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Green-Silver Nanoparticle Synthesis Using Different Plant Extracts for Various Applications

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ABSTRACT

Silver nanoparticles (AgNPs) serve as antibacterial agents in medicine. Silver nanoparticles, which vary in size from 1 to 100 nm, are frequently employed in industrial applications like photonics, electronics, and catalysis because of their distinctive optical, electrical, and magnetic properties. In addition, they can be utilized as composite fibers, antimicrobial agents, biosensor fabrics, cosmetics, electronic components, and to increase the shelf life of food items. During the previous few decades, one of the most well-liked research topics has been silver nanoparticles (AgNPs). AgNPs have several uses, particularly in the fields of agriculture and medicine, where they are employed as antioxidants, antibacterials, and antifungals. Their value is in their ability to be designed using various synthetic methods depending on their intended use and desired qualities. Recent advances in nanoscience and nanotechnology have profoundly changed how we detect, manage, and prevent a broad spectrum of diseases in all spheres of human existence. AgNPs, or silver nanoparticles, are one of the most significant and fascinating metallic nanoparticles that are used in biomedical applications. AgNPs are important in the domains of nanoscience and nanotechnology, particularly in nanomedicine. While different metallic compounds have been used for various purposes, AgNPs have drawn interest due to their use in cancer diagnostics and treatment.

INTRODUCTION

Globally, there is a rapid increase in nanotechnology research and development. The development and training of materials with special properties arising from their nanoscale dimension properties is known as nanotechnology. Numerous industries, including computing, materials science, energy, and medicine, have benefited from the use of nanotechnology. It is employed in the creation of novel materials and goods like medical implants, drug delivery systems, and sensors. Additionally, it is utilized to enhance already-existing products, like boosting solar cell and battery efficiency. Over the past few years, nanotechnology has become more significant in the domains of health and medicine. (1)

Particles of diameters ranging from 1 to 100 nanometers, or nm, are known as nanoparticles (NPs). Their unique physical, biological, and chemical characteristics set them apart from larger particles.

Medical applications have been made of nanoparticles, including such as tissue engineering, cancer therapy, medication delivery systems, and diagnosis. The properties of nanoparticles given its special qualities, silver (Ag), a noble metal, may find use in medicine. (2)

Many methods can be used to manufacture SNPs, including chemical vapor deposition, microwave, thermal process, sol-gel method, chemical precipitation, as well as the reverse micelle method in accordance with biological methods, etc. But biological Techniques that are inexpensive, environmentally friendly, and don't involve harmful chemicals are favored. Green synthesis is a faster process than previous biological synthesis methods for producing nanoparticles. SNP production employs a variety of plants with medicinal properties for biological and pharmacological applications. (3)

Since nanoparticles have special properties, like a high area of surface relative to volume proportion and magnetic, mechanical, optical, and chemical today is nanotechnology One of the most fascinating, expansive, and promising fields of study. [4]

The term "Nanotechnology" refers to the process of controlling shape and size at the nanoscale for the purpose of manufacturing, preparing, manipulating, and applying structures. The most active area of study in the material sciences is nanotechnology, and the production of nanoparticles (NPs) is expanding rapidly on a global scale. NPs exhibit entirely new or enhanced characteristics depending on certain attributes such as size (1–100 nm), shape, and structure. NPs exist in two main categories: inorganic and organic. [5]

- **Organic Nanoparticle**:-

E.g. Carbon nanotubes, fullerenes, and quantum dots are examples of organic NPs.

- **Inorganic Nanoparticles-**

E.g. metallic NPs (such as Au, Ag, Cu, and Al), magnetic NPs (such as Co, Fe, and Ni), and semi-conductor NPs (such as ZnO, ZnS, and CdS).

