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GREEN SYNTHESIS OF SILVER NANOPARTICLES BY PLANTS AND ITS APPLICATIONS

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ABSTRACT- Bio-molecules derived from various plant components and microbial species have been investigated as possible agents for synthesizing silver nanoparticles (AgNPs). There is worldwide interest in synthesizing silver nanoparticles by different methods for their anti-bacterial activity, catalysis, and anti-fungal activity. In medical science and illness therapy, developing the biologically inspired green synthesis of silver nanoparticles has gotten a lot of interest. Synthesized silver nanoparticles were detected using UV Vis spectroscopy to examine the silver nanoparticles that had been made. Moreover, X-Ray Diffraction, Fourier Emission Scanning Electron Microscopy (FESEM), spectrophotometry, Electron Dispersive Spectroscopy (EDS), and X-Ray Diffraction (EDS) were used for confirmation.

Keywords – AgNPs, green synthesis, silver nanoparticles, anti-microbial activity, anti-fungal activity

1 INTRODUCTION

Nano refers to a small particle measuring between 10 and 100 nm[1]. Nanoparticles have unique properties such as size depending on characteristics, and the surface-to-volume ratio is high. The use of nanotechnology in research and development divisions to build nanoscale products is increasing[2]. Professor Norio Taniguchi of Tokyo Science University created the term nanotechnology in 1974 to describe the precision creation of materials at the nanoscale level[3]. Nanoparticles are atom clusters that range in size from 1 to 100 nm. “Nano” is a Greek term that means very little and is synonymous with the word dwarf[4]. Nanoparticles have become a popular research topic in recent years due to their wide range of applications in fields such as diagnostics, biomarkers, cell labelling, anti-microbial agents, drug delivery, and cancer therapy. Silver is well-known for its inhibitory properties towards a wide range of germs and microorganisms present in various medical and industrial activities[5].

Different nanomaterials such as copper, zinc, titanium, magnesium, gold alginate, and silver have been developed. However, silver nanoparticles have proven to be the most successful due to their anti-bacterial activity against bacteria, viruses, and other eukaryotic microorganisms [4,5]. The current study suggests that silver ions or metallic silver, as well as silver nanoparticles, have more applications, low toxicity to human cells, and high thermal stability[6]. Various methods for synthesizing silver nanoparticles include physical, chemical, and biological methods. In the physical method, higher energy is required and takes a long time[7]. The synthesis of silver nanoparticles using the chemical methods is used several chemicals like ascorbic acid, sodium borohydride, and hydrazine trisodium citrate. Chemical approaches are successful, but because of the chemicals utilized and the difficulty in removing them, they may be harmful. Hence, chemicals utilized in these procedures are harmful to the environment[8]. Synthesis of silver nanoparticles using the chemical and physical method is not environmentally friendly and may create environmental pollution. On the other hand, the biological synthesis of NPS is rather eco-friendly [9].

Microorganisms can also synthesize silver nanoparticles, but duo the high cost of isolation, hard to maintain an aseptic condition, culture media, and some microorganisms are produced toxic components [10]. Silver nanoparticle synthesis using plants is important due to its quick, eco-friendly, non-pathogenic, and cost-effective properties [11]**.** Additionally, top-down or bottom-up techniques are frequently used to produce nanoparticles with sizes between 10 nm and 1000 nm in each spatial dimension[10].

Top-down approach :A top-down approach is used to gradually separate the mass materials into Nano sized materials[12]. The top-down technique is defined as the breakdown of the appropriate bulk material into its parts via size reduction[13].

Bottom-up approach : In a bottom-up process, atoms or particles are gathered to create sub-atomic structures in the nm range. A bottom-up approach is commonly employed for nanoparticle chemical and biological synthesis[12]. Atoms or molecules arrange themselves into structured nanostructures through chemical-physical interactions in a bottom-up procedure known as self-assembly. Positional assembly is the only process that permits the unlimited positioning of a single atom, molecule, or cluster at a time [13].

