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Review Article

Review on Silver Nanoparticle

Green Synthesis and Applications of Silver Nanoparticles Using Plant Extracts: A Review Article

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Abstract: The nanoparticle (NP) biosynthesis field is still underdeveloped and has long been known to impact many industries significantly. Recently, the synthesis of silver NPs has been given excessive attention in developed countries because of the requirement to develop environmental supporter technologies to synthesize materials. The uses of green chemicals are environmentally friendly, non-poisonous, and inexpensive. It has been shown that various microbes, including yeast, fungi, bacteria, and plants, can synthesize intracellular and extracellular AgNPs. All systematic information reflects the unique possessions of AgNPs, which have many uses such as antifungal, antibacterial, anticancer, and antiviral agents, brilliant natural catalytic larvae, dye-degrading, excellent antioxidants, treatment of complications associated with diabetes, and wound curative. Physical and chemical methods use high radiation levels and high concentrations of reducing agents and stabilizers that are dangerous to the environment and human health. Therefore, the synthesis of NPs is a one-step bioremediation approach and consumes low energy for an environmentally friendly synthesis of NPs. Recently, the development of effective green chemistry methods using reducing agents, limiters, and natural stabilizers to obtain AgNPs of good shape and sizes has become an area of research. This review aims to explore the green synthesis of silver nanoparticles using plant extract, and the characterization of synthesized silver nanoparticles with their different applications. Also, this review is meant to tell about the plants and their various parts that can be used for the green chemistry of silver nanoparticles in an environmentally friendly basis with their many therapeutic applications. Finally, this review summarizes the latest published data that can be used for research.

Keywords: Green Synthesis, Plant Extract, Nanotechnology, Silver nanoparticles, antimicrobial activities and Applications

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1. INTRODUCTION

Nanoscience has recently recognized itself as a novel interdisciplinary science. It is a comprehensive knowledge of the basic properties of nanoscale objects. Humans have been skilled in numerous scientific revolutions that have profoundly affected the sequence of the past. The first (engineering revolution) presented the vapor engine and steel production. The second was caused by a starter of electricity power on a manufacturing scale. We have witnessed a data revolt considering the common use of computer science devices. Nanotechnology is broadly recognized as the backbone of the upcoming industrial revolution. The concepts and ideas in nanotechnology were revealed in a lecture entitled The Bottom by physicist Richard Feynman[1]. Nanotechnology is concerned with nanoparticles ranging from 1-100 nm. Currently, nanoparticles (NPs) are used in different coating fields like electronics, energy contact, and medicine. [2] Silver nanoparticles (AgNPs) plays a vital role in general application of the NPs in pharmaceutical and other medical sciences. Biosynthetic AgNPs are more suitable for medical applications than chemically synthesized AgNPs due to their superior biocompatibility. The use of green chemistry with plant extracts and microorganisms is non-toxic, environmentally friendly, and inexpensive.[3,4] A recent method for improving drug efficacy is targeting microbial infections in combination with metal nanoparticles. The interactions of AgNPs with heavy metals during biologic treatments are not well understood.[5,6] The electrical bio removal of heavy metals increased with increasing AgNP concentration, indicating that the appropriate AgNP concentration had a stimulatory effect on heavy metal removal by Phanerochaete chrysosporium. AgNPs have unique properties that have revolutionized various uses like as antibacterial, anticancer, larvicidal, catalytic, and healing activities. In the past five years, much effort has been made to develop new, more environmentally friendly, and less expensive methods for synthesizing nanoparticles. Nanoparticle biosynthesis is an inexpensive and “environmentally friendly alternative to chemical and physical methods”. Nanotechnology may be defined as the creation, display, manipulation, and application of the structure by monitoring the sizes and shapes of the nanoscale. It is a dynamic area of exploration in materials science and proliferating worldwide. NPs can be further divided into inorganic nanoparticles and organic nanoparticles. Inorganic NPs include semiconductor NPs (e.g. ZnS, ZnO), metals (e.g.Ag, Au), and magnetics NPs (e.g. Ni), while organic contain carbon NPs (e.g. carbon nanotubes). Ag and Au nanoparticles have worldwide popularity because they offer superior properties and useful flexibility. Because Ag nanoparticles have a significant external area, they exhibit higher catalytic activity, biochemical reactivity, and atomic performance than larger elements of similar chemical composition. Ag NPs is catalytic, plasmonic, optoelectronic, biological sensors and antibacterial activity agents, DNA sequencing, weather change, environmental protection, biomedical applications, information storage, and energy production. The formulation of nanoparticles has brought tremendous progress in nanotechnology and the past decade has shown its potential[7]. Nanotechnology solves several problems in medicines, chemistry, surface sciences, biology, agriculture, and engineering, and uses the atom, electron, proton, and neutron in a variability of ways to understand how materials can be created for space exploration. It is a comprehensive manipulation science. Ocean and ocean sciences, geology, and geography. Researchers will invent new machinery or methods for producing a new product. [3] Spending on research in nanotechnology has grown rapidly around the world over the past decade[8].

