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Review Article

Recent Advances in Green Synthesis of Silver Nanoparticles and their Diverse Biological and Textile Applications

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Abstract

Since ancient times, silver has been utilized as an effective inorganic antibacterial and antifungal that is harmless and safe. Silver exhibits very great potential in a variety of biological applications, especially when it takes the form of nanoparticles. The need for ecological synthesis methods is growing as environmentally friendly synthesis techniques gain popularity in chemistry and chemical technologies with the goal of reducing polluting reaction by-products. The low cost and wide availability of raw materials are two additional key benefits of green synthesis techniques. In the past five years, a lot of work has gone into creating new, more affordable, environmentally friendly ways to create nanoparticles. Compared to previous synthesis procedures that produce hazardous by-products from destructive reductive organic species, the impetus for using less harmful synthesis methods has been cost reduction. The reduction or elimination of hazardous materials is one way that this environmentally friendly feature, which has now emerged as a major social issue, helps to fight environmental degradation. A brief summary of the study on the effects of the green production process on the size and morphology of silver metal nanoparticles is provided in this review.

Keywords: Silver nanoparticles; Plant extract; Green Synthesis; Characterization; Biological effects

Introduction

The use of nanoparticles in catalysis, pollution control, agriculture, waste management, and biomedical applications can be expanded by using natural sciences and nanotechnology's numerous, straightforward biosynthetic pathways. Typically, reduction and oxidation reactions using plant extracts, bacteria, and fungus as starting materials are used in the downstream process of nanoparticle production. Use of non-toxic chemicals is essential for the creation of cost-effectively acceptable processes for producing metal nanoparticles. By decreasing waste and boosting energy efficiency through the use of renewable resources, such green chemical procedures safeguard the environment. Nanoparticles are created from bio-sources, taking advantage of the large reservoir of alkaloids and flavonoids [1]. Nanoparticles are able to serve as ideal agents to carry out a variety of tasks at the cellular level, thanks to their special basic chemical, biological, and physical features. Nanoparticles (NP) come in a variety of types, including copper, gold, copper, iron, nickel, and silver etc [2].

Silver is a transitional, vivid, and white element with a wide range of therapeutic, environmental, and medical uses. Since the 19th century, antibacterial substances made of silver have been utilized in medicine, which dates back over 2,000 years. AgNPs are exceptional because they have been thoroughly investigated in many areas of human life, including laundry machines, food, medicine, and textiles. However, AgNPs must be manufactured in huge quantities in order to be used widely. In many industrial domains, nanotechnology is one of the most advanced at the atomic and molecular level [3]. The produced substance is most likely to have novel functional and size-related characteristics. On the basis of the fundamental features of the nanoscale, nanoscience is growing as a multidisciplinary field. There have been numerous studies on the production of AgNPs using chemical, plant-based, and microbial techniques [2].

Nanotechnology is a safe and environmentally friendly process to create nanoscale particles with a structure between 1 and 100 nm. The Nano size produces unique physicochemical properties with a high surface area that can lead to high reactivity [3]. One of the most widely used nanomaterials, silver nanoparticles are manufactured in quantities of 500 tons annually. These encompass a range of characteristics and uses, including those related to food, medicine, chemistry, and biochemistry etc [27]. Strong inhibitory, antibacterial, antifungal, anti-inflammatory, and antiangiogenic activities are all present in this valuable metal [4]. A green approach to the synthesis of silver NPs is less toxic, environmentally friendly, chemically

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and energy efficient [5]. The synthesis of greener nanoparticles involves biological synthesis methods. Green synthesis has proven to be an improved process due to slow kinetics and the promise of improved control through crystal growth and stabilization [27]. The use of nanotechnology has stimulated research into synthesis methods that allow a variety of well-controlled sizes and shapes [6].

Common synthesis techniques include microwave irradiation, chemical vapour deposition, laser ablation, ultrasonic irradiation, and electrochemical synthesis [4]. The use of hazardous and poisonous chemicals, which both have a negative impact on the environment and human health, and high manufacturing costs are the two features that distinguish this approach. Metal nanoparticle creation through green synthesis, particularly from plant extracts, is an eco-friendly alternative to using hazardous chemicals. In this technique, compounds originating from plant extracts like flavonoids, polyphenols, proteins, sugars, and saponins etc. are used in place of toxic chemicals [4].

Types of Nano Particles

Several inorganic nanoparticles, including magnetic nanoparticles (such as iron NPs and Copper NPs) precious metal nanoparticles (such as gold and silver), semiconductor nanoparticles (such as titanium and zinc), and organic nanoparticles, including carbon nanoparticles (fullerenes), can all be categorized as nanoparticles [3]. Due to their excellent material properties and functional flexibility, precious metal nanoparticles (gold and silver), which are inorganic nanoparticles, are becoming more and more popular. Due to their size characteristics and advantages over chemical imaging agents and pharmaceuticals, inorganic particles have been investigated as potential instruments for disease therapy and medical imaging. Inorganic nanoparticles have become widely used for cellular delivery due to their many beneficial properties, including accessibility, extended functioning, high compatibility, targeted drug delivery, and controlled drug release [3].

Green Synthesis

Nanoparticle assembly and synthesis employing biological systems like yeast, fungi, bacteria, and plant extracts is known as "green synthesis." The world of nanoparticle synthesis has undergone a revolution thanks to the creation of several colloidal metal nanoparticles, such as silver nanoparticles made utilizing green synthesis techniques. As it is readily available, safe to use, high in metabolites, and made from a plant stock that uses less energy and waste, this approach has gained popularity recently. A solvent must be used for the green synthesis of AgNPs [6]. Nanoparticle aggregation is avoided by the use of packing agents, mediums, and toxic stabilizing substances/compounds. Because of their reduced toxicity in this process, these nanoparticles can be employed to encapsulate therapeutic compounds [7] (Figure 1).

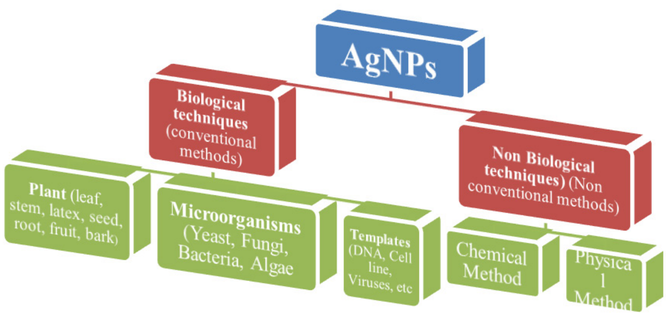

Figure 1: Silver nanoparticles created using a variety of methods.

There are numerous physical processes for producing silver nanoparticles, some of which include: [8]

1. Laser Ablation: In this technique, a silver target is vaporized by a laser beam in a liquid media to produce nanoparticles [8].

2. Sputtering: In this technique, a target is bombarded with high-energy ions in order to dislodge silver atoms from it. Nanoparticles are created by the condensation of these atoms [8].

3. Chemical Vapor Deposition (CVD): In this procedure, a silver precursor is vaporized and then deposited to create nanoparticles on a substrate [8].

4. Ion Implantation: In this technique, silver ions are implanted into a substrate and then heated to generate nanoparticles [8].

5. Electrochemical Deposition: With this technique, silver ions in a solution are reduced onto an electrode surface to create nanoparticles [8].

