Section A-Research paper

Synthesis of silver nanoparticles using plant extracts through environmentally friendly methods: A Review

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ABSTRACT

The development of new nanometals has been driven by their wide range of applications in various industries. Silver nanoparticles (AgNPs) are among these nanometals that play an important role for biomedicine and biotechnology. Traditional AgNP production processes entail the use of toxic chemicals that can be damaging to living creatures. To overcome this issue, sustainable chemistry-based biological techniques for the green synthesis of AgNPs have been used. Biological synthesizing AgNPs utilizing enzymes, bacteria, or extracts from plants is a more secure and environmentally friendly method. The green production of AgNPs addresses three main aspects: choosing a solvent medium, selecting environmentally friendly reducing substances, and assuring AgNP stability through non-toxic chemicals. Plant extracts have various advantages above other biological approaches for AgNP production, such as the elimination of time-consuming cell culture maintenance and the potential for scalability on a large scale. This review focuses on the ecologically friendly production of AgNPs utilizing plant extracts. Fourier Transform Infrared (FT-IR) spectroscopy, X- Ray diffraction, and ultraviolet (UV) spectroscopy are used to characterize the synthesized nanoparticles. These analyses provide insights into the absorbance, bond stabilization, particle sizes, and shapes of AgNPs, which contribute to their overall configuration. Furthermore, this review investigates a wide range of species of plants that can be used in a quick, one-step technique that favours ecologically beneficial practises over conventional methods. Silver nanoparticles' antibacterial capabilities are also examined, highlighting their potential usefulness in fighting bacterial infections. In general, the organic synthesis of AgNPs utilizing plant extracts is an useful and sustainable method of producing nanoparticles. By utilizing natural and renewable resources, this method contributes to the development of eco-friendly nanotechnology and addresses the concerns associated with hazardous chemicals in traditional synthesis approaches.

KEYWORDS

Nanoparticles, green production, plant extracts, environment friendly.

1. INTRODUCTION

Our environment is seriously being affected because of rapid expansion and urbanization, and toxic and undesirable gases, chemicals, or substances are being discharged into the environment [1]. The discharge of dangerous and unwelcome gases, chemicals, or other substances into the environment is seriously harming our ecosystem. Because they have a larger area-to-volume ratio, a distinct structure, and more function than macromolecules, nanoparticles have garnered a lot of attention [2]. Because of their higher activity than macromolecules, altered shape, and enhanced surface area to volume ratio, nanoparticle production has received a lot of interest [3]. Particles with a size between 1 nm and 100 nm are known as nanoparticles (NP). The optical, electronic, textile, medical, cosmetics, and medication delivery industries all use nanoparticles [4]. Textiles and apparel, packaging for food, treatment of water, insecticides, and household items all include AgNPs. Green chemistry synthesis approaches that use biological agents like enzymes, microbes, and plant extracts are used in the production of AgNPs [5]. The utilisation of plant extracts in the synthesis of AgNPs is a more environmentally friendly way than the currently utilised traditional chemical and physical methods. This technique is frequently employed to reduce toxicity and produce green chemistry [6]. AgNPs may be produced in a variety of methods utilizing various plant extracts. Researchers have employed a variety of biomolecules found in plants to convert metal ions into nanoparticles of different metals, including silver, gold, and others [7Many metal ions, biomolecules, and vital vitamins and minerals may be extracted from plants using techniques like chromatography, Soxhlet extraction, and other techniques. Because of its practical applications and advantages, nanoparticle research and use are currently of great interest in every branch of science [8]. In addition to medicinal or environmental technologies, nanotechnology has a diverse set of uses, including those for conventional chemical processes. The agricultural industry, cosmetics, food industry, textiles and clothing, photocatalytic organic dye-degradation activity, chemical sensing, antioxidants, as well as antimicrobial agents are just a few examples of the many applications that silver nanoparticles have significantly influenced [9]. Recent research has discovered ways to produce silver nanoparticles from naturally occurring materials and by products like neem (Azadirachta indica), leguminous shrubs (Sesbania drummondii) and leafy green tea (Camellia sinensis), various leaf broths, natural rubber, Aloe Vera plant extract, starch, lemongrass leaves extract, and others [10]. Silver nanoparticles adhere to bacteria cell walls, affecting cellular respiration and the permeability of cell walls. The nanoparticles can go