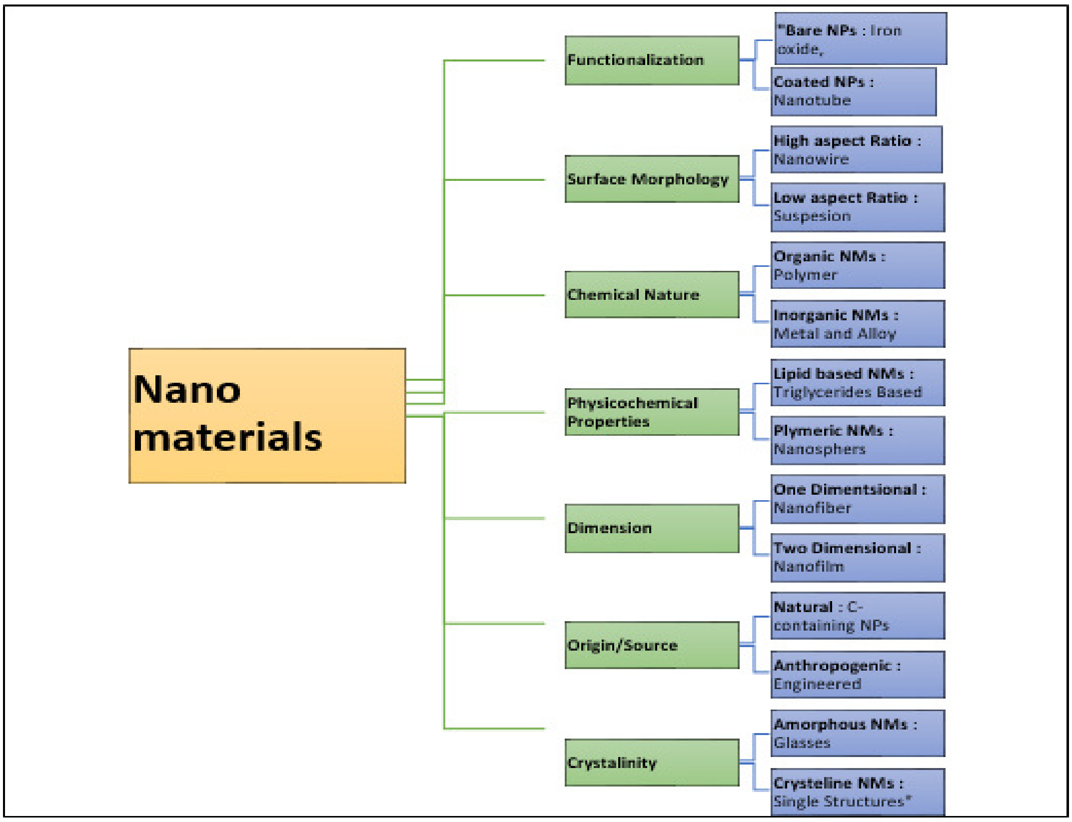

Fig 1: Illustrates the different types of nanomaterials based on the different properties like surface morphology, chemical nature, etc. of their different types of nanoparticles. [7]

2. VARIOUS TYPES OF NANOPARTICLES

Some of the described shape properties NPs are shell NPs, NPs with photochromic polymers, polymers-coated NPs, inorganic NPs, Ag NPs, Cu NPs, AuNPs, Pt NPs, Si NPs, and Ni NPs, while metal dioxides, metals, and other ZnO NPs, Cu NPs, MgO NPs, CeO2 NPs, and ZrO NPs.[1,9,10] Every NPs have a good set of features and different applications and is synthesized using traditional or non-traditional methods. The detailed classifications of NPs are shown in Fig.1.[11–13]

3. NANOPARTICLE SYNTHESIS

NPs can be synthesized by using the following methods.