6. The most prominent techniques for creating silver nanoparticles are chemical ones, and some of these include: [8,47]

1. Reduction Method: A reducing agent, like sodium borohydride or citrate, is used to reduce a silver salt in this process. This process generates nanoparticles with a size distribution of 2-100 nm [8,47].

2. Polyol Method: This process entails the reduction of a Polyol, such as ethylene glycol, with a silver precursor, such as silver nitrate. The size range of the very stable nanoparticles produced by this technique is 5–50 nm [8,47].

3. Sol-Gel Method: In this procedure, a sol-gel solution containing a silver precursor is dissolved in it before being heated to create nanoparticles. This process generates nanoparticles between 2 and 50 nm in size [8,47].

4. Micro emulsion Method: This technique involves dissolving a silver precursor in a surfactant-based micro emulsion. Highly monodisperse nanoparticles with a size range of 2–20 nm are produced using this technique [8,47].

5. Green Synthesis Method: This technique includes reducing silver precursors and forming nanoparticles using natural plant extracts or biomolecules like proteins. This process generates ecologically acceptable nanoparticles between 5 and 50 nm in size [8,47].

Citrate, borohydride, thio-glycerol, and 2-mercaptoethanol are only a few of the toxic and dangerous ingredients employed in the production of AgNPs. Apart from these drawbacks, the created particles lack the purity that was anticipated because it was discovered that substances had been deposited on their surfaces. A third step is necessary to prevent particle aggregation, making it extremely challenging to create AgNPs with a precise size. Furthermore, too many harmful and poisonous byproducts are removed throughout the synthesis process [47]. Chemical processes employ procedures like cryochemical synthesis. Lithography using laser ablation Chemical reduction,

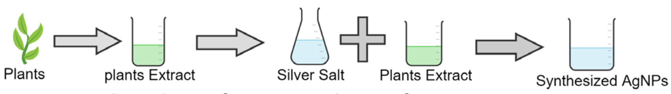

Figure 2: Flow chart of green synthesis of AgNPs.

thermal decomposition, electrochemical reduction, laser irradiation, and Sono-decomposition. The manufacture of nanoparticles chemically has the advantages of being simple, inexpensive, and high yield, however using chemical reduction agents can be dangerous to living things [9,47].

Green Synthesis

Simple room-temperature mixing of plant extracts and metal salt solutions results in the production of nanoparticles. The reaction usually ends quickly. This method can be used to produce nanoparticles of many other metals, including silver [10].

Because they are readily available, have little toxicity, and are harmless, plant extracts have been utilized to make silver nanoparticles instead of bacterial and fungal processes, which may be less efficient [11].

Making nanoparticles with plant extracts is beneficial because they are easily available, safe, and contain various biomolecules such as alkaloids, terpenoids, phenols, flavonoids, tannins, and quinine) [12].

1. A collection of leaves, seeds, stems or roots of various plants
2. To make an aqueous extract of the plant's parts, [13]
3. Preparation of silver nitrate or chloroauric acid solutions in 1 mM (AgNO3).
4. The plant's extract needs to be mixed with the metal salt solution and heated to between 60 and 80 degrees Celsius with sometimes pH maintain [13].
5. The mixture's color changes within 15 to 20 minutes, signaling the emergence of metal nanoparticles [13] (Figure 2).

A review of various plant parts including flowers, leaves, bark, seeds, stems, roots and branches is presented in the present study. It is clear that plants have been exploited extensively. The decrease in plant phytochemicals and greater stability are to blame for this [14,15].

Utilizing Various Plants for the Synthesis of Ag-NPs

Carmona ER, Benito N, Plaza T, Recio-Sánchez G using B. globosa extracts were combined with various aqueous AgNO3 solutions, and the mixture was homogenized by stirring at room temperature to create AgNPs. AgNO3 was synthesized with final concentrations ranging from 0.1 to 10 mM, while B. globosa extract made up 5% of the total volume [9].

Pirtarighat S, Ghannadnia M, Baghshahi S. Green synthesis of silver nanoparticles using the plant extract of Salvia spinosa grown in vitro and their antibacterial activity A 9:1 ratio of fresh S. spinosa plant extract to 1 mM silver nitrate was used in the mixture. At 27 ±2°C, the solution was shaken continuously for 6 hours. For every stage, three duplicates of the experiments were run [16].

Adak T, Swain H, Munda S, Mukherjee AK, Yadav MK, Sundaram A, et al. Green silver nano-particles: synthesis using rice leaf extract. The rice leaf extract-mediated production of silver nanoparticles (AgNPs) was carried out using the following method. The following ratios of plant extract to silver nitrate solution (1 mM in water) were used: 5:5, 7:3, 9:1, 9.5:0.5, and 9.9:0.1 v/v.(17)Similar to this, AgNPs were produced by forcing a set mixture of silver nitrate and plant extract (9:1 v/v) to react at different temperatures (10, 20, 40, and 60 °C).To determine the ideal period, a fixed silver nitrate: plant extract mixture was incubated for 0, 1, 2, 4, 6, 8, 12, 24, 36, 48, 60, and 72 h. With the aid of a spectrophotometer, UV-vis spectral analysis, silver ion was reduced to AgNPs [17].

To 88 ml of a 1 mM (10-3 M) solution of silver nitrate, 12 ml of A. indica's aqueous extract was added. At ambient temperature and in complete darkness, the reaction was carried out 24. We created an aqueous solution containing 103 M and 104 M silver nitrate (AgNO3) and 102 M D-sorbitol. 40 mL of AgNO3 solution was combined with 3 mL of Polyalthia long folia leaves extract and 1 mL of D-sorbitol, and the mixture was then incubated at room temperature at 25°C and 60°C, respectively. Silver nanoparticles are caused by dark brown colour development to occur [34] (Table 1).

Characterization

In order to characterize physiologically generated AgNPs, a number of characterization methods were used, such as the UV-Vis spectrophotometer, FTIR spectroscopy, scanning electron microscopy (SEM) with EDX JEOL JSM 7610F, and zeta potential analysis (Mavern zetasizer) [5].

UV-Spectroscopy

The optical properties of AgNPs generated physiologically were investigated using UV-vis spectrophotometry. It was possible to see the synthesis of AgNPs by mixing plant extract with a 1 mM AgNO3 solution in a number of different ratios, including 1:1, 1:2, 1:10, 1:15, and 1:20. In order to determine the greatest peak and absorbance at zero and after 24 hours at room temperature between 230 and 1100 nm, the findings

Table 1: List of plants used for Silver Nanoparticle synthesis.

