Reviewing the Green Synthesis and Antimicrobial Activity of Silver Nanoparticles

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Abstract

Nanotechnology is an area of modern physics that is constantly evolving, with nanoparticles (NPs) being a key focus due to their miniature size of 1-100 nm. This field is having a significant impact on various areas of human life, particularly in biotechnology and biomedical science. NPs are widely produced worldwide and used in a diverse range of applications. The process of plant-mediated synthesis of nanoparticles connects nanotechnology with plants, making it a green chemistry approach. The eco-friendly and cost-effective production of silver nanoparticles (AgNPs) using medicinal plants is a prime example. AgNPs possess unique physio-chemical properties that make them ideal for various applications such as antimicrobial activities. They have been discovered to have potent inhibitory and antibacterial effects, which make them useful against microbes and parasites. In this review study, the role of AgNPs in antibacterial activity and their potency against microorganisms are examined.

Keywords: Nanotechnology, green chemistry, nanomaterial, silver nanoparticles, antimicrobial

I. INTRODUCTION

The field of "Nanobiotechnology" involves the utilization of nanotechnology in the life sciences, including the investigation of nanomaterials for their potential impacts on health and the environment. This interdisciplinary area encompasses bionanotechnology, nano-biotechnology, and nano biology, which are all related to the interface between nanotechnology and biology. A crucial component of this field are nanoparticles, which are collections of atoms with sizes between 1 and 100 nm. The term "nano" comes from the Greek word meaning "dwarf," referring to their extremely small size. Nanobiotechnology involves merging biological research with various nanotechnological fields.

Biologically inspired nanotechnology takes inspiration from biological systems to create novel technologies. The primary objectives of nanobiotechnology are to apply nanotools to relevant medical and biological issues and improve upon these applications. This capability was first proposed by physicist Richard Feynman as early as 1959. The National Nanotechnology Initiative and the National Science Foundation define nanotechnology as the science and engineering of understanding, manipulating, and controlling matter at the scale of individual atoms and molecules. Applications for nanocrystalline particles include highly sensitive biomolecular identification and diagnostics, anti-microbial and therapeutic agents, catalysis, and microelectronics. (Krishnaveni and Priya, 2014;

Sridhara et al., 2012; Veera et al., 2012).

The goal of green chemistry, also known as environmentally friendly chemistry or sustainable chemistry, is to create chemical goods and procedures that drastically reduce or totally stop the usage and manufacture of toxic compounds. Paul Anastas and John Warner, two chemists, claim that this is the definition of "green chemistry" that is most commonly used. The green production of nanoparticles has drawn a lot of attention in recent years. The creation of nanoparticles can be accomplished in a number of ways, including a decrease in answer, photochemical and chemical actions in change micelles, thermal decomposition of nanoparticle substances (Akl Awwad and Nida Salem, 2012), radiation-assisted processes, electrochemical reactions, microwave-assisted processes, and, most recently, green chemistry (Ravindra et al., 2012).

The use of environmentally friendly materials offers numerous benefits such as reduced energy consumption and operating conditions that are not too extreme (for example, pressure and temperature), without the need for any hazardous substances. (Mie et al., 2014)

Silver nanoparticles, which are a member of the noble metal NP family, are frequently utilised in a wide range of goods, including toothpaste, shampoo, soap, detergent, and laundry liquid. They consequently come into interaction with human beings up close. (Bhattacharya and Mukherjee, 2008), (Bhumkar et al., 2007)

Using natural materials like green tea (Camellia sinensis), neem (Azadirachta indica), leguminous shrubs (Sesbania drummondii), different aloe vera plant extract, leaf broths, starch, natural rubber, lemongrass leaves extract, and other products, researchers have recently been successful in producing silver nanoparticles (Vijayaraghavan et al., 2012). However, due to the lack of widespread industrial adoption of novel approaches, the area of nanobiotechnology is still in its early phases of growth. It is crucial to create a technologically advanced, economically viable, commercially viable, and ecologically sustainable synthesis process in order to address the rising demand for silver nanoparticles across a number of industries. (Benerjee et al., 2014).