3.1. Non- Biological method
3.2. Biological methods

3.1 *Non-Biological Methods*

3.1.1 Physical Method

Vapor condensation is a standard method for synthesizing metal NPs.[14] In this method, the base material is placed in a boat in a centralized heater and evaporated in carrier gas. Fullerenes, gold, and silver NPs were synthesized by evaporative condensation. The pipelines used in the process are different. The disadvantages are that as the temperature rises around the starting material, it takes up a lot of space, consumes high energy, and takes the same amount of time to achieve thermal stability. In addition, medium-sized pipelines require several minutes of warm-up to achieve a stable operating temperature and a power of several kilowatts or more. One of the most common limitations of the method is defects in the surface structures of products, where the physical property of the NPs depends on the surface structure. Regardless of the widely used method, it is widely believed that the physical method will be used as calibration tools and NPs generators for long-time experiments to study respiratory toxicity. [15]

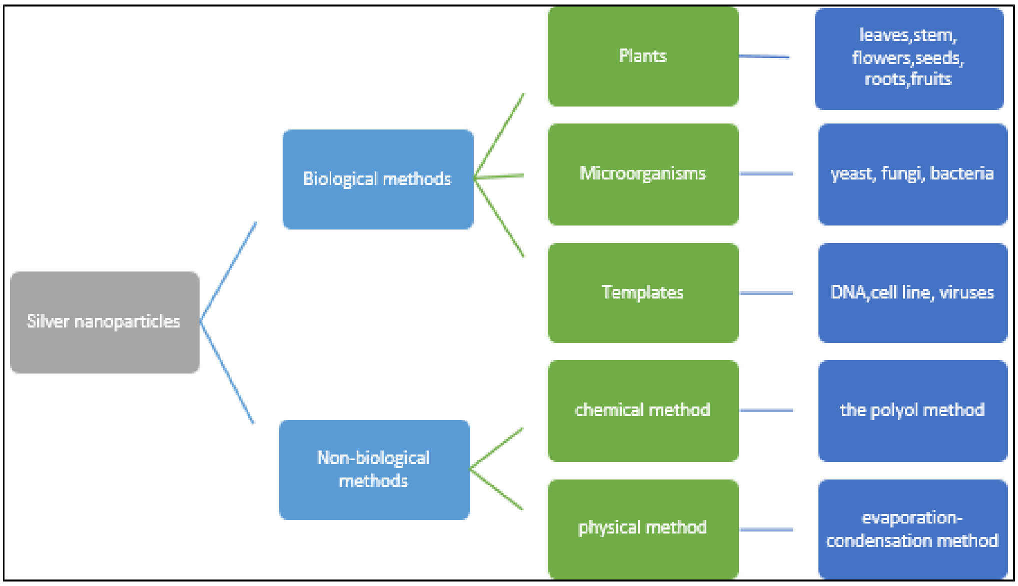

Fig 2: Illustrates that the silver nanoparticles can be synthesized using biological methods and non-biological methods[16]

3.1.2 Chemical Method

Chemical reduction is a commonly used method for synthesizing AgNPs. Various inorganic and organic reducing agent in the aqueous or the non-aqueous solutions are used to reduce Ag ions (eg polyethylene glycol block copolymer, essential hydrogen, toluene reagent, ascorbate, N, N-dimethylformamide, boron NaBH4). Coagulants are still used for stabilizing the size of the NPs.[17] The main advantage of this method is the ability to synthesize a huge amount of NPs in less time. However, the chemicals used in the synthesis are toxic and produce unwanted toxic effects.