Noble metal nanoparticles, such as gold and silver are becoming more and more popular because they offer excellent properties and practical flexibility. Due to their possible uses in catalysis, Ag-NP formation has attracted a lot of attention. Living things incorporate wet, dry, and computerized forms of nanotechnology. Wet nanotechnology incorporates biological agents such as membranes and organs, as well as enzymes. The synthesis of inorganic materials, such as carbon and silicon, as well as the investigation of surfaces and their chemical and physical characteristics, represent dry nanotechnology. The modeling and simulation of complex nanoscale structures is a component of computational nanotechnology. [6]

Green Synthesis:

Green nanoparticle synthesis is a unique and ecologically friendly method of producing nanoparticles. This process produces biocompatible and non-toxic nanoparticles while lowering the environmental effect of nanoparticle production by employing natural resources, including fruits, vegetables, and microbes, as stabilizing and reducing agents. Green nanoparticle synthesis is anticipated to be essential to the creation of novel materials and technologies, given the growing consumer demand for ecologically friendly and sustainable products. [7]

Metallic nanoparticles can be created in an in an environmentally friendly way by using a process called "green synthesis." It also poses less of a threat to the environment and people. [12] Some plants and extracts, such as Ficus ben ghalensis, Solanum tuberosum, Andrographis echioides, Alcea, J. glauca, Ocimum gratissimum, Morus alba, Nigella sativa, Corchorus capsulitis, Coffee Arabica, and Artemisia vulgaris, can be produced in an environmentally benign way to produce silver nanoparticles. Due to their antibiotic resistance and ability to be synthesized using a variety of materials and techniques, silver nanoparticles have attracted a lot of interest for use as antibiotics. (8)

Significance of the green silver nanoparticles:

One of the main drawbacks that affect the environment and public health is the use of hazardous chemicals and toxic solvents in conventional nanoparticle manufacturing techniques. Green synthesis is a cutting-edge method for creating nanoparticles from natural resources like microorganisms, fruits, and plants as stabilizing and reducing components. This process produces non-toxic, biocompatible nanoparticles while simultaneously reducing the environmental impact of nanoparticle production. [1]

There are various benefits to using natural materials in green synthesis as opposed to conventional synthetic techniques. Natural materials, for instance, are frequently less hazardous and environmentally sustainable, making the process safer for people's health as well as the environment. Furthermore, employing organic materials can also result in Particular characteristics of nanoparticles, like reduced toxicity and enhanced biocompatibility, make them beneficial for a range of biological uses. (1, 4)

Approaches of Nanoparticle Production:

There are currently three categories for man-made methods of producing AgNPs chemical, biological, and physical. The physical and chemical synthesis of AgNPs appears to be more time-consuming and riskier, even though the biological production of AgNPs exhibits positive properties such as high yield, solubility, and stability. Metallic nanoparticles can be produced by two different processes. (9)

1. The top-down approach method.
2. A bottom-up method.

Nanoparticles are manufactured by using the top-bottom method which involves the use of mechanical/ball rolling, electrochemical etching, thermal/laser burning, sputtering, evaporating vaporization, and air discharge.

The second approach bottom-top method needs to begin with atoms or molecules. Physical methods for producing nanoparticles include the evaporation-condensation process in a tubular furnace at atmospheric pressure; other methods include chemical-based, precipitating, vapor depositing, atomic/molecular condensation, sol-gel method process, and spray/laser/aerosol pyrolysis. Physical methods have the advantages of being quick, using irradiation as an antioxidant, and not requiring any dangerous chemicals. On the other hand, the drawbacks include low output, excessive power usage, contaminated solvents, and difficulty achieving uniform dispersion. Three categories apply to the methods of chemical synthesis: pyrolysis, electrochemical and chemical reduction. [(6)]

Biosynthesis of nanoparticles:

Applications such as biological metal recovery, biological remediation, bio leaching, and biomineralization involve the collaboration of metal ions or ore inside biological systems. Nowadays, nanoparticle preparation uses biomineralization to its advantage. When the biological system was subjected to lower levels of metal concentration, all of the previously described mechanisms were successful; higher levels of metal concentration led to toxicity. Microorganisms can interact with metal ions through different means, such as altering their redox state, precipitating or complexing extracellularly, reducing the metal ion intracellularly by α-NADH-dependent nitrate reductase, or because they lack a particular metal transport mechanism and flow forth. Nanoparticle biosynthesis can be accomplished by extracellular or intracellular mechanisms. Nanoparticles are synthesized intracellularly using biomass. The process of producing nanoparticles through extracellular synthesis involves using biomass-produced extracellular polysaccharides (EPS) to reduce noble metal ions. [(9)]

Ag-NP Synthesis Using Fungi:

Fungi provide a straightforward and dependable way for synthesizing AgNPs. AgNPs that are both intracellular and extracellular can be produced via fungi-mediated synthesis using cell walls and fungal cell-free filtrate, depending on where the nanoparticles are located. Because of the benefits of easy collection and post-synthesis processing, fungal extracellular production of AgNPs is preferred over intracellular synthesis. Due to their unique abilities for metals accumulation, high tolerance in metal-rich settings, quick mycelial development, release of various enzymes outside the cell, and economic viability, fungi are widely employed in the manufacture of AgNPs.[(10-14)], such as Fusarium oxysporum [(15)] Trichoderma harzianum [(16)], Penicillium polonicum [(18)], Phomopsis liquidambaris [(19)]. Certain fungi, including fungus oxysporum [(10)], are believed to be potentially harmful, which means that using them in the future could put your health at risk. While unnecessary fungal components can be removed by rinsing or precipitating the AgNPs produced extracellularly using the fungal extract. The production of AgNPs involves a number of organic components found in fungi, including nitrate-dependent reducer, xylanases (20), naphthoquinones, anthraquinones, and quinine derivatives of these compounds, which reduce silver precursor. Furthermore, shape-controlled AgNPs can be produced by using some specific proteins that fungus release as capping agents.[21] Different incubation circumstances, including temperature, light source, and different kinds of nitrogen and carbon supplies, may affect the properties of AgNPs. [22] In summary, fungal synthesis of AgNPs is a biological process that is feasible, effective, affordable, and energy-efficient. To achieve safe goods, it is advisable to take into account the reduction of possible microorganisms on the outermost layer of AgNPs.

Ag-NP Synthesis Using Bacteria:

Although microorganisms like molds, bacteria, and yeast are very interested in NP synthesis, the process is in danger due to protracted methods, inadequate regulation of NP size, and contamination of cultivating media. The site of synthesis determines which kinds of NPs produced by microbes can be divided into. Actinobacteria Rhodococcussp and Bacillus subtillus extracellular were used to synthesize AgNPs intracellularly. [22-24]

Ag-NP Synthesis Using Plants:

Nowadays, plant-mediated production of AgNPs has generated a lot of attention as a potentially effective method. Extracts from a range of plant parts, including as barking, peels, calluses, foliage, fruit, flowers, stems, seeds, and rhizomes, are used to create AgNPs in different sizes and forms. These extracts from different portions of plants contain organic elements such as oils, terpenoids, phenolic compounds, alcoholic beverages, flavonoids, alkaloids, quinines, and oils.[25,26] Many functional groups, including amidogen, hydroxyl, which and carbonyl, are present in these organic components and could help convert Ag+ to Ag0. Plant extracts such as the aforementioned components, together with a variety of plant derivative including cellulose, starch, chitin, dextran, along with alginates, serve as both reducing agents and stabilizers simultaneously.[27] Various reaction factors, including temperature, reaction duration, pH, and quantity of extracts from plants and precursors, impact the synthesis of AgNPs through plant-mediated means.[28] By adjusting the synthesis settings, AgNPs with varying sizes and shapes can be produced. In conclusion, a range of reaction circumstances can regulate the synthesis of AgNPs by plants. Furthermore, several plant sections demonstrate varying capacities for AgNP production. To understand the biological processes behind plants' production of AgNPs, more research is required. In conclusion, plant-mediated synthesis of AgNPs using plant extract is a feasible method due to its affordability, non-toxicity, simplicity, cost-effectiveness, and great reduction potential.[30]

Characterization techniques of nanoparticle:

After green nanoparticle creation, characterization is an essential step that enables the identification of the particles according to their physical characteristics such as size, shape, surface area, and dispersion. Nanomaterials can be characterized using a range of techniques, some of which are given below.