Plants	Plant Parts	Metal Salt Solution	Size and Shape of nanoparticles	Reference
Indica acalyptus	Leaves	Silver Nitrate(0.1MAqueous)	20–30 nm in diameter, spherical	2021 [34]
The onion sativum	outer layer	Silver Nitrate (1M)	round, 4-22 nm	2022 [35] 2019 [48]
Oval-folioled Boswellia	stem bark	5 mM silver nitrate	cocci shaped 30-40nm	2022 [36] 2020 [49]
Papaya cactus	Leaves	1 mM $AgNO_3$	spherical shaped 25-50nm	2022 [37] 2015 [48]
The rose-catharanthus	Leaves	1 mM of $AgNO_3$	Spherical 48-67nm	2020 [38] 2022 [50]
The portulacastrum sesuvium	Callus	10^{-3} M AgNO3	29-92 nm; round	2023 [39]
Tobacco matel	Leaves	1 mM of silver nitrate	superstructures 16 to 40 nm	2022 [40] 2017 [52]
The bulbous Dioscorea	Tuber	0.7 mM AgNO(3)	circular and flower shapes 8-20nm	2022 [41]
Prone Eclipta	Leaves	3 mM Cu(OAc)2	rings, pentagons, and hexagons, 35–60 nm	2022 [42,51]
Musa paradisiacal	leaves and flower	92 ml of AgNO3	Spherical 20nm	2019 [43,52]
Anemone nucifera	Root	90 ml of silver nitrate solution	25–80 nm, round, and triangular	2019 [44]
the vulgar tan acetum (Transy fruit)	Fresh fruits	(1 mM) of silver nitrate	spherical and triangular shapes16nm	2022 [45]
latex from euphorbiaceous	Root	5 mM silver nitrate	spherical shape 18nm Ag	2021 [46]

were evaluated using a UV-vis spectrophotometer (HALO DB-20S UV-VIS Double Beam, Australia) [17]. The stability of AgNPs created by biological methods for more than a year was shown by an SPR peak at the same wavelength that was discovered by UV-vis spectroscopy [18].

Evaluation of the production, growth, and dispersion of the silver particles during the reduction process was done using a PerkinElmer Lambda 35 UV/Vis spectrometer. To make the samples, a 25-ml dispersion was diluted with 100 cm3 of DI water. By using a JEOL (Tokyo, Japan) JSM6300 apparatus for field emission scanning electron microscopy, the dimensions and form of silver particles were assessed. With the aid of an x-ray difractometer (Bruker, Newark, DE) D8 focus difractometer (Cu-Ka1 radiation source) and transmission electron microscopy, their crystalline structure was examined (JEOL JSF7400). Electron micrographs were used to calculate the size distribution by averaging the sizes of 200 particles. Using a Pyris 1 analyzer and Thermo Gravimetric Analysis (TGA), the remaining organic stuff was identified (PerkinElmer). A Keithley 580 micro-ohm four-point probe was used to measure the electrical resistance of the silver film. Measured values are corrected using the appropriate correction factor for the probe range used and the published pattern dimensions [19].

XRD (X-Ray Diffraction)

A layer of AgNP solution was created on a glass microscope slide by applying it, letting it dry on a heated plate at 50 °C, and then repeating the process to create an X-Ray Diffraction (XRD) pattern. The dry samples were assessed using an XRD instrument (X'Pert Pro, analytical). The generated silver nanoparticles were examined using CUKa radiation at 30 kV voltage, 20 MA current, and 0.030/s scan rate. Utilizing X-ray diffraction spectroscopy, the size and phase variety of silver nanoparticles were determined, and the unique phases in the synthesised sample were detected using X pert high score software with search and compare functionality [20].

Infrared Spectroscopy with the Fourier Transform

This method identifies the functional group of the silver nanoparticles [21]. Fourier transform infrared (FTIR) spectra were recorded between 400 and 400 cm-1 using an FTIR spectrometer (PerkinElmer System 2000) [22].

SEM Analysis

SEM is used to investigate the surface topography and morphology of the AgNPs. The morphology of the synthesized AgNPs is almost spherical in shape and in an agglomerated state. The primary generated particles' sizes may be seen in the Nano size range in SEM pictures that were analyzed at a magnification of 50,000 and scale of 100 nm [23]. Displays the SEM image of AgNPs produced during biosynthesis. The SEM image shows highly spherical nanoparticles with a diameter of 25 nm [24].

FE-SEM Analysis

The homogeneous shape and spherical nature of the silver nanoparticles were shown by the surface morphology. The current study's particle size histogram spans the 20 to 50 nm range. Similar results were also reported for silver nanoparticles made using photosynthesis. This result strongly implies that Pedalium murex leaf extracts may act as a capping and reducing agent when silver nanoparticles are produced [25].

HRTEM Analysis of AgNPs

We examined colloidal silver nanoparticles from Hevea brasiliensis using a JEOL-JEM-100 CXII device. The shape of silver nanoparticles was studied by scanning Electron Microscopy (TEM), which involves drying a drop of colloidal solution after it has been washed into a copper pore covered with a conducting polymer. A 200 kW Ultra High Resolution TEM was used to measure and analyze the size and form of Ag nanoparticles from mangos teen leaves. (JEOL-2010). 100 cc of the leftover solution was centrifuged at 5000 rpm after the reaction and then put on a TEM grid. The centrifuged suspension in 10 mL of sterile, distilled water underwent this process three times [26].

Applications and Biological Effects of Silver Nanoparticles

Antimicrobial Activity

With regard to more than 650 different types of microorganisms, including gram-positive and gram-negative bacteria, fungi, and viruses, silver is a well-known antibacterial agent. Silver nanoparticles, a more contemporary version of the metal, are being used. Silver has been cited as a medicinal agent for numerous ailments in the traditional Ayurvedic medical system of ancient India. In order to stop the transmission of Neisseria gonorrhoea from infected mothers during childbirth, it became standard practise in 1884 to provide droplets of aqueous silver nitrate to the newborn's eyes. Silver has been determined to have the best antibacterial action and to be the least harmful to animal cells of all the metals with antimicrobial capabilities. To prevent microbial growth, silver started to be used often in medical treatments, such as those given to injured soldiers in World War I. Over 2000 years ago, silver's therapeutic benefits were discovered. In order to have an antibacterial effect, silver is often employed in the nitrate form. However, when silver nanoparticles are used, the surface area to which germs are exposed increases significantly. For analysing their antibacterial activity against various microorganisms, silver nanoparticles made from plant extracts (from various sources) have been utilised [55].

Ahmed et al. (2016) described green synthesis of silver nanoparticles as potential antibacterial agents. The gram positive (S. aureus) and gram negative (E. coli) bacterial strains were examined for their different antibacterial properties against the silver nanoparticles, demonstrating the zones of inhibition. Silver nanoparticles that were manufactured demonstrated good antibacterial efficacy against E. coli and S. aureus based on the zone of inhibition. However, the control and plant extract alone showed no antibacterial action. Even while it is to be assumed that the plant's leaves extract, which was employed, has antibacterial properties and should be reflected through a larger inhibitory zone, it alone exhibits very little activity [28].

Ahmed S, and his coworkers in 2015 reported on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications. The antimicrobial activity of the produced AgNPs was tested against a number of harmful microorganisms, such as Candida albicans, Escherichia coli, and Staphylococcus aureus. With a Minimum Inhibitory Concentration (MIC) ranging from 20 to 60 g/mL, the AgNPs demonstrated substantial antibacterial action against these microbes [31].

Biological Effect

Devanesan, S, Jayamala, M., and his coworkers reported in (2021) about Antimicrobial and anticancer properties of Carica papaya leaves derived di-methyl flubendazole mediated silver nanoparticles. In this study, di-methyl flubendazole, a physiologically active chemical identified from an extract of Carica papaya leaves and verified by GC-MS, 1H NMR, and 13C NMR studies, was used to create silver nanoparticles (AgNPs). An alternate therapeutic agent to synthetic compounds used in cancer chemotherapy is AgNPs derived from plant sources. Researchers have looked into the possibilities for using silver nanoparticles (AgNPs) obtained from plant sources in chemotherapy for cancer. The findings of a few research imply that AgNPs generated from plant sources may have anticancer effects and could be utilized as a potential substitute for conventional chemotherapy medications [29].