further deep into the cell wall, where they may react with DNA and protein, as well as other phosphorus and sulfur-containing compounds, to harm the cells [11]. The capacity of nanoparticles of silver to destroy bacteria is due to the particles' production of silver ions, which have an antibacterial impact. Furthermore, the size of the nanoparticle influences the effectiveness of the antibacterial activities [12]. Because of the equivalent silver mass concentration, the smaller particles provide better antibacterial effects. Microorganisms such as fungi, bacteria, and yeast that produce inorganic materials via biological synthesis, either intracellular or extracellular, have rendered nanoparticles more biocompatible in terms of medicinal applications [13]. Several studies have also been conducted on the creation of nanoparticles of silver using medicinal herbs such as *Capsicum annuum*, *Oryza sativa, Helianthus annus, Sorghum bicolor, Saccharum officinarum, Zea mays, Magnolia kobus, Aloe vera*, *Medicago sativa* (Alfalfa), *Cinamomum camphora,* and *Geranium* sp. a methanolic Eucalyptus extract hybrida was also used in the green production of silver nanoparticles [14]. The review articles investigate the potential applications of silver nanoparticles, including antimicrobial applications, as well as the green manufacture of AgNPs using various plants.

2. THE UTILIZATION OF PLANT EXTRACTS FOR THE PRODUCTION OF SILVER NANOPARTICLES.

By combining plant extracts with a metal salt solution, nanoparticles from plants can be created. In most cases, the reaction is finished quickly. AgNPs and many other metals could be made using this technique. Table-1 summarises research on the utilisation of several plant extracts in the production of silver nanoparticles. [15].

In the study conducted by Vijayakumar et al., Artemisia nilagirica leaf extract was used to create AgNPs. SEM and energy-dispersive spectroscopy (EDX) were used by the researchers to confirm the presence of silver nanoparticles. By analyzing their morphology with SEM, it was determined that the AgNPs exhibited an average diameter ranging from 70 to 90 nm. The EDX findings provided further evidence of the presence of elemental silver [16].

Roy et al. created AgNPs by lowering them with Vitis vinifera fruit extract. The reduction process was linked to the presence of terpenoids, flavones, phenolics, and polysaccharides in the extract. The size and structure of the crystals of the AgNPs were examined using a transmission electron microscope (TEM). The AgNPs possessed a delicate crystalline structure and were mostly spherical in shape, with diameters that ranged from 18 to 20 nm.

Surprisingly, the AgNPs inhibited both gram-positive Bacillus subtilis and gram-negative Escherichia coli [17].

AgNPs with diameters ranging from 5 to 25 nm were quickly synthesised using a standard microwave setup and an extract derived from the leaves of Stigmaphyllon littorale. The synthesised nanoparticles were subjected to UV-Vis, Fourier Transform Infrared (FTIR), SEM, and TEM examinations. The antibacterial activity of gram-positive (Bacillus subtilis and Micrococcus luteus) and gram-negative (Pseudomonas putida and Escherichia coli) bacterial pathogens was investigated. The AgNPs exhibited remarkable antibacterial properties against these pathogens.

Bindhu and Umadevi did another investigation in which AgNPs were created using Hibiscus cannabinus leaf extracts. The UV-Vis spectra confirmed the existence of AgNPs via a surface plasmon signal at 446 nm. The sphere AgNPs are monodispersed and average 9 nm in size. According to the FTIR results, the reducing agent was ascorbic acid found in Hibiscus cannabinus leaf extract. The antibacterial activity of the synthesised AgNPs against Proteus mirabilis, Shigella Flexner, and Escherichia coli was evaluated, demonstrating their efficacy against these microbiological strains [18].