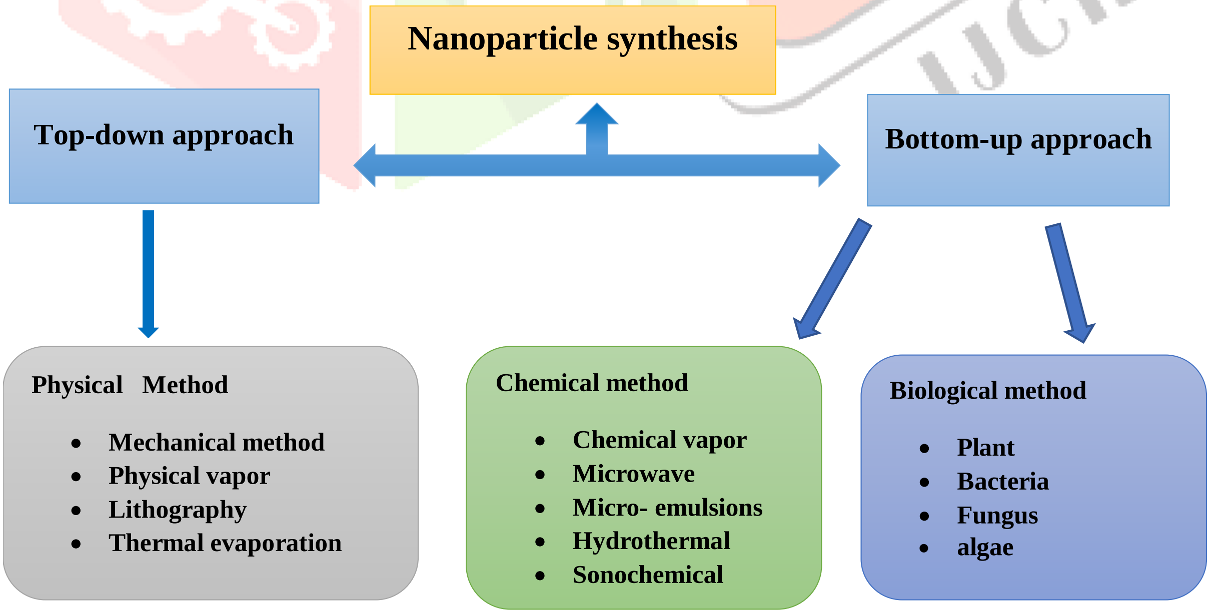

Figure 1: nanoparticle synthesis using a different method

1.1 MECHENISM OF SILVER NANOPARTICLES

an appropriate method for creating silver nanoparticles has yet to be discovered. The postulated hypothetical mechanism for nanoparticle formation is an enzymatic reaction in which a complex of reducing enzymes in the plant extract converts compounds like silver nitrate into silver ions and nitrate ions[14]. Plants have a complex network of antioxidant metabolites and enzymes that act together to protect cellular components from oxidative damage. Plant extracts were found to contain biomolecules such as polyphenols, ascorbic acid, flavonoids, sterols, triterpenes, alkaloids, alcoholic compounds, polysaccharides, saponins, glucose, and fructose, as well as proteins/enzymes that could be used as reductants to react with silver ions and thus used as scaffolds to direct the formation of AgNPs in the solution. Biosynthetic products or reduced cofactors might theoretically play a key role in reducing salts to nanoparticles[15]. More research is needed into synthesizing AgNPs from plants to identify the right biomolecules that serve as the capping and stabilizing agent. The hydroxyl groups in the secondary metabolite quercetin (2-(3,4-dihydroxy phenyl)-3,5,7-trihydroxy-4H-chromene-4-one) present in plant extract are converted to the 3,5,7-trihydroxy-2-chromen-4-one (4-hydroxy-3-oxocyclohexa-1,5-dien-1-yl) The reducing equivalents produced by -4H-chromen-4-one are utilized to convert silver metal ions (Ag^{+}) into elemental (Ag^{0}) nanostructures[16]. During the creation of nanoparticles, this frequently resulted in a colour change. Electrons for forming AgNPs can be obtained through dehydrogenation of acids and alcohols in hydrophytes, keto to enol conversions in emophytes, or both pathways in xerophytes plants[17].

The physical and chemical methods for producing silver nanoparticles are costly and harmful to the environment. To avoid this problem, researchers have found a route, the naturally occurring sources and their by-products that can be used to synthesize nanoparticles[18]. The green synthesis of AgNPs is called the plant extract, microbial enzyme, fungi, and yeast using synthesized silver nanoparticles. It is simpler than the physical and chemical methods. They are usually responsible for reducing metal compounds into their respective nanoparticles due to their antioxidant or reducing properties. Green synthesis has advantages over chemical and physical synthesis. It is less expensive, more environmentally friendly, and easier to scale up for large-scale synthesis because it does not require high pressure, energy, temperature, or harmful chemicals. Silver is also used in filters to purify drinking water and clean swimming pool water due to its anti-bacterial characteristics [19]. Green synthesis was created to avoid chemical toxicity. It is simpler to use a plant to synthesize nanoparticles and characterize their nanoparticles. Nanoparticles are a new branch of nanotechnology that will be used in the future to make biologically produced materials. Nanoparticles have been discovered to be very hazardous to various multidrug-resistant human diseases. Green synthesis is superior to chemical and physiological synthesis in terms of cost and environmental impact[20].