II. OBJECTIVE OF THE STUDY

This research paper aims to examine the antibacterial capabilities of medicinal plants used in the production of silver nanoparticles (AgNPs) utilising green chemistry techniques. Reviewing AgNPs' function in antimicrobial function and their effectiveness against bacteria is the goal of the study. The study discusses the importance of nanotechnology in biotechnology and biomedical science and explores the interdisciplinary field of nanobiotechnology, which focuses on the application of nanotools in medical and biological issues. The study also examines the benefits of using environmentally friendly materials in the production of nanoparticles and highlights the need to develop an economically viable, commercially feasible, and environmentally sustainable synthesis route using modern technologies.

III. REVIEW OF LITERATURE

The green production of silver nanoparticles (AgNPs) and their antibacterial activity are covered in this review paper. Because of their tiny size of 1-100 nm, NPs are an important focus in the rapidly developing field of nanotechnology. The creation of nanoparticles using plant-mediated synthesis links nanotechnology and plants, making it a green chemistry strategy. AgNPs are made from environmentally sustainable, economically viable medicinal plants. AgNPs have special physio-chemical characteristics that make them perfect for a variety of uses, including antibacterial activity. The review study examines the role of AgNPs in antibacterial activity and their potency against microorganisms. The field of nanobiotechnology involves the utilization of nanotechnology in the life sciences, including the investigation of nanomaterials for their potential impacts on health and the environment. The interdisciplinary area encompasses bionanotechnology, nano-biotechnology, and nano biology, which are all related to the interface between nanotechnology and biology. The significance of green chemistry, its processes for creating nanoparticles, and the utilisation of eco-friendly resources are also covered in this essay. Additionally highlighted is the usage of silver nanoparticles in numerous products, including pharmaceutical and medical ones. The paper concludes by giving a general review of the significance of AgNPs produced through green synthesis as well as some prospective uses for them in biotechnology and biomedical research, particularly in the field of antibacterial activity.

IV. WHY NANOPARTICLES?

Nanoparticles are made up of one dimension that is 100 nanometers or smaller. When created from nanoparticles, the characteristics of many conventional materials change. This is frequently due to the fact that larger particles lack the amount of area per weight that nanoparticles possess, making particular molecules more reactive to them.

Nanomaterials have a very high surface area to volume ratio as a result of their small size, which causes a significant portion of the atoms in the material to be surface or interfacial atoms. This causes the characteristics of the material to be more "surface" dependent.

The majority of materials are single crystals when their size is decreased to the nanoscale. Elastic moduli have been demonstrated to drastically decrease in metallic nanocrystalline materials. However, it has been discovered that the properties of the lattice could not be the same as in bulk materials, even while some nanomaterials with a little higher atom count (>50–60 atoms) may obtain bulk crystalline solids.Other characteristics of nanoparticles include:

1. Colour: Red nanoparticles made of grey silicon and yellow gold are present.

2. Silver nanoparticles dissolve at substantially lower temperatures than silver slabs (1064 °C), at about 115 °C for 2.5 nm size.

3. Compared to thin films that consist of ongoing sheets of bulk material, the absorption of the sun's rays in photovoltaic panels is substantially higher in nanoparticles because of their smaller size.

V. SILVER NANOPARTICLES

Silver nanoparticles are used in a variety of goods, from photovoltaic cells to biological and chemical detectors, because of their distinctive optical, electrical power, and thermal capabilities. Due to their exceptional conductivity, electrical balance, and low sintering temperatures, silver nanoparticles are used as an example in conductive inks, pastes, and fillers. According to Pathak and Hendre (2015), one important area of nanotechnology is the development of "green synthesis," in which biological materials such as microorganisms, plant extracts, or plant biomass are used in place of chemical and physical processes to produce AgNPs. Utilising a variety of chemical and biological methods, AgNPs are created, allowing researchers to control their size and structure.