In a separate study, AgNPs were synthesised utilising an extract of the leaves from Ocimum sanctum, also known as Tulsi. The AgNPs had particle sizes that varied between 4 to 30 nm. Surprisingly, the conversion of Ag+ ions into AgNPs took only 8 minutes when the Ocimum sanctum leaves extract was used. The synthesised AgNPs exhibited robust antibacterial activities, successfully fighting both gram-negative and gram-positive infections [19].

Baishya et al. synthesised AgNPs from a leaf extract of Bryophyllum pinnatum (Lam.) in a study. The AgNPs produced ranged in size from 70 to 90 nm. The ultraviolet-visible absorption spectrum of the nanoparticle solution displayed a surface plasmon resonance band near 418 nm, indicating that the particles were dispersed in the water-based solution without aggregation. The XRD pattern confirmed the crystalline structure of the AgNPs. TEM examination revealed that the AgNPs were mostly spherical. Notably, the synthesised AgNPs were highly effective against E. coli and Staphylococcus aureus [20].

The methanol-based extract of Adhatoda vasica was used as both a reducing agent and a capping agent in the method of synthesising AgNPs. The UV-Vis spectra revealed a peak of absorbance at 395 nm that can be attributable to the nanoparticles' surface plasmon absorption. Through TEM analysis, it was observed that the AgNPs had an average size of

15-20 nm and displayed a spherical morphology. The synthesized AgNPs demonstrated remarkable capabilities in terms of scavenging DPPH free radicals and reducing power. Furthermore, the AgNPs exhibited potent activity against various human diseases and were found to possess anti-diabetic properties. It is worth noting that AgNPs were identified as highly effective against several illnesses and also showed promise as an anti-diabetic medication [21].

Rout et al. created AgNPs by reducing them with Ocimum sanctum leaf extract. The presence of AgNPs in the aqueous solution resulted in a dark yellowish-brown color, which was attributed to surface plasmon resonance phenomena. SEM images showed that the AgNPs ranged in size from 0 to 50 nm and had a spherical morphology. The bio-organic phase may crystallise on the outermost layer of the AgNPs, according to XRD data. The antifungal and antibacterial properties of the synthesised AgNPs were also tested against a variety of microorganisms. Staphylococcus aureus, Staphylococcus saprophyticus, Escherichia coli, Klebsiella pneumoniae, Enterococcus faecalis, Enterobacter cloacae, and Proteus vulgaris were among the pathogens evaluated. AgNPs were found to have antibacterial and antifungal properties against these pathogens [22].

Dhanalakshmi and Rajendran created very stable AgNPs from Tridax procumbens leaves. The existence of AgNPs was confirmed by the appearance of a surface plasmonic absorption band around 460 nm in the ultraviolet-visible absorption spectrum of the AgNPs solution. SEM investigation showed visible AgNPs over the outer layer at high magnification, allowing both the shape and size of the AgNPs to be further characterised. The AgNPs' average size was measured to be 55 nm. The standard technique of disc diffusion was used to evaluate the antibacterial efficacy of the synthesised AgNPs. Human-harmful bacteria such as Vibrio, Shigella, Salmonella, and Escherichia coli were tested. The results showed a considerable level of inhibition, showing that the AgNPs produced have good antibacterial activity against these harmful microorganisms.

Table-1 Various plant extracts used for green synthesis of AgNPs [23].

No.	***Plants***	***Shape***	***Size and shape***
1.	*Aloe vera*	Spherical	70 nm
2.	*Clitoria ternatea*	Spherical	20 nm
3.	*Eclipta alba*		310 to 400 nm
4.	*Tea leaf*	Spherical	20 nm