For instance, a 2018 study reported in the journal "International Journal of Nanomedicine" examined the lethal effects of AgNPs made from the plant Carica papaya leaf extract on breast cancer cells. The study discovered that the AgNPs have the ability to cause cancer cells to undergo apoptosis (programmed cell death) and to have a dose-dependent inhibitory effect on their proliferation [56].

Another 2020 study that appeared in the journal "Journal of Molecular Liquids" looked into the anticancer effects of AgNPs made from Vitis vinifera plant leaves on human lung cancer cells. The study discovered that, in a dose-dependent manner, the AgNPs were able to cause cell death in the cancer cells and restrict their proliferation [57].

Bouqellah, and his coworkers reported in (2018) about Synthesis of eco-friendly silver nanoparticles using Allium sp. and their antimicrobial potential on selected vaginal bacteria. Both Allium sativa and Allium cepa are widely available across the country and are utilised in every home for cooking, making it possible to manufacture and employ their active Nano compounds successfully in the fields of diagnostic, antimicrobial, and medicinal [32].

Silver nanoparticles were produced in the work by Bouqellah et al. (2018) utilizing Allium sp., specifically Allium sativa and Allium cepa. The scientists discovered that silver nanoparticles could be manufactured successfully and remained stable for three months. The nanoparticles were exceptionally stable, as evidenced by their large average size of 34 nm and low zeta potential of -31.7 mV [32].

The antibacterial ability of silver nanoparticles was tested against vaginal pathogens such as E. coli, Staphylococcus aureus, and Candida albicans. The silver nanoparticles were found to have substantial antibacterial action against all three bacteria, with Minimum Inhibitory concentrations (MICs) ranging from 12.5 to 50 g/mL. The researchers came to the conclusion that silver nanoparticles derived from Allium sp. could be employed as an antibacterial agent against vaginal germs [32].

Antifungal and Antiviral Activities of AgNPs

Cho M, Seo Y-S, and his coworkers reported in 2020 about the Silver nanoparticles are formulated using cow's milk and have antifungal properties against phytopathogens. According to the findings of several investigations, various phytopathogenic fungi can be successfully combatted with silver nanoparticles made from cow's milk [60].

As an illustration, a 2014 study in the journal "Colloids and Surfaces B: Biointerfaces" examined the antifungal activity of silver nanoparticles made with cow's milk against four phytopathogenic fungi: Fusarium oxysporum, Fusarium solani, Colletotrichum gloeosporioides, and Alternaria alternata. According to the study, all four fungi were significantly inhibited by silver nanoparticles, with Fusarium oxysporum showing the most antifungal effects [58].

Aspergillus Niger, Fusarium oxysporum, and Rhizoctonia solani were only a few of the phytopathogenic fungi that the antifungal activity of silver nanoparticles made from cow's milk against was examined in a different study that was published in the journal "Molecules" in 2020. The research discovered that the silver nanoparticles had high antifungal action against all three fungus, with Aspergillus Niger showing the largest effect [59].

According to some studies, AgNPs are effective against Colletotrich cocci, Monilinia sp., and Candida spp. And it has dose-effective and dose-dependent antifungal effects against various plant pathogenic fungi. Some research suggest that inhibitory activity may be influenced by the sort of cultural media employed in the study. Additionally, H1N1 influenza virus, herpes simplex, human par influenza virus, and hepatitis B virus were all targets of AgNPs' potent antiviral activity (HBV). AgNPs with a size less than 10 nm adhere very well to virus surfaces and show antiviral activity, which can be explained by their wide reaction area [30].

Silver Nanoparticles (Ag-NPs) that have been Bio Reduced or Produced Sustainably as Anti-Cancer Treatments

Al-Rubaye HI, Al-Rubaye BK, Al-Abodi EE, and Yousif EI in 2017 has been reported about Green Chemistry Synthesis of Modified Silver Nanoparticles. Cancer is still one of the leading causes of mortality worldwide, despite all the recent advances in cancer treatment. We already know that traditional therapeutic methods frequently result in a variety of negative side effects. As a result, researchers are trying to come up with brand-new approaches to cancer diagnosis and therapy. The pharmaceutical industry has recently paid a lot of attention to the green synthesis of AgNPs. AgNPs' high levels of biodegradability and clearance are essential for preventing the potential effects of long-term toxicity. In cases of treatment based on Nano medicine, the AgNPs demonstrated remarkable potential. [33] Clinical studies of AgNPs-based Nano medicine, however, are essential for directing the future course of their application. Investigations into biodegradability, dosage, and delivery method are currently the main challenges that need to be overcome in clinical studies. AgNPs can also be employed as a crucial tool for cancer cell imaging and detection when making an early diagnosis of the disease. Rawat M. Green synthesised silver nanoparticles using a variety of plant extracts. Silver nanoparticles with anticancer effects against human cancer cells have been made using a variety of plants. The cytotoxic effect of the produced silver nanoparticles on cervical cancer cells was investigated [33].

Silver nanoparticles are extracted from Saccharina japonica and used as a reducing and masking agent. They examined the features of apoptosis such as nuclear size reduction and cytoplasmic condensation by both fluorescence and confocal laser scanning microscopy. The concentrations of silver nanoparticles of 0.16 and 0.32 mg/ml can be harmful to healthy cells. They found that silver nanoparticles in Saccharina japonica extract suspension had significant HeLa cells are subjected to cytotoxicity with a specified concentration response relationship. Podophyllum hexandrum Royal leaf extract was used in the green synthesis of 14 nm-sized Ag-NPs. They identify the deadly effects of green-produced Ag-NPs on human cervical cancer cells using the ROS, RT-PCR, MTT assay, and western blotting procedures. Their research suggested that the cellular mechanism of HeLa can be inhibited by greenly generated Ag-NPs due to DNA damage. Apoptosis was seen in this study along with morphological alterations in cell shape and chromatin condensation. Acridine orange and ethidium bromide staining were used to determine if green produced silver nanoparticles could cause apoptosis [11,33].

Applications of AgNPs in Textile Sector

Because of their distinctive qualities and possible uses, silver nanoparticles have attracted a lot of interest in the textile industry. Silver nanoparticles are used in a variety of ways in textiles, including: [61].

Antibacterial textile: Green synthesis of silver nanoparticles transformed synthetic textile dye into less toxic intermediate molecules through LC-MS analysis and treated the actual Wastewater. The findings of research looking at the use of silver nanoparticles (AgNPs) in antibacterial textiles. Due to their powerful antibacterial qualities, silver nanoparticles have attracted a lot of attention. AgNPs have been incorporated into textiles using a variety of techniques, and studies have been done to determine how well they prevent bacterial growth. The findings show that when compared to normal textiles, textiles treated with silver nanoparticles have stronger antibacterial properties. Inhibiting bacterial cell growth and decreasing bacterial colonization on the textile surface, the AgNPs produce silver ions that enter bacterial cells. Durability is ensured by the antibacterial effects, which continue even after numerous washings or extended use. Despite the need for more investigation, safety considerations point to a low danger associated with silver nanoparticles in textiles. Problems like cost-effectiveness and standardized testing procedures still need to be solved [61].

Excellent antibacterial qualities of silver nanoparticles make them useful at preventing the formation of microorganisms on fabrics. They can be added to textiles to create antibacterial socks, garments, wound dressings, and other medical textiles [61].