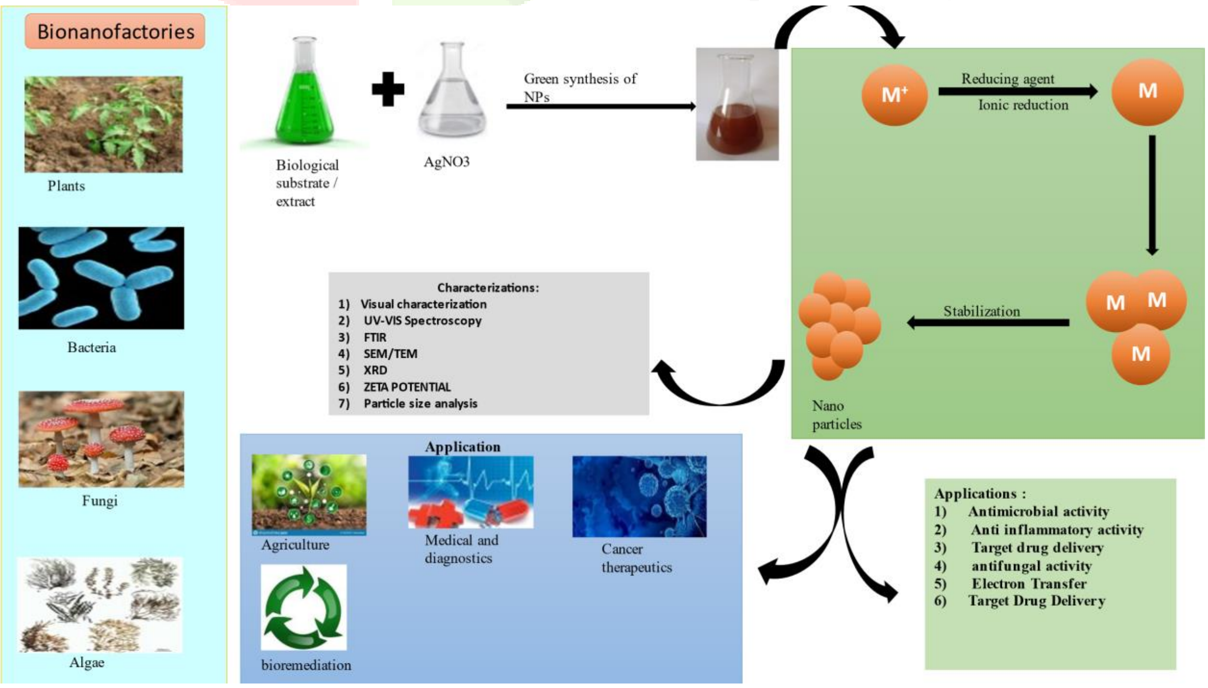

Figure 2 : procedure for green synthesis of silver nanoparticles using various biological entities and applications [72]

2 GREEN SYNTHESIS OF SILVER NANOPARTICLES

are essential for any nanotechnology because of their unique features related to their size, distribution, and morphology [21]. Various physical, chemical, biological, and hybrid methods are now used to create various nanoparticles[2]. Chemical processes include chemical reduction, electrochemical treatments, and photochemical reduction. Because of the increased interest in environmentally friendly products, plant-based nanoparticles have gotten more attention. Other advantages of employing plants to synthesize nanoparticles include using safer solvents, fewer harmful chemicals, softer response conditions, practicality, and adaptability in medical, surgical, and pharmaceutical applications[22]. Plants, microbes, and other biopolymers have been used in the green synthesis of AgNPs. Because it does not require the maintenance of cell cultures and includes support for large-scale nanoparticle synthesis, using plants for nanoparticle synthesis has several advantages over other biological synthesis approaches. The synthesis of silver nanoparticles (AgNPs) plant includes Aloe vera, alfalfa sprouts, neem, green tea, and Banyan. The colour of the liquid The Reduction of silver nitrate to silver ions was confirmed by the colour changes from light yellow to brown, indicating the formation of silver nanoparticles[2]. The selected plant methanol extract contains carbohydrates, proteins, alkaloids, reducing sugar, and tannin. The presence of reducing agents in the abstract was confirmed in the phytochemical screening of the abstract of the banyan tree aerial root tip[23]. Primary physical and chemical parameters that determine AgNPs synthesis include reaction temperature, metal ion concentration, extract content, pH of the reaction mixture, reaction duration, and agitation.. Metal ion concentration, extract composition, and reaction time impact AgNp's size, shape, and morphology [10]. In addition to plant extracts, AgNPs have been produced utilizing biopolymers, microbial cell biomass, or cell-free growth media. The plants used to synthesize AgNPs range from algae to angiosperms. However, angiosperms are the best choice due to the lack of data on the lower plants. Plant components like leaves, bark, roots, and stems were used to make AgNPs[24]. Compared to using plant extracts and biopolymers as reducing and capping agents, synthesizing AgNPs by microorganisms is tedious due to the difficulty in growth, culture maintenance, and inoculum size standardization. Several bacterial and fungi species were used to finish the synthesis successfully. One of two distinct pathways one that used extracellular components generated in the growing medium and the other that directly used microbial cell biomass was used to produce AgNPs in most cases. The bacteria produce AgNPs both intracellularly and extracellularly. The synthesis of AgNPs inside cells has seldom been observed[25]. The benefits of employing plants to synthesize nanoparticles are readily available and safe for use in plants. To manage and access a wide range of active agents that encourage silver ion reduction. The majority of plant components are similar to leaves, roots, latex, bark, stem, and seeds to create nanoparticles[26]. The most important element is the active agent present in certain locations, enabling the decline and stability. Eco-friendly plant extracts contain biomolecules that act as capping and reducing agents to produce stable, shape-controlled nanoparticles. The primary components that affect the reduction and capping of the nanoparticles are biomolecules such as phenolics, terpenoids, polysaccharides, flavones, alkaloids, proteins, enzymes, amino acids, and alcoholic chemicals. The usage of quinol and chlorophyll pigments, linalool, methyl chavicol, eugenol, caffeine, theophylline, ascorbic acid, and other vitamins has also been mentioned in publications. The non-toxic phytochemicals have the unique chemical capacity to both effectively reduce and surround nanoparticles, preventing their aggregation, such as the phenols and flavonoids discussed above. Phenolic substances have hydroxyl and carboxyl groups that can bind to metals[27]. Most AgNPs produced by green synthesis are being studied for use in biomedicine, specifically as anti-bacterial agents or cancer treatments. Recent studies have demonstrated that extracts of *Chrysanthemum indicum L*. or *Acacia leucophloea* can be used to create AgNPs with diameters ranging from 38 to 72 nm to 17 to 29 nm, respectively. Both samples showed excellent bactericidal qualities. Similarly, AgNPs were created using *Ganoderma neojaponicum Imazeki* as possible cytotoxic agents against breast cancer cells[25].