5.	*Skimmia laureola*	Spherical	38±0.27 nm
6.	*Mukia maderaspatana*	Spherical	58- 458 nm
7.	*Croton sparsiflorus morong*	Spherical	22-52 nm
8.	*Withania somnifera*	Spherical	70-110 nm
9.	*Prenus yedoensis*	Spherical, oval	18-20 nm
10.	*Pistacia atlantica*	Spherical	10-50 nm
11.	*Azadirachta indica*	Spherical	250-700 nm
12.	*Urtica dioica*	Spherical	20-30 nm
13.	*Sulunum nigrum*	Spherical	28 nm
14.	*Leptadenia reticulate*	Spherical	50-70 nm
15.	*Tamarix gallica*	Spherical	5-40 nm
16.	*Cardiospermum halicacabum*	Spherical	74 nm
17.	*Pedalium guajava*	Spherical	10-90 nm
18.	*Terminalia arjuna*	Spherical	8-16 nm
19.	*Momordica charantia*	Spherical	11-16 nm
20.	*Croton bonplandianum*	Spherical	15-40 nm
21.	*Crotalaria retusa*	Spherical	80 nm
22.	*Ficus virens*	Spherical	4.98-29 nm
23.	*Prosopis farcta*	Spherical	8-11 nm
24.	*Justicia adhatoda L.*	Spherical	5-50 nm
25.	*Grewia flaviscences*	Spherical	60 nm
26.	*Raphanus sativus*	Spherical	6-38 nm
27.	*Tectona grandis Linn*	Spherical	26-28 nm
28.	*Artocarpus altilis*	Spherical	20-50 nm
29.	*Pedalium murex*	Spherical	20-50 nm
30.	*Azadirachta indica*	Spherical	34 nm
31.	*Terminalia chebula*	Spherical	10-30 nm
32.	*Psidium guajava*	Spherical	10-90 nm
33.	*Cassia fistula*	Spherical	39.5 nm
34.	*Canna edulis*	Spherical	less than 40 nm
35.	*Talinum triangulare*	Spherical	13.86 nm
36.	*Psidium guajava*	Spherical	25 nm
37.	*Lavandula x intermedia*	Spherical	11-47 nm

38.	*Lippia citriodora*	Spherical	10-45 nm
39.	*Taraxacum officinale*	Spherical	5-30 nm
40.	*Catharanthus roseus*	Spherical	10-88 nm
41.	*Petiveria alliacea L.*	Spherical	16.7-33.74 nm
42.	*Ricinus communis*	Spherical	8.96 nm
43.	*Brassica oleracea L.*	Spherical	30-100 nm
44	*Artemisia vulgaris*	Spherical	27-53 nm
45.	*Erythrina suberosa*	Spherical	15-34 nm
46.	*Phlomis*	Spherical	25 nm
47.	*Ziziphus oenoplia*	Spherical	10 nm
48.	*Jatropha curcas*	Spherical	20-50 nm
49.	*Indoneesiella echioides*	Spherical	29 nm
50.	*Lantana camara*	Spherical	20-200 nm

2.1 A procedure for synthesizing silver nanoparticles using plant extracts

In one investigation, 10 g of Nelumbo lucifera leaves were cooked in 100 ml of water that had been distilled in a conical container. The filtrate (12 ml) was then treated with 88 ml containing a 1 mM AgNO3 solution. The resulting combination had been incubated at room temperature, and the brownish-yellow colour of the solution indicated the synthesis of AgNPs [24]

In another experiment, 5 mL of a seed extract was mixed into a 20 mL solution containing aqueous silver nitrate. After 15 minutes of heating at 80 °C, the mixture turned scarlet, suggesting the creation of silver nanoparticles [25]. Additionally, different volumes (5 ml, 10 ml, and 15 ml) of leaf extract were added to a 25 ml AgNO3 solution (103 M) and vigorously stirred for 5 minutes. Reduction of AgNO3 to AgNPs occurred slowly at 300 K and was completed within 30 minutes, resulting in a stable light brown color. Silver nanoparticles were also produced by mixing 25 ml of the extract with 100 ml of AgNO3 (103 M) at 373 K. Similarly, at 300 K and a pH of 8, the rapid reduction of AgNO3 solution with 5 ml of the extract produced brilliant brown silver nanoparticles [26].