3.2 *Biological Methods*

Physical and chemical methods use high radiation levels and high concentrations of reducing agents and stabilizers that are dangerous to the environment and human health. Therefore, the synthesis of NPs is a one-step bioremediation approach and consumes low energy for an environmentally friendly synthesis of NPs. Recently, the development of effective green chemistry methods using reducing agents, limiters, and natural stabilizers to obtain AgNPs of good shape and sizes has become an area of research. Biological methods synthesize AgNPs without the uses of harsh, toxic and expensive chemicals. Biological processes use plant extracts, bacteria, fungi, microalgae such as blue-green algae, diatoms, algae (control algae), and environmental resources such as enzymes. Bio recovery of metals ions by a combination of biomolecules contained in extracts of the organisms like (enzymes/proteins, amino acids, polysaccharides, and vitamins) is environmentally friendly. Recently the biosynthesis of nanoparticles in plant extract has gained great importance. [18]

3.2.1 Synthesis of AgNPs from Bacteria

The first proof that bacteria synthesize AgNPs comes from the Pseudomonas stutzeri AG259 strain isolated from silver mines.[19,20] The biosynthesis of AgNP was studied in 30 cyanobacteria, where an aqueous extract of cyanobacteria at 30°C was used for AgNPs synthesis. Scanning an aqueous extract containing AgNPs in UV spectra shows only one peak. TEM images of AgNPs from cyanobacterial extracts showed that although the synthesis of nanoparticles occurs in all strain, the rxn time (31-360 hours), shape and size (38-88 nm) of the nanoparticles differed (Table 1). Extracellular AgNP biosynthesis has been reported using P. aeruginosa and E.coli. In addition, pathogenic and opportunistic human microorganisms, namely S. aureus, Staphylococcus epidermidis, Enterococcus faecalis, Proteus mirabilis are reported. There are several microbes that can live and grow at conc. of metal ions. The mechanisms associated with resistance are efflux systems, changes in toxicity and solubility through oxidation or reduction, biosorption, bioaccumulation, extracellular complexing or metal deposition, and the absence of definite metallic transport systems. Although these organisms can grow at lower concentrations, there is another aspect: introduction to high concentrations of metal ions can cause toxicity. The typical mechanism for Ag synthesis is the existence of the enzyme nitrate reductase. Enzymes convert nitrates to nitrites.[20]

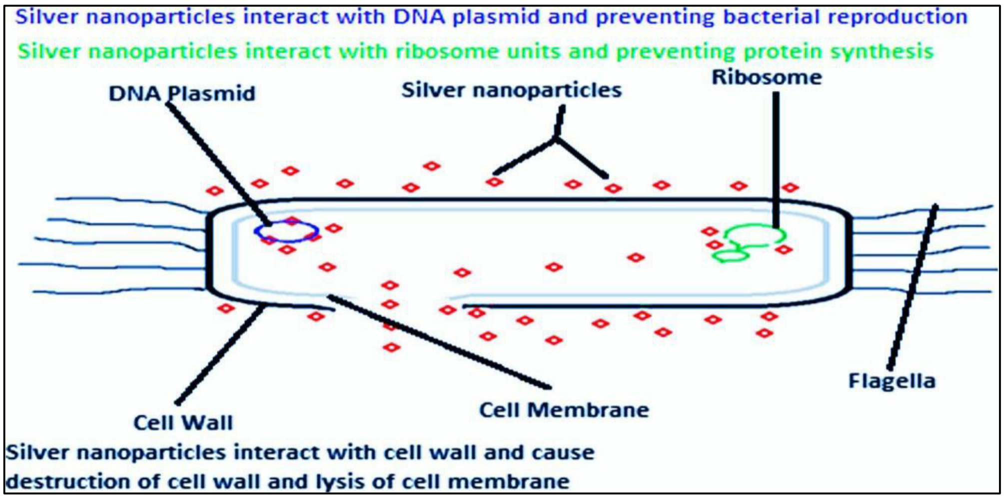

Fig 3: Illustrates the Antibacterial activity mechanisms of silver nanoparticles.[21]