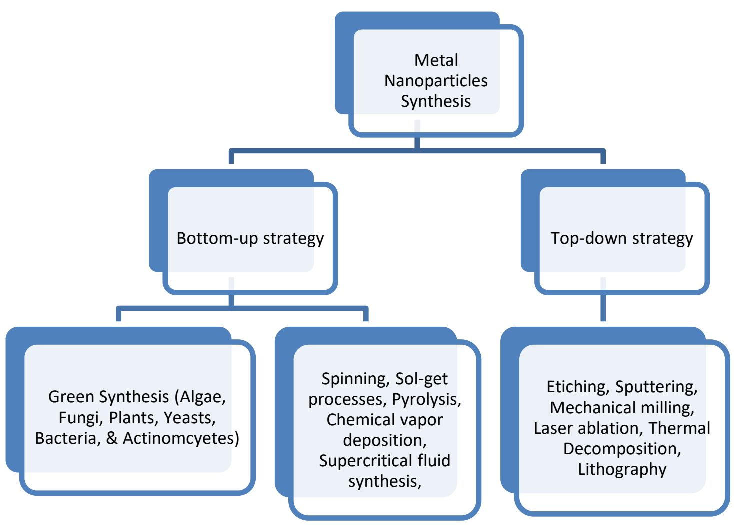
Due to its significant applications in antibacterial, catalysis, and surface-enhanced Raman scattering, silver nanoparticles have drawn intense scientific interest (Gokulkrishnan et al., 2012). A nanoparticle is an essential scientific instrument which has been and is still being investigated for use in a variety of microbiological, pharmaceutical, and pure technological applications. They serve as a bridge between atomic or molecular molecules and bulk materials. Because of their unusually enormous surface area, nanoparticles outweigh the modest bulk of the material's contributions.

In order to create silver nanoparticles, two alternative methods are used:

(1) A top-down strategy

(2) A bottom-up strategy.

In the top-down strategy, the Ag metals will be dissolved in a solvent and reduced to create the AgNPs, with the addition of a reducing agent to reduce the likelihood of nanoparticle accumulation. In the top-down approach, the size of the Ag metals will be reduced to create the nanomaterials using lithography and laser ablation. AgNPs are produced using a variety of processes, such as the use of reducing representatives, electrochemical procedures, physio-chemical reduction, and radiolysis, which are all considered chemical approaches.



Silver nanoparticles break down quickly, releasing ionic silver that interacts with crucial thiol groups to inactivate critical bacterial enzymes. According to Parveen et al. (2012), silver ions can harm bacterial cytoplasm membranes, prevent the replication of bacterial DNA, deplete intracellular adenosine triphosphate (ATP), and ultimately result in cell death. Due to the emergence of resistant strains, bacteria are becoming more resistant to antibiotics and bactericides when exposed to silver nanoparticles. Many people are interested in figuring out how to create new kinds of safe and affordable biocidal materials because some antibacterial activities of agents are exceedingly harmful and irritating (Dhrutika et al., 2013). Green synthesis techniques are becoming more important because the reducing chemicals used to create silver nanoparticles are frequently regarded as harmful or dangerous (Panacek et al., 2006).

More significant uses for silver nanoparticles include their use as optical receptors for biolabeling as well as discriminating covering for lunar energy absorption. The abundance of sulfur-containing proteins in bacterial cell membranes interacts with silver nanoparticles both outside and inside the cell membrane, affecting the survival of the bacteria and increasing the permeability of the cell membrane (Sharma et al., 2015).

VI. NEED FOR GREEN SYNTHESIS

Green synthesis is a method that is safe for the environment and uses no harmful chemicals (Logeswari et al., 2013). It is a ground-breaking technology that ushers in a new age by revealing plants' potential to synthesise stable NPs, lengthening their shelf lives, and overcoming the drawbacks of chemical and physical procedures (Kavitha et al., 2013; Malik et al., 2014). Compared to traditional methods, it is a quicker and more reliable methodology that scales up the synthesis of economically useful NPs with minimal or no toxicity. As a result, plants are used in the synthesis of NPs because they actively take up and decrease metal ions, which allows for the production of complex metal NPs (Singh et al., 2014; Gardea-Torresdey et al., 2002).