2.1 Synthesis using bacteria

create inorganic compounds either extracellularly or intracellularly. The metabolic process in a few microorganisms is linked with metal ions, which are required to grow the microbes one by one. It is responsible for the bioconversion of metal ions to make nanoparticles[73]. Although silver is well known for its biocidal effects, some bacteria are known to be silver resistant[74]. The use of prokaryotic microorganisms as nano factories was initially investigated. Silver was used in the first noble metal nanoparticle production utilizing microorganisms like *Pseudomonas stutzeriAG259* and *Proteus mirabilis PTCC 1710*. Using a bacterial strain for bio-producing silver nanoparticles has several advantages over other biological sources, including ease of handling and a short cultivation period. A bacterial strain produces silver nanoparticles with well-defined forms, such as pyramidal and hexagonal silver nanoparticles with diameters up to 200 nm[72]. To detect the various formed crystals in the generated nanoparticles, TEM and XRD were used to quantify them. The disadvantage of using bacteria as a synthesis of nanobacteria the synthesis rate is very slow, costly & time-Consuming [75]. For the manufacture of Ag, Au, and Au core-Ag shell nanoparticles, Spirulina platensis single-cell protein was combined with aqueous AgNO3 and HAuCl4[76]. Due to varying degrees of contact with the cell membrane and thereby generating membrane disruption, AgNPs of varied shapes have been found to have diverse anti-bacterial activity [77]. The concentration of nanoparticles is another key element. This characteristic is linked to microbial species [78].

2.2 Synthesis using fungi

compared to bacteria, can make more nanoparticles because they can release more proteins, which immediately translate to increased nanoparticle productivity[10]. Nanoparticles synthesize by entrapment of Ag^+ ions on the surface of fungal cells and subsequent silver ion reduction by enzymes present in the fungal system[79]. Extracellular enzymes such as naphthoquinones and anthraquinones contribute to the reduction process[11]. The reduction of ions and production of AgNPs occur when the fungus is exposed to $AgNO_3$ solution. The nanoparticles have a diameter of approximately 25 nm and a monodispersed, spherical form. Unlike bacteria, AgNPs were generated underneath the fungal cells' surface. The mechanism of nanoparticle generation was next investigated, with the central idea being that NPs are created on the surface of the mycelia rather than in the solution in the case of fungi-based synthesis. It was therefore proposed that Ag^+ ions are adsorbed on the surface of fungal cells in the first phase as a result of electrostatic interaction between negatively charged carboxylate groups in enzymes found in mycelia's cell wall and positively charged Ag ions [10]. Fungi are increasingly used in green synthesis due to their Eco-friendliness and ease of handling compared to other groups of microorganisms. For example, fungus, such as white rot, is non-pathogenic and leads to the mass manufacturing of agricultural nanoparticles[80]. The reaction rate is another significant consideration when choosing a synthesis process. The first report of fast synthesizing fungi was with Aspergillus fumigatus, which produced monodispersed AgNPs in less than 10 minutes[81].

The use of algae as a feedstock for nanoparticle production remains unknown and underutilized. Recent reports indicate that algae are being utilised as a bio factory to generate metallic nanoparticles. Silver, gold, and silver-gold nanoparticles are formed using a mushroom extract[17]. Marine algae are also exploited to produce silver nanoparticles as a source of synthesis[82].