Odor control textile: The Antibacterial and odor control finishing of textiles using silver nanoparticles. Because of their distinct antibacterial capabilities, silver nanoparticles (AgNPs) have become a popular ingredient in odor-controlling fabrics. In this study, we looked into the efficiency of AgNPs in odour removal from and reduction of textile materials. AgNPs were produced via a green and economical process, and their size, shape, and stability were assessed. A straightforward and scalable coating process was used to integrate the AgNPs into the textile fibres. A standardized odour panel test was used to gauge the textiles' ability to effectively manage odors. Comparing textile samples treated with AgNPs to untreated textiles, a significant reduction in malodor perception was seen. Additionally, the AgNP-coated fabrics demonstrated odour control abilities that remained effective for a considerable amount of time even after numerous washings. The AgNPs demonstrated potent antibacterial activity against odor-producing bacteria that are frequently found in textiles, according to further investigation. The fabrics coated with AgNP displayed remarkable antibacterial activity, limiting bacterial growth and odour production. Additionally, the AgNP-coated textiles displayed advantageous physical traits such colorfastness, tensile strength, and durability, indicating that AgNPs are compatible with textile materials. The findings of this study demonstrate the potential of silver nanoparticles as a successful and long-lasting odour control method in textiles. The addition of AgNPs not only lessens the sense of odour, but also provides antibacterial action, improving textile product hygiene and freshness. These results help the textile sector create novel, environmentally friendly odour control techniques [64].

Textiles that manage and get rid of odors brought on by microbial activity can be made using silver nanoparticles. They remove and neutralize odor-causing substances, giving clothing, athletic gear, and other textile products a long-lasting freshness [61].

UV protection textile: The Effect of silver nanoparticles on UV Protection property of cotton fabric Due to their distinctive optical and antibacterial properties, silver nanoparticles (AgNPs) have emerged as a promising choice for improving UV protection in textiles. In this work, we looked into the use of AgNPs in UV-protective clothing and assessed how well they blocked dangerous UV rays. AgNPs were created utilizing a sustainable and scalable approach, and their size, shape, and stability were assessed. Then, using a quick and effective coating method, the AgNPs were integrated into the fibres of the textiles. Using standardized UV transmittance measurements, the AgNP-coated fabrics' UV protection abilities were assessed. The outcomes showed that the fabrics' UV protection properties were greatly improved by the addition of AgNPs. When compared to untreated textiles, the AgNP-coated textiles showed a significant reduction in UV transmission. Additionally, even after numerous wash cycles, the AgNP-coated textiles' UV protection efficacy remained constant, demonstrating the coating's longevity. Additional research showed that the AgNPs efficiently absorbed and dispersed UV light, preventing it from penetrating the textiles' deeper layers and reducing the likelihood of UV-induced skin damage. Furthermore, the AgNP-coated textiles showed outstanding antibacterial activity, enhancing hygiene and the toughness of the textile goods. The results of this study show that silver nanoparticles have the potential to be an effective technique for improving UV protection in textiles. AgNPs can be used to create fabrics with enhanced UV-blocking capabilities in a cost-effective and sustainable way. With applications in sun-protective clothing, outdoor gear, and other UV-sensitive textile items, this research helps the textile sector enhance UV protection solutions [65].

To improve the Ultraviolet (UV) protection capabilities of textiles, silver nanoparticles can be added. They efficiently absorb and reflect UV light, which lessens its ability to pass through fabric and potentially harm skin [62].

Conductive textile: Enhanced electrical conductivity of cotton fabrics via in situ synthesis of silver nanoparticles using a facile microwave-assisted method. Due to their special electrical and thermal characteristics, silver nanoparticles have found extensive use in conductive textiles. This summary summarizes recent studies on the use of silver nanoparticles in the creation of conductive textiles and emphasises significant findings from a few investigations. A number of studies have shown that adding silver nanoparticles to textile fibres, yarns, and coatings successfully improves conductivity. The homogeneous distribution of silver nanoparticles inside the textile matrix was successfully accomplished using the synthesis and dispersion procedures used in these investigations. The resulting conductive fabrics had improved conductivity, and their resistivity values were much lower than those of conventional textile materials, according to electrical testing. The heat conductivity of conductive fabrics containing silver nanoparticles was also examined, in addition to their electrical conductivity. Measurements of thermal conductivity showed increased heat transfer properties, making them appropriate for use in applications like thermally conductive fabrics or wearable heating components. The investigations also investigated the effects of several parameters on the electrical and thermal properties of conductive fabrics, including the concentration of silver nanoparticles, the composition of the textile, and the processing conditions. The results showed that higher silver nanoparticle concentrations generally boosted conductivity, whereas larger textile structures encouraged better dispersion and enhanced electrical performance. These conductive fabrics have a wide range of possible uses, from smart textiles and wearable electronics to biomedical devices and energy storage systems. A viable route to the creation of adaptable, lightweight, functional materials with a wide range of uses is through the inclusion of silver nanoparticles in textiles [66].

By adding electrical conductivity to fabrics, silver nanoparticles enable the incorporation of wearable electronics. They make it possible to create smart textiles that can be used for things like interactive clothing, heating elements, and sensors [62].

Stain Resistance

Super hydrophobic and stain-resistant Cotton fabrics coated with silver nanoparticles Due to their special qualities and potential to improve fabric performance, silver nanoparticles are being used to treat textiles to make them stain resistant. The major findings from chosen studies are highlighted in this abstract, which gives a succinct overview of recent research on the use of silver nanoparticles in the creation of stain-resistant textiles. The improvement of stain resistant qualities has been demonstrated to be possible through the insertion of silver nanoparticles into textile surfaces. Studies have shown that silver nanoparticles may be successfully made and applied to textile substrates utilizing a variety of methods, including dip coating, pad-dry-cure, and plasma treatment. These techniques have been successful in distributing silver nanoparticles uniformly across the fabric's surface, giving it stain resistance properties. Significant improvements have been found in experimental assessments of the stain resistance characteristics of fabrics treated with silver nanoparticles. Compared to untreated materials, the treated fabrics showed improved resistance to everyday stains including oil, coffee, and wine. Silver nanoparticles' hydrophobicity and antibacterial qualities helped make stains less likely to stick to textile surfaces and to repel them. Investigations have also looked at the stain resistant treatment's durability and wash ability. The effectiveness of the silver nanoparticles was shown to endure over many washing processes, demonstrating its potential for long-lasting stain resistance applications. Studies have also looked into how fabric type, treatment technique, and silver nanoparticle concentration affect stain resistance performance, offering insights into optimization tactics. The use of silver nanoparticles in stain resistance treatments is extremely important in many different industries, including healthcare, home textiles, and clothing. Increased cleanliness, longer product lifespans, and less maintenance work are all benefits of the development of stain-resistant textiles [67].

To give fabrics stain resistance, silver nanoparticles can be integrated into the fabric. Liquids and stains cannot penetrate the fabric surface because of the protective barrier that the nanoparticles create [62].