In another study, 88 ml of a 1 mM silver nitrate solution was combined with 12 ml of an aqueous extract of A. indica. The reaction was carried out at room temperature in the dark for 24 hours, resulting in the formation of AgNPs. Aqueous solutions of D-sorbitol (102 M) and

silver nitrate (103 M and 104 M) were also prepared. Mixing 40 ml of the AgNO3 solution with 3 ml of Polyalthia longifolia leaf extract and 1 ml of D-sorbitol, followed by incubation at 25°C and 60°C, led to the formation of silver nanoparticles, indicated by the dark brown color [27].

Furthermore, in a different experiment, the stem bark of Boswellia ovalifoliolata was finely ground and added to a solution containing 1 mM silver nitrate. The mixture was centrifuged, and the resulting pellet was frozen at -40°C. The supernatant was subjected to temperatures ranging from 500 to 950 degrees Celsius, resulting in a color change of the solution during the heating process [28].

2.2 Factors Affecting Green synthesis of Silver Nanoparticles.

Several factors influence the manufacturing, analysis, and application of nanoparticles. A few variables that influence synthesis are pH, temperatures, concentration of extract, size, and raw material concentration [29]. Despite the advantages of organic green synthesis, managing nanoparticle polydispersity is difficult. The reaction conditions can be improved to address this problem by modifying the pH, temperature, incubation period, radiation, salt content, and redox state. For instance, pH is important for the green production of nanoparticles. Variations in pH affect the charge of phytochemicals in plants, which involves Ag reduction and binding during synthesis [30]. Most of the time, environmentally friendly technology is used to produce nanoparticles at temperatures below 100 degrees Celsius. Furthermore, particle size influences the properties of green synthesized silver nanoparticles [31].

3. CHARACTERIZATION

3.1 High-Resolution Transmission Electron Microscopy

JEOL-JEM-100 CXII equipment was used to examine colloidal silver nanoparticles from Hevea Brasiliense. Transmission electron microscopy (TEM) was used to examine the morphology from the silver nanoparticles, which required drying a small amount of a colloidal mixture after it had been washed over a grid of copper covered in the conductive polymer [32]. The shape and size of silver nanoparticles generated by mangosteen leaves were examined using a 200 kV Ultra High-Resolution TEM (JEOL-2010). After the reaction, 100 ccs of the remaining solution had been centrifuged at 5000 rpm for ten minutes before being placed on TEM grids. After centrifugation, the solution was re-dispersed into 10 millilitres of sterile, distilled water, and the operation was done three times. Using an

HRTEM (JEOL 3010) and 25 l of material sprayed on a coated copper stub, silver nanoparticles produced physiologically by Bacopa Monnier are examined. A dry nanoparticle coating was applied to the XRD grid, and a Philips PW 1830 X-ray generator was used to record the spectra. It operated at a 40 kV voltage and a 30-mA current under Cu K1 radiation. The silver concentration was determined using an AAS, or atomic absorption spectrophotometer [33]. Biogenic Ag nanoparticles produced from Ulva lectica extract were analyzed using HRTEM, and the results showed that the particle's diameter was between 20 and 30 nm. According to studies on the synthesis as well as long-term viability of silver nanoparticles via Jatropha curcas seeds extracted in an aqueous colloidal solution, as the amount of silver nitrate increases, the surface plasmon resonance (SPR) band changes to red from 103 to 102 (M), and the colour shifts from reddish yellow to deep red [34]. According to HRTEM, the particles are bigger, irregularly shaped, and range in size from 30 to 50 nm. The diameter of the spherical particles is between 15 and 25 nm. The particle sizes at the two different concentrations of AgNO3 are consistent with the reported surface plasmon resonance (SPR) band, which is at 425 and 452 nm [35].