2.3 Synthesis using plant

Plant extracts are chosen over microbe-based nanoparticle manufacturing because of their simplicity, efficiency, and viability. A plant's ability to collect and detoxify heavy metals has been extensively established. A plant extract contains a variety of metabolites and reductive biomolecules that help metal ions to be reduced. All examples are terpenoids, flavones, ketones, aldehydes, amides, carboxylic acids, carbohydrates, proteins, and vitamins[25]. Polysaccharides, among many other natural compounds, provide a suitable scaffold for this purpose. In recent years, polysaccharides such as starch and chitosan have been used for AgNPs production. The employment of plants for the manufacture of silver nanoparticles has piqued researchers' interest due to its quick, cost-effective, and environmentally acceptable procedure, as well as the fact that it provides a single-step technique for the biosynthesis process[26]. The general procedure for making nanoparticles entails the collection of the relevant plant part or plant material from the available sites, washing it thoroughly twice or three times with distilled water to get rid of both epiphytes and necrotic plants, and then washing it once more with sterile distilled water to get rid of any associated debris. After that, clean and fresh plant sources are dried in the dark for 10 -15 days before being ground in a home blender. Approximately 10 g of the dry powder is cooked in 100 mL of deionized distilled water to prepare the plant broth. The filtrate is then gathered, and $AgNO_3$solution must be added to this filtrate (Raw/Diluted) at a final concentration of 1 mM. The mixture is then occasionally agitated in a shaking incubator after addition[27,28].

Due to the rapid decrease of pure Ag+ ions to Ago, the mixture's color changes. To detect the unique absorption properties of nanoparticles, which provide insight into nanoparticle formation, the resulting sample must then be observed in UV-visible spectra of the solution at regular intervals[27]. The flavonoid and terpenoid components in leaf broth are predicted to stabilize the production of nanoparticles, in contrast to the high molecular weight proteins found in fungal biomass[28]. The water-soluble heterocyclic and polyol components are principally responsible for the decline in silver ions (Ag^+) and the stability of nanoparticles. The function of reductases in the creation of nanoparticles is explained in detail[29]. Differences in the form of generated nanoparticles could explain variances in optical properties. It is generally known that silver nanoparticles exhibit a brownish appearance in an aqueous solution when surface Plasmon vibrations are stimulated[30].

Alfalfa roots can absorb Ag from agar medium and transport it to the plant's shoots in the same oxidation state[31]. These Ag atoms organized themselves in the shoots to produce nanoparticles by coming together and forming bigger arrangements. Green synthesis using plants looks faster than green synthesis using bacteria and fungi[32]. Depending on the nature of the plant extract, the formation of metal nanoparticles in the metal salt solution could be accomplished in minutes at room temperature[33]. The concentration of the plant extract, the metal salt, the temperature, the pH, and the contact time are the primary parameters[34]. Plants are advantageous for nanoparticle synthesis because they are readily available and safe to handle, and they contain a wide range of active substances that can promote the reduction of silver particles. Nanoparticles are made from various plant elements, including leaves, roots, latex, bark, stems, and seeds[35]. Biomolecules in environmentally friendly plant extracts work as reducing and capping agents, resulting in stable and shape-controlled nanoparticles. The primary chemicals that affect the reduction and capping of nanoparticles are phenolics, terpenoids, polysaccharides, flavones, alkaloids, proteins, enzymes, amino acids, and alcoholic compounds. Most AgNPs produced via green synthesis are studied in biomedicine, primarily as anti-bacterial agents and cancer treatments[36].

Table 1: Different plants used for Nanoparticales synthesis

Sr. no	Plant name	Plant part	Size (nm) Shape	Application	References
	Cycas spp.	Leaf	2-6 spherical	Antimicrobial	37
	Pinus desiflora	Leaf	15-500 Spherical	Antimicrobial	38
	Abutilon indicum	Leaf	7-17 Spherical	Antibacterial	39
	Pistacia atlantica	Seed	10-50 Spherical	Antibacterial	40
	Ziziphora tenuior	Leaf	8-40 Spherical	Antibacterial	41
	Tephrosia purpurea	Leaf	20 Spherical	Antioxydant, Antibacterial	42
	Delphinium denudatum	Root	<85	Antibacterial	43
	Eucalyptus leucoxylon	Leaf	50	Antioydant	40
	Myrmecodia pendan	Leaf	10-20 Spherical	Promising therapeutic value , Antifungal	44
	Parthenium hysterophorous	Root	5-6 Spherical	Larvicidal activity	45
	Withania somnifera	Leaf	5-30 spherical	Antibacterial, antifungal	46
	Boerhaavia diffusa	Whole plant	25 spherical	antibacterial	47
	Plectranthus amboinicus	Leaf	20 Spherical	Antibacterial	42
	Lantana camara	Whole plant	48.1 Spherical	Antibacterial, antifungal	48
	Citrus limon	Whole plant	25 Spherical	antibacterial	49
	Couroupita guianensis	Leaf, fruit	10-45	Antibacterial, Stabilizing agent	50
	Viburnum lantana	Leaf	20-80 Spherical	Antibacterial	51
	Cocos nucifera	Water	70-80 Spherical	Metabolites and protein as a capping agent	52
	Tinospora cordifolia	Stem	60 Spherical	Antibacterial	53
	Aloe vera	Leaf	20 Spherical	Antibacterial	54
	Mangifera indica	Peel	7-27 Spherical	Antibacterial	55
	Artocarpus heterophyllus	Seed	3-25 Ireegular	Antioxidant	56

