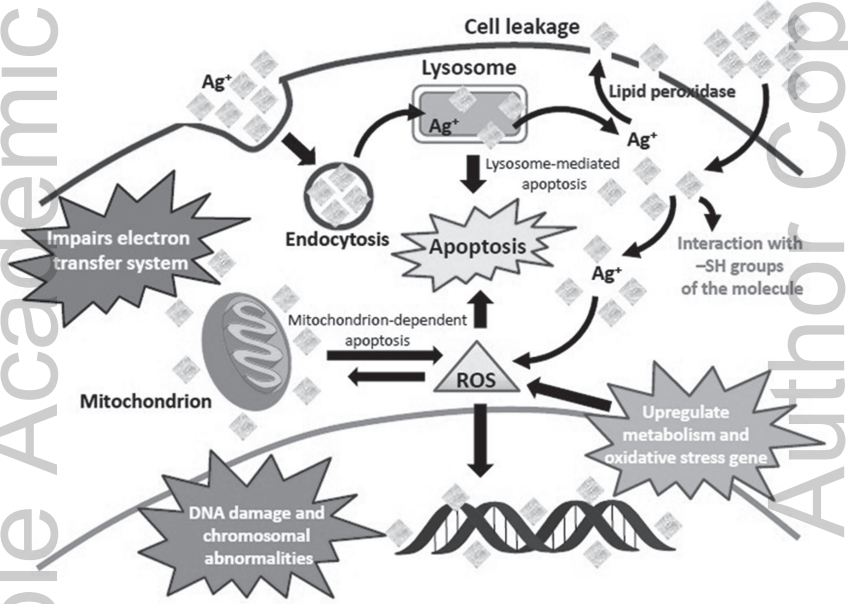


**FIGURE 11.4** Anti-cancer mechanism of action(s) of AgNPs.

Metals and metal containing compounds possess a tremendous high nucleolytic potential and exhibit cytotoxicity.[56] In recent times, the cytotoxic potentials of AgNPs on numerous human cell lines like A549, BRL3A, G292, H157, HaCaT, HeLa, HEp-2, HepG2, HL-60, HSC-3, HT144, IMR-90, KB, Lu, MCF-7, U251, Vero, etc. have been reported by various researchers. In vitro cytotoxic potential of AgNPs have been reported against HepG2, KB, Lu, and MCF-7 with $IC_{50}$ range of 3.74–6.09

μg/mL.[402] The potential of AgNPs on the skin were evaluated against HaCaT cell line with $IC_{50}$ value of 6.8 μM after 7 days of contact which concluded a long-lasting cell growth inhibition.[444] Leaf extract of *Piper longum* mediated fabrication of AgNPs of size range 17–41 nm expressed striking cytotoxic effect against Hep-2 cell line.[144] A noticeable antiproliferative activity of AgNPs fabricated from *Citrullus colocynthis* calli extract have been reported where the prepared nanomaterials significantly reduced the HEp2 viability to 50% of the initial level via apoptosis process.[355] Biocompatible AgNPs of size range 10–20 nm fabricated from table sugar exhibited excellent antitumor perspective against both HT144 and H157 cell lines.[264] In an interesting study, fabricated stable AgNPs from *Melia azedarach* displayed dose-dependent cytotoxic action against HeLa cells with $LD_{50}$ value of 300 μg/mL.[385]

In search for chemonanotherapeutics, Nano-Ag biosynthesized from the *Syzygium cumini* fruit extract expressed potential anticancer activity against dalton lymphoma cell line.[234] A dose-dependent cytotoxic action against HeLa cell line have been demonstrated by AgNPs biofabricated from *Calotropis gigantean* latex extract with $IC_{50}$ value of 91.3 μg/mL.[313] Nanoparticles of Ag biosynthesized from the *Eucalyptus chapmaniana* leaf extract wielded a dose-dependent cytotoxic activity against HL-60 cell line.[386] In a similar research, screening of *Eucalyptus chapmaniana* mediated fabricated AgNPs against HL-60 cell line presented an effective dose-dependent decline in cellular viability.[386] In the direction of exploring the potentials of biofabricated AgNPs, *Erythrina indica* root extract mediated synthesized Ag nanomaterial demonstrated noteworthy effect against MCF-7 and HepG2 cell lines with $IC_{50}$ values of 23.89 and 13.86 μg/mL, respectively.[383] The screening of a marketed product (Nanocid®) of mean particle size 7–20 nm against osteoblast (G292) cell line revealed that the product exerted concentration-dependent toxicity with $IC_{50}$ of 3.42 μg/mL.[238]