Economic efficiency, environmental friendliness, simple scaling up for large-scale synthesis, absence of need for high pressure, and ease of scaling up are the benefits of green synthesis over physical and chemical approaches. (2012) Ravindra et al. energy, heat, and dangerous substances.

To create green nanoparticles, reagents that are non-toxic and safe for the environment are used. In order to extract a metal from biomass and make money, Lamb et al. (2001) defined phyto mining as the use of hyper-accumulating plants. Green synthesis techniques offer advantages over traditional ones that use chemicals with environmental toxicity, such as mixed valence polyoxometalates, polysaccharides, Tollens, and biological, and irradiation processes.

VII. PARTS OF THE PLANTS THAT CAN BE USED FOR THE SYNTHESIS OF NANOPARTICLES:

The nanomaterial that intervenes with plants has recently drawn more attention because of its extensive usage in many different industries and unique physicochemical properties. Only after being created from natural resources have the numerous metallic nanoparticles, including magnetite, gold, platinum, zinc, copper, nickel, titanium oxide, and silver, been studied (Dhuper et al., 2012). In the biological manufacture of metallic nanoparticles of various shapes and sizes, a variety of plant parts, including the seed, stem, fruit, callus, root, peel, flower, and leaves, are utilised.

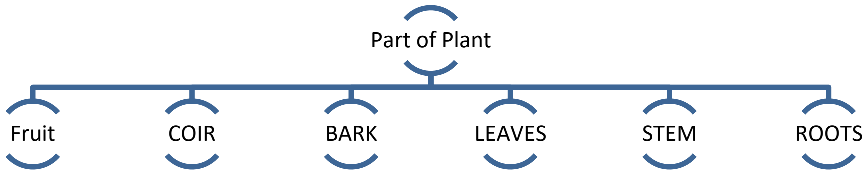


Table-1 Plant part used for the synthesis of silver nanoparticles.

S. No.	Natural Resource	Part used	Size [nm]	Shape	References
1	*Alternanthera sessilis*	Whole	40	Spherical	Niraimathi *et al.*, 2012
2	*Andrographis paniculata*	Leaves	67–88	Spherical	Suriyakalaa *et al.*, 2013
3.	*A. mexicana*	Leaves	20–50	Spherical	Singh *et al.*, 2010
4.	*Boswellia serrata*	Gum	7–10	Spherical	Kora *et al.*, 2012
5.	*Carica papaya*	Fruit	15	Spherical	Jain *et al.*, 2009
6.	*Cinnamon zeylanicum*	Leaves	45	Spherical	Sathishkumar *et al.*, 2009
7.	*Citrullus colocynthis*	Calli	5–70	Triangle	Satyavani *et al.*, 2011
8.	*Citrus sinensis*	Peel	35	Spherical	Kaviya *et al.*, 2011
9.	*Dillenia indica*	Fruit	11–24	Spherical	Singh *et al.*, 2013
10.	*Dioscorea bulbifera*	tuber	8–20	Rod, triangular	Ghosh *et al.*, 2012
11.	*Euphorbia prostrata*	Leaves	52	Rod, spherical	Zahir *and* Rahuman 2012
12.	*Gelsemium sempervirens*	whole	112	Spherical	Das *et al.*,2011
13	*H. canadensis*	Whole	113	Spherical	Das *et al.*,2011
14.	*Tinospora cordifolia*	Leaves	34	Spherical	Jayaseelan *et al.*, 2011
15.	*Calotropis gigantea*	Leaves	40-50	Spherical	Joshi *et al.*, 2017
16.	*Ocimum tenuiflorum*	Leaves	28	Irregular	Logeswari *et al.*, 2015
17.	*Azadirachta indica*	Leaves	34	Spherical	Ahmed *et al.*, 2015
18.	*Caesalpinia gilliesii*	Leaves	3-6	Spherical	Emam *et al.*, 2017
19.	*Citrullus lanatus*	Fruit Rind	17	Spherical	Ndikau *et al.*, 2017
20.	*Coriandrum sativum*	Leaves	6.45	Spherical	Khan *et al.*, 2018