	Olea europaea	Leaf	20-25 Spherical	Antibacterial	57
	Lxora coccinea	Leaf	13-57 Spherical	-	58
	citrus sinensis	Whole plant	41-53 Irregular	Antibacterial	59
	Trianthema decendra	Whole plant	17.9-59.6 Irregular	Antibacterial	60
	Bambusa vulgaris	Leaf	13	Antibacterial	61
	Rumex hymenosepalus	Root	2-40 Spherical		62
	Wrightia tinctoria	Leaf	5-20.5 Spherical	Antibacterial	63
	codium captium	Weed	3-44	Antibacterial	64
	Elaeagnus indica	Leaf	30 Spherical	Antibacterial, Antifungal	65
	Azadirchata indica(neem)	Leaf	15-20 Spherical	Antibacterial, antioxidant	66
	Morinda citifolia	Leaf	10-60 Spherical	Antibacterial	67
	Terminalia chebula	Fruit	25		68
	Crossandra infundibuliformis	Leaf	38 Flake	Antibacterial	69
	Tribulus terrestris	Fruit	16-28 Spherical	Antibacterial	70
	Papavera somniferum	Leaf	3.2-7.6 Spherical		71

3 CHARACTERIZATION

The reduction of silver nitrate by the plant extract and formation of silver nanoparticles were primarily characterized by visual observation. The colour of the solution was changed from light brown to dark brown [2].

UV-Vis spectroscopy was utilized to analyse the silver nanoparticles, one of the most extensively used techniques for structural characterization of silver nanoparticles. UV Visible absorption spectrophotometer with a resolution of 1nm between 300 to 700 nm was used [83]. The function and composition of Ag nanoparticles were characterized by Fourier-Transform Infrared (FTIR) spectroscopy in the range 4000–280 cm^{-1}. X-ray diffraction (XRD) analysis utilizing an X-ray diffractometer was used to determine the crystalline nature of silver nanoparticles. For every molecule, the size, shape, lattice parameter determination, and phase fraction analysis of the unit cell can be calculated by XRD[84].

The net surface charge that nanoparticles have is related to the zeta potential. It is essential for figuring out the colloidal stability of charged particles and comprehending how well your system works under various circumstances. The size and size distribution of molecules and particles are typically measured in the submicron range, and with the most recent technology, down to less than 1nm, using the non-invasive, well-established technique known as dynamic light scattering (DLS), also known as quasi elastic light scattering (QELS)[102]. SEM and TEM investigations were used to track changes in the shape of the bacterial cell before and after treatment with silver nanoparticles. Observable changes in cell shape and perforation Several researchers have documented and exploited several researchers as an indication of AgNPs anti-bacterial activity[85].

Table 2: technique used for characterization of nanoparticles

Purpose	Technique used	Reference
Morphological characterization	SEM/ TEM, polarized optical microscopy (POM)	[5],[101]
Structural characterization	XRD, EDX, zeta size analyser, SEM/TEM, FTIR	[41]
Particle size analysis	SEM/TEM, atomic force microscopy, XRD, DLS, nanoparticle tracking analyser (NTA)	[38]
Optical characterization	UV-Vis Spectrophotometry, Photoluminescence, Diffusion Reflectance Spectroscopy(DRS)	[42]

Scanning electron microscope (SEM), Transmission electron microscopy (TEM), polarized optical microscopy (POM), X-ray diffraction (XRD), Energy dispersive X-ray analysis (EDX), Fourier transform infrared spectroscopy (FTIR) , Dynamic light scattering (DLS), nanoparticle tracking analyser (NTA), UV-Vis Spectrophotometry

4 APPLICATION

4.1 Anti-microbial activity

silver ions and nanoparticles are highly poisonous and harmful to microorganisms, as is well known. Because silver nanoparticles exhibit numerous inhibitory and bactericidal actions, their use as an anti-bacterial agent has been expanded. The anti-bacterial activity against human pathogenic bacteria such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Klebsiella pneumonia* can be tested using the standard well diffusion method and the usual disc diffusion method[14]. The zone of inhibition is used to determine the anti-bacterial activity of silver nanoparticles and can compare with the zone formation by several antibiotics[18]. By adhering to the cell surface, silver nanoparticles have been found to impact membrane permeability and respiratory function in various investigations. Another theory is that silver nanoparticles interact not only with the membrane's surface but also with the bacteria inside. Another finding explains why silver nanoparticles have a better anti-bacterial action against gram-negative bacteria than gram-positive bacteria, maybe due to the smallest AgNPs[86].