## 11.3 NANOSILVER-BASED PRODUCTS IN MARKET

In the recent years, a few innovative products have come to the market for clinical utility. The nanocrystalline AgNP product Acticoat® as wound dressing in burns to improve wound healing.[90] SilvaSorb® is a product of Medline composed of AgNP-based hand gel used for personal and medical

uses.[63] Recently, Ag-coated catheters Silverline® and ON-Q-SilverSoaker® finds application for the drainage of fluids and drug delivery.[65]

## 11.4 INDIAN PLANTS AS BIOMASS FOR THE REDUCTION OF SILVER NITRATE AND THEIR PROBABLE MECHANISMS

India is privileged for its wide biodiversity. Several plants grow in this subcontinent due to different climatic conditions. Commonly, *Allium sativum, Camellia sinensis, Terminalia catechu, Mentha piperita, Parthenium hysterophorus, Carica papaya, Citrus limon, Datura metel, Piper longum, Swietenia mahogany, Glycyrrhiza glabra, Andrographis paniculata, Astragalus gummifer, Piper betle*, *Piper nigrum, Azadirachta indica, Allium cepa,* etc. are the main plants present. Several researchers have reported the fabrication of AgNPs from these biomasses (Table 11.1).

**TABLE 11.1** Some Common Indian Plants Used for Biosynthesis of AgNPs.

| S. no. | Plant | Plant part | Size of AgNPs (nm) | References |
|---|---|---|---|---|
| | *Abutilon indicum* | Leaf | 5–25 | [228] |
| | *Abutilon indicum* | Leaf | 7–17 | [33] |
| | *Acalypha indica* | Leaf | 20–30 | [187] |
| | *Allium cepa* | Whole plant | 33.6 | [359] |
| | *Allium sativum* | Whole plant | 3–6 | [436] |
| | *Andrographis paniculata* | Leaf | 13–27 | [392] |
| | *Andrographis paniculata* | Leaf | 35–55 | [273] |
| | *Andrographis paniculata* | Leaf | 40–60 | [377] |
| | *Astragalus gummifer* | Gum | 12–14 | [184] |
| | *Azadirachta indica* | Leaf | 5–35 | [366] |
| | *Azadirachta indica* | Leaf | 15–20 | [404] |
| | *Azadirachta indica* | Leaf | NA* | [201] |
| | *Azadirachta indica* | Leaf | 20–50 | [229] |
| | *Azadirachta indica* | Leaf | NA | [330] |
| | *Bacopa monniera* | Leaf | 10–30 | [215] |