Flame Retardancy: Enhanced flame Retardancy of cotton fabrics treated with chitosan/silver nanoparticles multilayers. Due to their special qualities and ability to improve fabric safety, silver nanoparticles have drawn a lot of attention in the field of flame-retardant treatments for textiles. These abstract covers major findings from selected studies and gives a succinct synopsis of recent research on the use of silver nanoparticles in the creation of flame-resistant textiles. To increase the flame Retardancy of textile substrates, silver nanoparticles have been included in a number of research. These investigations' synthesis and application methods were successful in depositing silver nanoparticles on fabric surfaces, improving their flame-retardant qualities. These processes have demonstrated potential for lowering flammability and enhancing self-extinguishing properties in textiles. Promising findings have been obtained from experimental assessments of the flame Retardancy of fabrics treated with silver nanoparticles. In comparison to untreated materials, the treated fabrics showed lower flame spread rates, less heat release, and enhanced char formation. A barrier created by the integration of silver nanoparticles effectively stopped the spread of the flames and constrained the emission of flammable gases. Studies have also looked into how long the flame-retardant treatments last and how well they stand up to washing. The results showed that the silver nanoparticles' flame-retardant properties persisted even after several washing cycles, indicating its potential for long-term use. Additional studies optimized the concentration of silver nanoparticles, treatment processes, and fabric architectures to improve the performance of flame Retardancy. The use of silver nanoparticles in flame-resistant textiles is crucial for sectors like transportation, home furnishings, and protective apparel. The creation of textiles with improved fire-retardant qualities can help to improve safety, lessen fire risks, and boost compliance with fire safety requirements [68].

A textile's ability to withstand ignition and limit the spread of flames can be improved by adding silver nanoparticles to it. Protective apparel and upholstery textiles benefit the most from this treatment [63].

Anti-static textile: Anti-static cotton fabric by silver nanoparticles modification. Due to their distinct electrical characteristics and potential to improve fabric functionality, silver nanoparticles are being used to treat textiles to prevent static electricity. This abstract combines major findings from selected studies and gives a succinct synopsis of recent research on the use of silver nanoparticles in the creation of anti-static textiles. Numerous studies have looked into how silver nanoparticles might be added to textile substrates to give them anti-static qualities. To introduce silver nanoparticles onto textile surfaces, a number of techniques have been used, such as in situ production, coating, and surface modification. These methods have been successful in distributing silver nanoparticles uniformly, leading to improved anti-static performance. The surface resistivity and static charge dissipation of anti-static fabrics coated with silver nanoparticles have significantly improved, according to experimental assessments. The fabrics' surface resistance was dramatically decreased by the addition of silver nanoparticles, which minimized the buildup of static charges. Additionally, the treated fabrics demonstrated effective and speedy static charge dissipation, avoiding static build-up and lowering the risk of electrostatic discharge. Additionally, investigations have looked into how long-lasting and wash-resistant the anti-static treatments are. Results showed that silver nanoparticles' anti-static properties remained persistent even after several washing cycles, making them appropriate for long-term uses. The anti-static performance was found to be influenced by the silver nanoparticle concentration, treatment techniques, and fabric properties, offering helpful insights for optimization tactics. The use of silver nanoparticles in anti-static fabrics has wide-ranging effects on sectors like electronics, healthcare, and protective clothing. Improved anti-static textiles have the potential to reduce dust attraction, increase comfort, and improve safety in areas where static electricity is a concern [69].

Reduced static electricity buildup can be achieved by adding silver nanoparticles to textiles. In garments used in settings where static discharge may result in damage or discomfort, this characteristic is advantageous [63].

Thermoregulation: Thermoregulation of textiles with silver nanoparticles for improved comfort. Due to their special qualities and potential to improve the comfort and functionality of fabrics, silver nanoparticles are being used in thermo regulating textiles. The major findings from chosen studies are highlighted in this abstract, which gives a succinct overview of recent research on the use of silver nanoparticles in the creation of thermo regulating fabrics. In order to gain better thermoregulatory qualities, silver nanoparticles have been incorporated into textile substrates in a number of studies.

The deposition of silver nanoparticles onto fabric surfaces using the production and application techniques used in these investigations has successfully improved the ability of the fabric to regulate heat. The thermal conductivity, breathability, and heat retention qualities of fabrics used for thermoregulation that have been treated with silver nanoparticles have been significantly improved, according to experimental tests. By using silver nanoparticles, textiles have been proven to have improved thermal conductivity, allowing for better heat transfer and dispersion throughout the fabric. Additionally, the treated materials showed greater breathability, allowing for better moisture management and increased comfort. As a result of the silver nanoparticles' ability to retain heat, various external conditions were better insulated against, and the temperature could be controlled. Additionally, investigations have examined the thermo regulating therapies' robustness and wash resistance.

The results demonstrated the promise of silver nanoparticles for long-term uses, showing that their thermo regulating properties persisted even after numerous washing cycles. The performance of thermoregulation was discovered to be influenced by the silver nanoparticle concentration, treatment methods, and fabric architectures, offering new information for optimization tactics. Numerous industries, including sportswear, outdoor apparel, and bedding, have a great deal to gain from the use of silver nanoparticles in thermo regulating textiles. Improved moisture management, temperature control, and comfort for the wearer can all be a result of the creation of fabrics with better thermoregulatory capabilities [70].

It is possible to create fabrics with improved thermal characteristics using silver nanoparticles. By effectively storing or releasing heat, they can control body temperature, making people feel comfortable in a variety of climates [63].

Conclusion

There is no doubt that this study area will continue to draw a lot of interest in the coming years, given the many advantages of employing plant extracts to greenly synthesize AgNPs and their excellent antibacterial properties alone or in combination with antibiotic medicines. With so many newly developed, highly contagious, and drug-resistant microorganisms, this presents a novel and intriguing potential. Because of this, even though this research field is young, it has recently become a "hot" topic. The method by which AgNPs interact with medications and how their synergistic interactions with bacteria change how they assault them must be thoroughly researched and empirically validated in order to gain a deeper grasp of the subject. In the near future, green synthesis could be used for a variety of medical purposes.

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Author Contributions

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References

1. Sasidharan D, Namitha TR, Johnson SP, Jose V, Mathew P. Synthesis of silver and copper nanoparticles using Myristica fragrans fruit extract: Antimicrobial and catalytic applications. Sustain Chem Pharm. 2020; 16: 100255.

2. Adnan M, Sajjad W, Wu F, Bibi N, Shah K, Yali Z, et al. Journal of Hazardous Materials Advances Green synthesis of silver nanoparticles and their shortcomings, animal blood a potential source for silver nanoparticles: A review. J Hazard Mater Adv. 2021; 1: 100005.

3. Moreno-v MJ, Rodríguez-f F, L AG, Del-toro-s CL. Heliyon Sustainable-green synthesis of silver nanoparticles using saf fl ower (Carthamus tinctorius L.) waste extract and its antibacterial activity. 2021; 7.

4. Sharma L, Dhiman M, Singh A, Sharma MM. Materials Today: Proceedings Biological synthesis of silver nanoparticles using Nyctanthes arbor-tristis L.: A green approach to evaluate antimicrobial activities. Mater Today Proc. 2021; 43: 2915–20.

5. Naaz R, Uddin V, Ullah S, Ahmad W. Materials Today: Proceedings Green synthesis of silver nanoparticles using Syngonium podophyllum leaf extract and its antibacterial activity. Mater Today Proc. 2021; 46: 2352-358.

6. Roy N, Gaur A, Jain A, Bhattacharya S, Rani V. Green synthesis of silver nanoparticles: An approach to overcome toxicity. Environ Toxicol Pharmacol. 2013; 36: 807–12.