The activity, biodistribution, safety, and effectiveness of nanoparticles are influenced by their physicochemical characteristics. Among the analytical methods used for characterization are X-ray diffusion (X-ray), Fourier transformation infrared spectrum (FTIR imaging), X-ray photoelectron spectrum (XPS techniques), dynamically scattered light (DLS), scanning electron microscopy, (electron microscopy), transmission electron microscope (TEM), and nuclear force microscopy. [31]

1. **UV-Vis spectrophotometer**:

Metallic nanoparticles can be recognized, described, and examined with this equipment. Light wavelengths between 200 and 800 nm are typically used to define the size range of 2-100 nm.[32] One very useful and reliable technique for the initial characterization of manufactured nanomaterials is UV-Vis spectroscopy. AgNP synthesis and stability are also visible. It is a simple, quick, and delicate operation. [33]

2. **Dynamic light dispersion (DLS):**

This method evaluates the surface charge, size distribution, and quality of nanoparticles. It's also quite helpful to know the polydispersity index of the produced nanoparticles. The non-destructive DLS method can be used to ascertain the dimensions and shape dispersion of elements in physiologically or aqueous solutions. It depends on the way light and particles interact. It is possible to measure narrow particle size distributions, ranging from 2 to 500 nm.

It monitors scattered light from a laser traveling through a colloid and functions on the basis of Rayleigh scattering generated by suspended nanoparticles. [33]

3. Zeta potential measurement:

The zeta potential of the manufactured nanomaterial determines its stability; the more stable the sample, the greater the zeta potential value. According to electron transmission microscopy (TEM), dynamically scattered light (DLS), and potential zeta study, the Ag NPs have a mean hydrodynamic size of 20 nm and a zeta potential of −11:37 ± 0:04 mV, indicating that they are extremely stable within the colloidal solution.(34)

4. X-ray diffraction (XRD):

X-ray diffraction (XRD) is used to characterize the crystal structure of the nanoparticles and identify their phases by examining the overall oxidation state of the particles over time. Each crystalline substance can be identified and its crystallinity evaluated using a unique X-ray diffraction (XRD) pattern. This is a non-destructive procedure. [34]

5. Transmission Electron Microscopy (TEM):

TEM is one of the most important and commonly used methods for characterizing particles. With the use of this TEM technique, we can ascertain the quantitative aspects of the size of particles, the distribution of particle size, and the morphological features of particles. The magnification of the TEM will depend on the separation between the objective's lens and the specimen, as well as between the objective lens and the image plane. When it comes to analysis and resolution, TEM is better than SEM. [35]

Conclusions:

In summary, it is concluded that during the last decade many efforts have been made for the development of green synthesis. Green synthesis gives headway over chemical and physical methods as it is cost-effective, eco-accommodating and effectively scaled up for large-scale synthesis. Nature has exquisite and inventive methods for making the most competent miniaturized functional materials. An increasing awareness towards green chemistry and utilization of green route for production of metal NPs, especially Ag-NPs led a desire to develop eco-friendly methods. Organisms ranging from straightforward bacteria to highly complex eukaryotes can be utilized for the synthesis of NPs with desired size and shape.

However, the development of the micro-organisms and vast scale formulation residue are tricky compared with others. For the production of Ag-NPs using plants can be advantages over other biological entities which can overcome the slow route of using microorganisms and sustain their culture which can lose their potential towards the production of NPs. Other advantages of synthesis from plant extracts are provision of hygienic working environment, health and environment shielding, lesser wastages and most stable products. Ag-NPs have emerged in present and future era, with a variety of applications incorporating cardiovascular implants, dentistry, medicine, therapeutics, biosensors, agriculture, and many more.

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