**TABLE 11.1** *(Continued)*

| S. no. | Plant | Plant part | Size of AgNPs (nm) | References |
|---|---|---|---|---|
| | *Camellia sinensis* | Leaf | 40 | [428] |
| | *Camellia sinensis* | Leaf | 4 | [207] |
| | *Carica papaya* | Fruit | 15 | [147] |
| | *Carica papaya* | Callus | 60–80 | [243] |
| | *Citrus limon* | Fruit | 2–10 | [360] |
| | *Citrus limon* | Fruit | 50 | [298] |
| | *Citrus limon* | Fruit | 75 | [326] |
| | *Citrus sinensis* | Peel | 35 | [172] |
| | *Citrus sinensis* | Peel | 91 | [36] |
| | *Datura metel* | Leaf | 16–40 | [174] |
| | *Datura metel* | Flower | 20–30 | [265] |
| | *Datura metel* | Leaf | 20–36 | [398] |
| | *Datura metel* | Leaf | 50–100 | [270] |
| | *Glycyrrhiza glabra* | Root | 20–30 | [83] |
| | *Murraya koenigii* | Leaf | 10 | [287] |
| | *Murraya koenigii* | Leaf | 10–25 | [71] |
| | *Murraya koenigii* | Leaf | 20–35 | [384] |
| | *Murraya koenigii* | Leaf | 35.43 | [52] |
| | *Ocimum sanctum* | Leaf | 10–20 | [287] |
| | *Ocimum sanctum* | Leaf | 42 | [325] |
| | *Ocimum sanctum* | Root and stem | 8–12 (root)<br>4–6 (stem) | [4] |
| | *Ocimum sanctum* | Leaf | 3–20 | [219] |
| | *Ocimum sanctum* | Leaf | 18 | [318] |
| | *Ocimum sanctum* | Leaf | 40–50 | [33] |
| | *Ocimum sanctum* | Leaf | 4–30 | [376] |
| | *Piper betle* | Leaf | 5–30 | [319] |
| | *Piper longum* | Leaf | 17–41 | [144] |
| | *Piper nigrum* | Flower | 5–50 | [111] |
| | *Swietenia mahogany* | Leaf | 10–25 | [240] |
| | *Zingiber officinale* | Leaf | 10–30 | [373] |

NA = not available

The mechanism of AgNPs formation by the bioreduction process is quite interesting. The constituents present in plant extracts like vitamins, polyphenols, enzymes, alkaloids, proteins, terpenoids, amino acids, flavonoid, polysaccharides, etc. and other chemically complex environmentally benevolent substances are supposed to play imperative role in the reduction of $Ag^{+}$ ion $Ag^{0}$. White II et al.[436] synthesized AgNPs of size 3–6 nm using *Allium sativum* extract. The reduction of metal salts into metal nanoparticles takes place by sugar components like sucrose, fructose, and other reducing sugars. Daniel et al.[74] fabricated AgNPs using *Achyranthus aspera* extract containing various polyol principles which account for exhibiting bioreduction of Ag. Similarly, polyols present in extracts of *Anacardium occidentale*, *Mirabilis jalapa*, etc. are reported to exhibit bioreduction of metal. Polyphenols or the "tannins" present in various plants is one of the prime principles for nano-Ag biofabrication. Various plant extracts like *Camellia sinensis, Dioscorea bulbifera, Dioscorea oppositifolia, Leonuri herba, Terminalia catechu*, etc. exhibited bioreduction by their polyphenolic components. Rajaram et al.[308] investigated and characterized the rich phenolic and flavonoids groups of compounds in *Tephrosia tinctoria* using phytochemical quantification and FT-IR. Authors revealed that during the green synthesis, the isoflavonoids and phenolic groups were attached with the Ag to form AgNPs. Thus, concluded the role of biochemical components in fabrication of nanoparticles. Some of the individual components present in plant extracts are splendidly known to exhibit bioreduction of Ag metal salts. Few phytopharmaceuticals like plastohydroquinone (in *Datura metel*),[174] menthol (in *Mentha piperita*),[9] oxalic acid (in *Chenopodium album*) ,[92] ascorbic acid (in *Allium cepa*),[276] neem principles (salanin, nimbin, azadirone, azadirachtin),[345] citric acid (in *Citrus limon*),[298] piperine (in *Piper longum*),[144] eugenol (in *Szyygium aromaticum*),[371] sorbic acid (in *Sorbus aucuparia*),[87] verbascoside, isoverbascoside, luteolin, and chrysoeriol-7-*O*-diglucoronide (in *Lippia citriodora*),[73] curacycline (in *Jatropha curcas*),[46] catechin (in *Parthenium hysterophorus*),[275] thiamine (in *Glycyrrhiza glabra*) ,[83] hydroxylimonoids (in *Swietenia mahogany*),[240] etc. are chief components for biosynthesis of AgNPs. Proteins have also been identified as potential constituent for exhibiting bioreduction of silver metal salt into its corresponding