7. Krithiga N, Rajalakshmi A, Jayachitra A. Green Synthesis of Silver Nanoparticles Using Leaf Extracts of Clitoria ternatea and Solanum nigrum and Study of Its Antibacterial Effect against Common Nosocomial Pathogens. 2015; 2015.

8. Carmona ER, Benito N, Plaza T, Recio-Sánchez G. Green synthesis of silver nanoparticles by using leaf extracts from the endemic Buddleja globosa hope. Green Chemistry Letters and Reviews. 2017; 10: 250–6.

9. Ghaffari-Moghaddam M, Hadi-Dabanlou R, Khajeh M, Rakhshanipour M, Shameli K. Green synthesis of silver nanoparticles using plant extracts. Korean J Chem Eng. 2014; 31: 548–57.

10. Al-Rubaye HI, Al-Rubaye BK, Al-Abodi EE, Yousif EI. Green Chemistry Synthesis of Modified Silver Nanoparticles. J Phys Conf Ser. 2020; 1664: 1–26.

11. Dhal NK, Rath M, Panda SS. Synthesis of Silver Nano Particles from Plant Extract and its Application in Cancer Treatment: A Review. Int J Plant Anim Environ Sci. 2014; 4: 137–45.

12. Santra TS, Tseng FG, Barik TK. Biosynthesis of Silver and Gold Nanoparticles for Potential Biomedical Applications — A Brief Review. 2014.

13. Anandalakshmi K. Green Synthesis of Silver Nanoparticles Using Plant Extracts – a Review. Plant Arch. 2021; 21: 2091–7.

14. Ahmad S, Munir S, Zeb N, Ullah A, Khan B, Ali J, et al. Green nanotechnology: A review on green synthesis of silver nanoparticles — An ecofriendly approach. Int J Nanomedicine. 2019; 14: 5087–107.

15. Pirtarighat S, Ghannadnia M, Baghshahi S. Green synthesis of silver nanoparticles using the plant extract of Salvia spinosa grown in vitro and their antibacterial activity assessment. J Nanostructure Chem. 2019; 9: 1–9.

16. Adak T, Swain H, Munda S, Mukherjee AK, Yadav MK, Sundaram A, et al. Green silver nano-particles: synthesis using rice leaf extract, characterization, efficacy, and non-target effects. Environ Sci Pollut Res. 2021; 28: 4452–62.

17. Zhang X-F, Liu Z-G, Shen W, Gurunathan S. Molecular Sciences Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches. 2016.

18. Balantrapu K, Goia DV. Silver nanoparticles for printable electronics and biological applications. 2009; 13699.

19. Kumar M, Kumar N, Kumar M, Manjari P. Materials Today: Proceedings Green synthesis of silver nanoparticles and its potential effect on phytopathogens. Mater Today Proc. 2020; 35: 233-238.

20. Singh A, Kaur K. Biological and Physical Applications of Silver Nanoparticles with Emerging Trends of Green Synthesis. Eng Nanomater - Heal Saf. 2019.

21. Menazea AA, Ahmed MK. Synthesis and antibacterial activity of graphene decorated by silver and copper nanoparticles. J Mol Struct. 2020; 1218: 128536.

22. Sci-Hub. Green synthesis, characterization and photocatalytic application of silver nanoparticles synthesized by various plant extracts. Arabian Journal of Chemistry. 2020; 1878-5352.

23. Mahendran N, Anand B, Rajarajan M, Muthuvel A, Mohana V. Materials Today: Proceedings Green synthesis, characterization and antimicrobial activities of silver nanoparticles using Cissus quadarangularis leaf extract. Mater Today Proc. 2021; 49: 2620-2623.

24. Anandalakshmi K, Venugobal J, Ramasamy V. Characterization of silver nanoparticles by green synthesis method using Pedalium murex leaf extract and their antibacterial activity. Appl Nanosci. 2016; 6: 399–408.

25. Hyperlipidemia D. Academic Sciences. 2013; 6: 4–7.

26. Hashemi Z, Mohammadyan M, Naderi S, Fakhar M, Biparva P. Green synthesis of silver nanoparticles using Ferula persica extract (Fp-NPs): Characterization, antibacterial, antileishmanial, and in vitro anticancer activities. Mater Today Commun. 2021; 27: 102264.

27. Ahmed S, Saifullah, Ahmad M, Swami BL, Ikram S. Green synthesis of silver nanoparticles using Azadirachta indica aqueous leaf extract. J Radiat Res Appl Sci. 2016; 9: 1–7.

28. Antimicrobial and anticancer properties of Carica papaya leaves derived di-methyl flubendazole mediated silver nanoparticles. Journal of Infection and Public Health. 2021; 14: 577–587.

29. Xu L, Wang YY, Huang J, Chen CY, Wang ZX, Xie H. Silver nanoparticles: Synthesis, medical applications and biosafety. Theranostics. 2020; 10: 8996–9031.

30. Ahmed S, Ahmad M, Swami BL, Ikram S. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise. J Adv Res. 2016; 7: 17–28.

31. Bouqellah NA, Mohamed MM, Ibrahim Y. Synthesis of eco-friendly silver nanoparticles using Allium sp. and their antimicrobial potential on selected vaginal bacteria. Saudi Journal of Biological Sciences. 2019; 26: 1789-1794.

32. Rawat M. Green Synthesis of Silver Nanoparticles via Various Plant Extracts for Anti-Cancer Applications. Glob J Nanomedicine. 2017; 2.

33. Saravanan S. Functional, structural and morphological property of green synthesized silver nanoparticles using azadirachta indica leaf extract. Materials Today: Proceedings. 2021.

34. Nguyen NT, Nguyen L, Nguyen TD, Liew RK, Nguyen DTC, Van Tran T. Recent advances on botanical biosynthesis of nanoparticles for catalytic, water treatment and agricultural applications: A review. Science of the Total Environment. 2022; 827: 154160.

35. Alshameri AWF, Owais M. Antibacterial and cytotoxic potency of the plant-mediated synthesis of metallic nanoparticles Ag NPs and ZnO NPs: A review. OpenNano. 2022; 8: 100077.

36. Shyamalagowri S, Charles P, Manjunathan J, Kamaraj M, Anitha R, Pugazhendhi A. In vitro anticancer activity of silver nanoparticles phyto-fabricated by Hylocereus undatus peel extracts on human liver carcinoma (HepG2) cell lines. Process Biochemistry. 2022; 116: 17–25.

37. Rohaizad A, Rahim NA, Shahid M, Rashid NEA, Hir ZaM, Ramly MR, et al. Green synthesis of silver nanoparticles from Catharanthus roseus dried bark extract deposited on graphene oxide for effective adsorption of methylene blue dye. Journal of Environmental Chemical Engineering. 2020; 8: 103955.

38. Laha S, Subrahmanyeswari T, Verma SK, Kamble SN, Singh S, Bhattacharyya S, et al. Biogenic synthesis, characterization and application of silver nanoparticles as biostimulator for growth and rebaudioside-A production in genetically stable stevia (Stevia rebaudiana Bert.) under in vitro conditions. Industrial Crops and Products. 2023; 197: 116520.

39. Chinnaiah K, Krishnamoorthy R, Kannan K, Sivaganesh D, Saravanakumar S, Theivasanthi T, et al. Ag nanoparticles synthesized by Datura metel L. Leaf extract and their charge density distribution, electrochemical and biological performance. Chemical Physics Letters. 2022; 807: 140083.