4.2 Anti-fungal activity

Fungal infections are very common in immunocompromised persons. It is difficult to treat all fungal infections due to the limited number of anti-fungal medications available. As a result, biocompatible, non-toxic, and environmentally friendly anti-fungal drugs are urgently needed[3]. Nano silver is a very powerful and fast-acting fungicide that works against various fungal species, including *Aspergillus spp.*, *Saccharomyces spp*., *Phoma lomerate*, *Candida herbarum*, *Fusarium semitectum*, *Trichoderma spp.*, *Candida albicans*, *Candida tropicolis*, *Candida glabrata*, *Candida krusei*, *Candida parapsilosis*, and *Candida mentagrophytes*[16]. Moreover, AgNPs were found to have anti-fungal action against *Alternaria alternata*, *Macrophomina phaseolina*, *Rhizoctonia solan*, *Sclerotinia sclerotium*, *Circularis lunata*, and *Bipolaris sorokiniana* in another investigation[12]. *Aspergillus fumigatus*, *Penicillium brevis ompactum*, *Chaetomium globous*, *Cladosporium cladosporoides*, *Mortierella alpina*, and *Stachybotrys chartarum* all can be suppressed by AgNPs[87].

4.3 Anticancer activity

Cancer is a serious life-threatening disease that affects one out of every three people at some point in their lives. Researchers must formulate nanomaterials with no adverse effects and precisely target the intended cells or tissues, which is both important and interesting. Anticancer actions have been found in both in vitro and in vivo model systems[7]. Furthermore, the effects of uracil phosphoribosyl enzyme (UPRT)-expressing cells and non-UPRT-expressing cells in the presence of fluorouracil on cell death, as well as the induction of apoptosis and sensitization of cancer cells by AgNPs, were investigated. Coated with starch, they displayed anticancer effects in healthy human lung fibroblast cells and glioblastoma cells[88]. The selective cell-specific toxicity of cancer cells in human lungs has been demonstrated using plant extract-mediated AgNPs production[11]. Anticancer drugs must be synthesized as soon as possible. AgNPs also have significant anticancer properties[89].

4.4 Wound dressings

Nanotechnology has substantially contributed to wound healing as improved anti-inflammatory and anti-bacterial. Activity is linked to wound healing[90]. Pore size, swelling index, non-toxicity or biocompatibility, biodegradation, and mechanical strength of AgNPs based bio composites are all important factors to consider when developing materials for wound-dressing applications. Burns, particularly severe burns, can cause significant skin damage. Such burns may result in a loss of bodily fluid as well as severe inflammation[24].

The toxicity and unfavourable effects of silver nanomaterials have been addressed in recent studies on the medicinal use of silver nanoparticles using medication delivery. Reduced mitochondrial function and induction of apoptosis are two concerns about the influence of silver nanoparticles on cell health, with the mitochondria being a sensitive target of AgNPs cytotoxicity[15]. While the mechanism of AgNPs toxicity is unknown, it is thought to involve surface binding of thiol-containing proteins, such as glutathione and key component enzymes of the cell's antioxidant system, which leads to an increase in reactive oxygen species (ROS) propagation, oxidative damage, and apoptosis, an involute programmed cell death pathway. Functionalizing metal nanoparticles with polyethylene glycol (PEG) radical, lipids, polymers, and minute peptides are some of the mechanisms used to improve biocompatibility. Using thiol-modified biomolecules on the surface of silver nanoparticles increased silver biocompatibility and intracellular uptake. With low toxicity, the phospholipid-protected silver nanoparticles were disseminated into 3T3 fibroblast cells and platelet cells[91].

4.5 Environment application

silver nanoparticles can be used to purify water to prevent environmental pollution [92]. Anti-bacterial silver nanoparticles have a wide range of applications, ranging from cleaning equipment and household appliances to water purification[93]. In our daily lives, silver nanoparticles are widely used. AgNPs and other designed NPs, have a wide range of commercial and industrial applications. Because of its unique physiochemical qualities, it's also been used in bioremediation and biomedicine[35]. The Fe_3O_4 attached Ag nanoparticles can be used to clean water and quickly removed using a magnetic field to avoid environmental pollution [94]. Because of its gradual and steady reactivity with serum and other physiological fluids, silver sulfadiazine promotes faster burn wound healing[95]. Sheets, washers, toothpaste, polluted water treatment, shampoo and textiles, food wrapping materials, food storage containers, water purifiers, odor-resistant socks and undergarments, room sprays, laundry detergents, and other products include AgNPs[10]. They are often used in the home to clean microorganisms from vacuum cleaners, refrigerators, air conditioners, laboratory coats, plastics, paints, and fabrics, among other items, as well as other medical applications such as bandages, Surgical gowns, wound dressings, feminine hygiene supplies, and bone grafts are just a few of the items available[15]. Its anti-microbial properties limited the growth rate of Gram-positive and Gram-negative bacteria due to its anti-microbial activity, which is significant for several drug-resistant pathogens[10]. Nano silver particles are also effective against various ordinary fungi, including Aspergillus fumigates, Mucor, Saccharomyces cerevisiae, and Candida tropicalis[96].

Antiviral properties of silver nanoparticles can be utilized to treat HIV, hepatitis B, and the Herpes simplex virus. NPs functionalized with certain biomolecules can effectively destroy cancer cells or microbes due to their high surface-to-volume ratio[97]. Because of its electrical conductivity, anti-bacterial action against a wide range of pathogens, and the influence of localized surface Plasmon resonance, AgNPs is widely employed[18]. As a wound treatment, silver nanoparticles comprising polyvinyl nanofibers show effective anti-bacterial properties[98].