3.2 UV Spectrometry Analysis

The extracellular production of silver nanoparticles utilising Euphorbia hirta (Shimadzu) leaves was determined after 5 hours using the reaction solution's UV-VIS spectra. Colloidal nanoparticles of silver from Hevea brasiliensis show a unique surface plasmon absorption peak at 435 nm in UV-Vi spectra [36]. Smaller particles arise from lower AgNO3 levels. Silver nanoparticles are spherical in shape and range in diameter from 2 to 100 nm. The UV-vis absorption spectra of the colloidal dispersions were recorded using an UltraSPARC 2100 spectrophotometer. The Malvern Instruments Zeta-Sizer equipment was used to determine the particle size distribution. The maximal absorbance of silver nanoparticles generated from plant extract is 430 nm, and it increases with reaction time. Ultimate absorption intensity at 430 nm rise by up to 1.5 angstrom units when using magnolia leaf broth, but only by up to 0.5 angstrom units when using neem leaf broth [37]. Although pure solanum torvum plant extract does not appear to absorb in the UV-vis spectrum between 400 and 800 nm, maximum absorbance was discovered around 434 nm when subjected to AgNO3 solutions due to the formation of nanoparticles[38].

3.3 Scanning Electron Microscopy

The generation of spherical-shaped nanoparticles of silver isolated from Syzygium aromaticum, varying in size between 20 nm to 149 nm, was confirmed using SEM. A Hitachi S-4500 SEM equipment was used for scanning electron microscopic (SEM) investigation. The absorbance of a silver nanoparticle synthesised in 10 minutes is 430 nm, and the widening of the peak suggests polydispersion. The SEM reveals the formation of a spherical nanoparticle with a diameter of 40-50 nm [39]. The Green Production of tiny silver particles using Cleome viscosa was investigated using SEM. For SEM research, a ZEISS EVO 40 EP Electron microscope was employed. According to SEM analysis, silver nanoparticles are equally dispersed across the outermost layer of the cells. This does not imply that every nanoparticle is adhered to the cell surface. This could be due to solution-dispersed particles accumulating on cell surfaces. [40].

3.4 X-ray diffraction analysis

X-ray diffraction (XRD) analysis of naturally generated Eucalyptus hybrida silver nanoparticles. The data were collected using an X'Pert Pro X-ray diffractometer with a Cu K X-ray at a voltage of 40 kV and a current of 30 mA. indica aqueous leaf extract was utilized to create silver nanoparticles, which were then deposited on an XRD grid and used for XRD research. With the use of a Philips PW 1830 X-ray generator, the spectra were studied. It employs Cu K1 radiation and runs at 40 kV voltage and 30 mA current. The face-centered cubic structure of metallic silver shows three unique diffraction peak angles of 38.1°, 44.3°, and 64.4° at two different values indexed to (1 1 1), (2 0 0), and (2 2 0), respectively, according to XRD study [41]. A grid of silver nanoparticles derived from Nelumbo nucifera leaf extract was used to acquire XRD spectra on the Phillips PW 1830 instrument, which operates at 40 kV and 30 mA and uses CuK1 radiation. The silver nanoparticles' average size was found to be 45 nm. As a result, silver nanoparticles made from Neem leaf broth have crystalline planes (111), (200), (220), (311), and (222). Consequently, the reduction of crystalline Ag + ions produces silver nanoparticles [42].

The XRD patterns of silver nanoparticles produced from Jatropha curcas seed extract revealed multiple Bragg reflections with two values of 38.03°, 46.18°, 63.43°, and 77.18°, each, corresponding sets of lattice planes to the (1 1 1), (2 0 0), and (3 1 1), respectively. They are listed as the band for cubic structures with a silver face as their center. The produced silver nanoparticles are shown to be crystalline by the XRD pattern. According to prior studies, X-ray diffraction patterns of S. torvum leaf extract shows strong peaks of

nanoparticles of silver having an average size of 14 nm [43]. The energy of a photon in the X-ray diffraction (XRD) patterns varies from 100 eV to 100 keV for the plant-mediated synthesis of silver nanoparticles. For diffraction applications, short-wavelength hard X-rays with energies ranging from 1-120 keV were utilised 34. The XRD pattern of dry silver nanoparticles using Chenopodium album leaf extract exhibits diffraction peaks at 38.13°, 44.21°, 64.47°, 77.37°, 81.47°, 98.01°, 110.56°, and 114.80° [44].