40. Nadaf SJ, Jadhav NR, Naikwadi HS, Savekar PL, Sapkal I, Kambli MM, et al. Green synthesis of gold and silver nanoparticles: Updates on research, patents, and future prospects. OpenNano. 2022; 8: 100076.

41. Tulli F, Whyte J, Gallucci MN, Turbay MBE, Rey V, Borsarelli CD. Synthesis, properties, and uses of silver nanoparticles obtained from leaf extracts. Elsevier EBooks. 2022: 317–357.

42. Gulla S, Bilgrami AL, Ahmad T, Shankar MV, Reddy KR, Soni SK, et al. Recent advances in nanoparticles-based strategies for cancer therapeutics and antibacterial applications. Elsevier EBooks. 2019; 46: 255–293.

43. Ahn EE, Jin H, Park Y. Assessing the antioxidant, cytotoxic, apoptotic and wound healing properties of silver nanoparticles green-synthesized by plant extracts. Materials Science and Engineering: C. 2019; 101: 204–216.

44. Hasan KF, Xiaoyi L, Shaoqin Z, Horváth PG, Bak M, Bejó L, et al. Functional silver nanoparticles synthesis from sustainable point of view: 2000 to 2023 – A review on game changing materials. Heliyon. 2022; 8: e12322.

45. Ameta R, Kumar A, Vyas S, Bhatt JM, Ameta SC. Green synthesis of nanocomposites using plant extracts and their applications. Fundamental Principles and Methods. 2021; 1: 663-682.

46. Zhang F, Liu G, Shen W, Gurunathan S. Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches. International Journal of Molecular Sciences. 2016; 17: 1534.

47. Bouqellah NA, Mohamed MM, Ibrahim Y. Synthesis of eco-friendly silver nanoparticles using Allium sp. and their antimicrobial potential on selected vaginal bacteria. Saudi Journal of Biological Sciences. 2019; 26: 1789-1794.

48. Adebayo IA, Usman AI, Shittu FB, Ismail NZ, Arsad H, Muftaudeen TK, et al. Boswellia dalzielii-Mediated Silver Nanoparticles Inhibited Acute Myeloid Leukemia (AML) Kasumi-1 Cells by Inducing Cell Cycle Arrest. Bioinorganic Chemistry and Applications. 2020: 2020.

49. Rani M, Yadav J, Meenu, Keshu, Shanker U. Plant-meditated methods for synthesis of silver nanoparticles. Elsevier EBooks. 2022: 685–706.

50. Tyagi PK, Rizvi T, Kapse AV. Evaluate the toxicity of silver nanoparticles by chemical and green synthesis methods. Materials Today: Proceedings. 2022: 80-85.

51. Gomathi M, Rajkumar P, Prakasam A, Ravichandran K. Green synthesis of silver nanoparticles using Datura stramonium leaf extract and assessment of their antibacterial activity. Resource-Efficient Technologies. 2017; 3: 280-284.

52. Chung M, Rahuman AA, Marimuthu S, Kirthi AV, Anbarasan K, Padmini P, et al. Green synthesis of copper nanoparticles using Eclipta prostrata leaves extract and their antioxidant and cytotoxic activities. Experimental and Therapeutic Medicine. 2017; 14: 18-24.

53. Maruthai J, Muthukumarasamy A, Baskaran B. Fabrication and characterisation of silver nanoparticles using bract extract of Musa paradisiaca for its synergistic combating effect on phytopathogens, free radical scavenging activity, and catalytic efficiency. IET Nanobiotechnology. 2019; 13: 134-143.

54. Yadav HK, Yadav RK. Green synthesis of silver nanoparticles using plant extracts as a biodegradable approach: A review. IET Nanobiotechnology. 2019; 13: 822-830.

55. Chowdhury S, Ghosh S, Das T, Mandal M, Chakraborty S, Tripathy S. Green synthesis of silver nanoparticles using Carica papaya leaf extract for in vitro cytotoxicity against breast cancer cell line. International Journal of Nanomedicine. 2018; 13: 821-836.

56. Ghorbani R, Saadatmandzadeh M, Khosravi A. Green synthesis of silver nanoparticles using Vitis vinifera leaf extract and their anticancer activity against human lung cancer cells. Journal of Molecular Liquids. 2020; 311: 113351.

57. Elgorban AM, El-Samawaty AMA, Hussein MH, Alkhalafawy MA, Al-Zahrani HS, Alnoman MA, et al. Antifungal activity of silver nanoparticles produced from cow milk using a low-cost biological method. Colloids and Surfaces B: Biointerfaces. 2014; 123: 491-6.

58. Sudha A, Rajamanickam K, Gowri S, et al. Green synthesis of silver nanoparticles using cow milk and evaluation of their antifungal activity against phytopathogenic fungi. Molecules. 2020; 25: 1097.

59. Cho M, Seo YS, Hwang PH, Govarthanan M, Lee KJ, Park SH, et al. Silver nanoparticles are formulated using cow's milk and have antifungal properties against phytopathogens. Molecules. 2020; 25: 1195.

60. Ahmed T, Noman MZ, Shahid M, Niazi MBK, Hussain S, Manzoor N, et al. Green synthesis of silver nanoparticles transformed synthetic textile dye into less toxic intermediate molecules through LC-MS analysis and treated the actual. 2020.

61. Ahmed T, Noman M, Shahid M, Niazi MBK, Hussain S, Manzoor N, et al. Green synthesis of silver nanoparticles transformed synthetic textile dye into less toxic intermediate molecules through LC-MS analysis and treated the actual wastewater. Environmental Research. 2020; 191: 110142.

62. Amare M, Worku A, Kassa A, Hilluf W. Green synthesized silver nanoparticle modified carbon paste electrode for SWAS voltammetric simultaneous determination of Cd (II) and Pb (II) in Bahir Dar Textile discharged effluent. Heliyon. 2020; 6: e04401.

63. Shahid-Ul-Islam, Butola BS, Kumar A. Green chemistry based in-situ synthesis of silver nanoparticles for multifunctional finishing of chitosan polysaccharide modified cellulosic textile substrate. International Journal of Biological Macromolecules. 2020; 152: 1135–1145.

64. Roy Choudhury K. Green chemistry and the textile industry. Textile Progress. 2013; 45: 3-143, 2013.

65. Arif R, Jadoun S, Verma A. Green chemistry in textile industry and their positive impact of implementation," in Green Chemistry for Sustainable Textiles: Elsevier. 2021; 113-119.

66. Raj A, Chowdhury A, Wazed Ali S, Green chemistry: Its opportunities and challenges in colouration and chemical finishing of textiles. Sustainable Chemistry and Pharmacy. 2022; 27: 100689.

67. Nimkar U. Sustainable chemistry: a solution to the textile industry in a developing world. Current Opinion in Green and Sustainable Chemistry. 2018; 9: 13-17.

68. To MH, Uisan K, Ok YS, Pleissner D, Lin CS. Recent trends in green and sustainable chemistry: rethinking textile waste in a circular economy. Current Opinion in Green and Sustainable Chemistry. 2019; 20: 1-10.

69. Shahid M, Mohammad F. Green Chemistry Approaches to Develop Antimicrobial Textiles Based on Sustainable Biopolymers A Review. Industrial & Engineering Chemistry Research. 2013; 52: 5245-5260.

70. Nambela L, Haule LV, Mgani Q. A review on source, chemistry, green synthesis and application of textile colorants. Journal of Cleaner Production. 2020; 246; 119036.