4.6 Textile application

The antifungal properties of two silver-coated natural cotton fabric constructions created with a supercritical carbon dioxide ($scCO_2$) solvent were examined. Scanning electron microscopy has shown that cotton fabric textiles may be produced with uniform silver nanoparticle coatings using the $scCO_2$ method. Using a modified Kirby-Bauer disc diffusion test, these textiles' ability to inhibit fungal growth was assessed. Cotton fabric samples treated with Ag(hepta) and Ag(cod)(hfac) demonstrated quantifiable zones of inhibition. On the other hand, the uncoated cloth lacked an inhibitory zone[1].

4.7 Silver nanoparticles used as drug

Drug-resistant pathogenic bacteria are a serious concern for human health since it is difficult to manage them with currently available antibiotics. However, green synthesised AgNPs show antimicrobial activity. The shortcomings of commercial antibiotics can be solved by using green generated AgNPs. AgNPs produced during biosynthesis are well known for their antibacterial effectiveness against a variety of pathogenic pathogens. The limitations of commercial antibiotics were resolved in the current investigation by AgNPs[95].

4.8 Agriculture application

In general, the synthesis of NPs is of tremendous interest because of the special features that can be incorporated into composite fibres, biosensor materials, cryogenic super-conducting materials, cosmetic items, and electrical components. The synthesis of AuNPs and AgNPs from plant extracts, and even more so from agricultural wastes, is an important topic for supporting sustainable development in agro-industrial labours, though, due to climate change and the depletion of natural resources. Due to their low toxicity, the generated NPs can be used in numerous agroindustry-related activities, from the application in the soil to the food chain, since plants constitute the cornerstone of this green synthesis. Regarding the direct usage of AuNPs and AgNPs in agriculture, numerous studies in this area have concentrated on seed germination, root extension, and plant reactions to the presence of metal NPs, such as cellular oxidative stress or cytotoxicity[101].

4.9 Silver nanoparticle as electron transfer

High intensity electron transport is a property of silver nanoparticles. They can make it easier for an electron to move from a protein's redox centre to the electrode surface since proteins are large, bulky molecules. In this study, silver nanoparticles were placed in the 1 V potential area on the surface of a graphite carbon electrode. Transmission electron microscopy was used to detect the deposition of silver nanoparticles with a diameter of between 70 and 150 nm on the graphite electrode (TEM)[1].

5 Future perspective

silver nanoparticles can be used in magnetic disinfection systems to treat waterborne diseases, a new development due to their different robust capabilities as powerful disinfectants for preventing microbiological infections. Using silver nanoparticles as a sorbent sand driving force for eliminating ecological contaminants is effective. Surfaces, instruments in kindergartens and schools, various types of equipment, and computers might benefit from nano silver-based disinfection solutions, which could lead to nano silver-based consumer items in the future. Silver-based nanocomposites have the potential to be environmentally friendly, and they could be used to generate new products. Few studies have been published on the parameters that drive or are accountable for metal nanoparticle production[24]. Microbes have been employed to synthesize nanoparticles for several decades. Using microorganisms to synthesize nanoparticles is well recognized as a significantly slower process than physical or chemical approaches. Microorganisms are still only used in the laboratory for synthesis. Efforts should be made to investigate the use of microbes in nanoparticle manufacturing[99]. Nanoparticles have already been used in medical applications such as wound infection, dressing, and preclinical treatment. Unanswered questions include the exact mechanism of silver nanoparticles' interaction with bacterial cells, how the surface area of nanoparticles affects their killing activity, the use of animal models and clinical studies to better understand the anti-microbial efficiency of silver dressings, and the toxicity of silver dressings, if any, and so on[100].

6 CONCLUSION

Various plants are used to manufacture silver nanoparticles (AgNPs), according to the findings of this study, which includes a simple, environmentally friendly, and useful way to make silver nanoparticles without using the toxic component at room temperature. Silver nanoparticles made in the green have special uses that greatly enhance nanotechnology. Since employing plants instead of other biological agents can avoid the time-consuming procedure of using microorganisms and maintaining their culture, which can diminish the potential for the synthesis of nanoparticles, doing so can be beneficial for the synthesis of nanoparticles. As a result, using plant extract for synthesis has the potential to make a significant impact in the years to come. Again, in the bacteria studied, biosynthesized silver nanoparticles show a high anti-microbial effect. It's a straight forward, low-cost, the eco-friendly and rapid method. Chemical and physical approaches are more challenging than the biosynthetic method. In agricultural biotechnology, nanoparticle solutions with distinct nanoparticle ranges had various application modes for disease preparation. AgNPs are excellent at treating infectious diseases and can even target specific locations, such as hard-to-reach areas where germs can hide. When these pathogens are treated with AgNPs, the AgNPs penetrates the cell wall, interfering with essential cellular biochemistry non-specifically. Infectious infections were also fought with AgNPs biopolymer composites.

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