4. APPLICATIONS

4.1 Antimicrobial activity

Silver nanoparticles are widely acknowledged to be exceedingly poisonous and harmful to microorganisms. Silver nanoparticles have several bactericidal and inhibitory properties, increasing their utility as an antibacterial agent. The zone of inhibition is used to measure the antibacterial activity of silver nanoparticles. Several studies have found that silver nanoparticles can influence membrane permeability and respiratory function by sticking to the cell surface. Based on a different theory [45], Silver nanoparticles engage with bacteria within the cell and on the surface of the membrane. Nanosilver is a far more efficient and speedier fungicide for a wide variety of prevalent fungi, like Aspergillus, Candida, or Saccharomyces. Using the usual well diffusion method, the effectiveness of antibacterial agents against pathogenic bacteria that affect humans, like E. coli, P. aeruginosa, or Bacillus subtilis, was examined [46]. The antibacterial activity of the produced nanoparticles was tested in vitro using the Kirby-Bauer technique, verifying the National Committee for Clinical Laboratory Standards (NCCLS) approved standards [47]. The antibacterial capacity of the silver nanoparticles generated was evaluated by the technique of diffusion on agar wells. The previously demonstrated inhibitory zone formed by silver nanoparticles was compared to the inhibition zone established by different antibiotics [48]. Antibacterial research on human harmful bacteria such as E. coli and Pseudomonas aeruginosa was also conducted using the usual disc diffusion technique. Bacteria were grown in Luria Bertani (LB) broth/agar medium. Nanoparticles are frequently used for antimicrobial (including antibacterial or antifungal) purposes [49]. Fusarium oxysporum extracellularly produced gold or silver nanoparticles can be used in a number of materials, including garments. In hospitals, these sterile clothes are intended to prevent or reduce the spread of hazardous pathogens such as Staphylococcus aureus. The typical inhibition zones for P. aeruginosa were 35 mm, 30 mm

for K. pneumonia, 36 mm for S. aureus, 40 mm for S. typhi, 38 mm for S. epidermis, and 34 mm for E. coli [50].

CONCLUSION

Green chemistry or environmentally friendly approaches for synthesizing metal nanoparticles have gained popularity in recent years. Plant extracts have come to light as a possible alternative for silver nanoparticle manufacturing. These measures not only save money and energy, but they also encourage safer working conditions, safeguard the environment, therefore result in lesser waste and safer products. The use of plant extracts in nanoparticle synthesis offers a greener and more sustainable approach. Compared to other biological entities such as bacteria, plants have advantages in terms of simplicity and ease of use. They eliminate the need for complex bacterial cultures and maintenance processes, thus streamlining the nanoparticle synthesis process. As a result, plant extracts have the potential to revolutionize the field of nanotechnology. Various plant extracts, as mentioned earlier, have been extensively studied for their ability to reduce silver ions and produce silver nanoparticles. However, it is important to acknowledge that plant extracts from different parts of the world may have variations in their chemical composition, leading to different outcomes in different laboratory settings. Therefore, it is crucial to understand the specific plant biomolecules responsible for mediating nanoparticle formation, enabling a standardized and economically viable approach. To overcome the challenges associated with using plant extracts as reducing and stabilizing agents, ongoing research aims to identify key plant biomolecules that can efficiently facilitate nanoparticle synthesis in a rapid and single-step process. This approach holds great potential for enhancing green silver nanoparticle production and addressing the limitations previously encountered. In conclusion, the use of plant extracts for silver nanoparticle synthesis has garnered significant attention due to its numerous advantages in terms of cost-effectiveness, environmental friendliness, and safety. By further exploring the capabilities of plant biomolecules in nanoparticle synthesis, we can unlock the full potential of green chemistry and pave the way for sustainable and efficient nanoparticle manufacturing in the future.

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