nanoparticle. Excellent fabrications of AgNPs are reported from extracts of *Astragalus gummifer*, *Hydrilla verticilata*, *Pedilanthus tithymaloides*, *Piper betle*, *Piper nigrum*, *Plumeria rubra*, etc. containing various types of proteins. A large number of antioxidant components gifted by nature serve excellent reducing and capping agents for production of silver nanomaterials. Phytoconstituents like flavonoids, terpenoids, hydroxyflavones, flavones, glycoside, limonoids, etc. present in plant extracts like *Andrographis paniculata*, *Carica papaya*, *Coleus aromaticus*, *Glycyrrhiza glabra*, *Lantana camara*, *Morinda pubescens*, *Parthenium hysterophorus*, *Swietenia mahogany*, *Trianthema decandra*, etc. have demonstrated rapid reduction of silver ion into silver metal and it gets oxidized simultaneously.[170]

## 11.5 IMPACT OF AgNPs ON ENVIRONMENT

Although AgNPs have wide range of applications, due to their small size and high surface area, they tend to react very swiftfully to produce several adverse effects. These nanomaterials in the size range of 10–500 nm are quite toxic to the aquatic life and fish often bioconcentrates the aquatic contaminants which in the successive food cycles or food chains affect the human health. Several policies and guidelines have been framed by the regulatory bodies for the prevention and control of nanomaterials from mixing, deposition, accumulation of these metallic wastes in fields. To combat such situations, improved analytical techniques are must to detect the exposure of AgNPs and will have attributes for differentiating AgNPs from the ionic silver species in the environment.

## 11.6 FUTURE DIRECTIONS

Nanotechnology is a subject that cannot be neglected and is the coming future. Till date, nanomaterials of size 1–100 nm have come into varied applications and a number of advanced materials are coming in the near years. None of the fields, whether, it will be therapeutics, diagnostics,

theranostics, biomedical research and clinical practices, all utilize nanomaterials for the specific function at the cellular, atomic, and molecular levels. But, meeting so much high requirement of nanomaterials since their applications in wide variety of activities like antiparasitic, anticancer, antimicrobial, anti-inflammatory, antiviral, etc. by using the most preferable economic wet chemical approach is the most hazardous technique as it severly affects the environment due to toxic, production of harmful byproducts, and flammable nature of chemicals. Recently, the world has witnessed the impact of climatic change and waste disposal problems due to the applications of these harmful approaches over the years. A shift to green approach will revolutionize the modern ways of nanomaterial production. The plant extract mediated ecofriendly, simple, and size/shape-controlled biosynthesis of AgNPs will be an impressive approach to meet the demands of the upcoming generation. The bulk production of nanoparticles by the efficient green chemistry method (biogenic approach) at higher synthesis rate will replace the traditional synthetic methods.

## 11.7 CONCLUSION

In this decade, global warming, climatic changes, and environment destruction remained the burning issues across the globe. Nature itself is the greatest inspiration to mankind. All hidden secrets are present in the lap of Mother Nature. The chapter will provide an approach for replacing the influence of certain harmful chemicals like sodium borohydride, dimethyl formamide, hydrazine hydrate, ethylene glycol, etc. in the fabrication of AgNPs, with plant extracts for overcoming the drawbacks. The extract-mediated synthesis of therapeutic nanostructures has high efficacy, is easily obtainable, economic, environment friendly, and sustainable method. However, few associated disadvantages such as sluggish process, to some extent complicated in attaining the desired size/shape, nonspecific conjugation of phytoconstituents during the synthesis process, and failure to validate the precise way(s) for nanoparticles development remained few challenges in the application of natural bioreductants. In spite of all these issues, the plant-mediated biosynthesis of AgNPs is an attractive method for commercial fabrication of nanomaterials with indispensable environment protection attributes.

## KEYWORDS


- **nanoparticles**
- **silver**
- **fabrication**
- **nanomedicine**
- **nanoproducts**
- **mechanisms**
- **plant extract**


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