VII. ANTI-MICROBIAL PROPERTIES OF SILVER NANOPARTICLES:

Over the course of human development, silver metal has generally been used for a variety of reasons. Silver is used by many social orders as elegant silverware, ornaments, and gems. A well-known antibacterial agent, silver is effective against more than 650 different types of microorganisms, including gram-positive and gram-negative bacteria, fungi, and viruses. Recently, silver nanoparticles made from the metal have been used (Ahmed et al., 2016). Silver has been mentioned as a potential treatment agent for numerous ailments in the traditional Indian medical system (known as Ayurveda).

In the bacterial system, the nanoparticles' reciprocal action disrupts the cell membrane and interferes with the process of protein synthesis (Sondi and Sondi, 2004). Bacterial cell walls are ruptured as silver nanoparticle concentrations rise because they have a quicker rate of membrane permeability than lower concentrations (Kasthuri et al., 2009).

Kim et al. (2007) claims that interactions among bacteria and metallic silver and gold nanoparticles interfere with cell cycle events by engaging with the active region of the cell membrane. When silver nanoparticles are used, the surface area that bacteria can contact increases significantly compared to when silver nitrate is typically used to have an antibacterial effect.

Silver nanoparticles must first adhere to the bacterial cell wall and then enter it in order to alter the structure of the cell membrane, leading to increased cell membrane permeability and cell death. "Pits" also develop on the cell surface in addition to the accumulation of nanoparticles. Studies utilising electron spin resonance spectroscopy have shown that the interaction of silver nanoparticles with bacteria results in the production of free radicals. According to Danilcauk et al. (2006), these free radicals have the capacity to erode cell membranes and make them permeable, which may ultimately lead to cell death.

The possibility that the nanoparticles release silver ions has also been raised (Feng et al., 2008). These nanoparticles' impact on the cell may trigger a reaction that leads to cell death. The fact that phosphorus and sulphur make up a significant component of DNA is another reality. Nanoparticles may interact with these soft bases and disrupt DNA, which would undoubtedly cause cell death (Morones et al., 2005). It was shown that the nanoparticles dephosphorylate the tyrosine residues in the peptide substrates, which prevents signal transduction and halts proliferation. However, it is crucial to emphasise that additional research on the topic is required to completely substantiate the claims (Hatchell and Henry, 1996).

The multifunctional AgNPs effectively halt fungal growth and show promising results against spore-producing fungi. Significant modifications to the fungus cell membrane structure were made employing metallic nanoparticles (Gardea-Terresdey et al., 2002).

1. Size and the environmental (size, pH, ionic strength)

2. Capping agent

VIII. CONCLUSION

- The nanomaterials have incredibly tiny dimensions.
- Based on the production process and the properties of the particles, the nanoparticles can be various types.
- Nanomaterials are now being used more and more in disciplines including biology, electronics, and many others.
- The choice of nanomaterials was made for their greater surface area and smaller size.
- Silver nanoparticles (AgNPs) in particular offer a variety of properties and applications.
- Both top-down and bottom-up techniques can be used to create silver nanoparticles (AgNPs).
- Green synthesis is necessary because of its useful qualities, such as its low cost, etc.
- Green synthesis is the process through which non-toxic components of nanomaterials are created. Various plant parts can be utilised in this process.
- AgNPs have anti-microbial activity.
- It will change the physical and chemical characteristics of the microbe, affecting either the cell wall or the transmission of signals.
- In the event of AgNPs, cell wall destruction will take place.
- The AgNPs are going to stop the cells from signaling, making death easier.

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