3.2.2 *Synthesis of AgNPs from Fungi*

Because fungi can secrete more protein than bacteria, they can produce more nanoparticles, which directly leads to higher nanoparticle productivity. Microorganisms and Fungi are good for the synthesis of metal NPs of various sizes (Table 1) due to their ability to secrete many enzymes. Microorganisms excrete various reducing agents. The study reports that the use of fungus Hypocrea lixii is a novel, efficient and environmentally friendly bioprocess for producing NPs. AgNP biosynthesis ranged from 123–195 nm for the fungus Pestaloptiopsis pauciseta and 49 to 100 nm and 21 to 81 nm for Candida albicans.[22] The mechanism of production of AgNPs by the fungus is the capture of silver ions on the surfaces of fungal cell and successive reduction of Ag ion by an enzyme present in the fungal system.[23] Extracellular enzymes such as naphthoquinone and anthraquinone are thought to aid in recovery. Taking F. oxysporum as an example, it is supposed that NADPH-dependent nitrate reductase and extracellular quinine shuttle processes are involved in the synthesis of NPs.[24] The mechanism of forming AgNPs by the fungus has not been elucidated, but this phenomenon is considered the cause of the process. The main cons of using microorganisms to synthesize AgNPs is a very slow process compared to the plant extract. [25,26]

Table 1: Bacterial and fungal biosynthesis AgNPs with Various sizes

Producer Organism	Size (Nm)	Reference
Candida albicans	50-100	27
Fusarium sp.	12-20	27
Fusarium solani	5-30	28
Aspergillus versicolor	15-17	29,30
Sclerotinia sclerotiorum	25-30	30
Colletotrichum sp.	20-50	31,32
Aspergillus clavatus	25-145	32
Aspergillus niger	25-175	32
Aspergillus flavus	45-185	32
Aspergillus fumigatus	5-95	32
Trichoderma viride	15-17	33
Penicillium expansum	14-25	34
Aspergillus terreus	10-18	32
Cyanobacterial aqueous	38-88	19
Nocardiopsis valliformis	5-50	35
Bacillus pumilus	77-92	36
B. persicus	70-95	37
Bacillus subtilis	40-60	38

Table 1 illustrates the bacteria and fungi are used to synthesize the different sizes of silver nanoparticles with their different applications.

3.2.3 Synthesis of AgNPs by Algae

The algae synthesis process was rapid, and Ag NPs (34.05 nm) was formed within some min.[39] after contacting Ag ions with extracts from the algae Pithophora oedogonia.[19] According to one study, AgNPs were produced by different strains of microalgae, including Botryococcus braunii, Coelastrum sp. and Spirulina sp. and Limnothrix sp. Silver nanoparticles of size 15 and 47 nm with diameters of 15.67, 19.28, 13, respectively. 85 and 25.65 nm were biosynthesized using aqueous extract of Chlorella vulgaris as a reducing agent.[40] They investigated the antitumor efficacy of different biosynthetic Ag-NPs from blue-green algae, Anabaena oryzae, Nostoc muscorum and Calothrix Marchic in Ehrlich ascitic carcinoma in vitro. Red marine macroalgae, aqueous extract of Amphora fragilissima, was used as a reducing agent for AgNP synthesis. AgNPs have demonstrated antibacterial activity against E. coli, B. subtilis, K. pneumoniae, S. aureus, and P. aeruginosa.[41] AgNPs (25 nm) synthesized with aqueous extract of the green algae Caulerpa racemosa exhibited antibacterial activity. A research study of this algae showed good catalytic activity against Ag nanoparticles that decompose methylene blue. The red algae Laurencia Aldingensis and Laurenciella sp. Extracts were used to prepare AgNPs.

Table 2: Algal and plant biosynthesis AgNPs with various sizes

"Producer Organism	Size (Nm)	Reference
Ocimum tenuiflorum	28	42
Solanum trilobatum	26.5	42
Syzygium cumini	65	42
Centella asiatica	22.3	42
Citrus sinensiss	28.4	42
Ziziphus jujuha	20-30	43,44
Emblica officinalis	15	44
Prosopis farcta	10.8	45
Rauvolfia serpentina	7-10	46
Botryococcus braunii	15.67	19
Coelastrum sp.	19.28	19
Spirulina sp.	13.85	19
Limnothix sp.	25.65"	19

Table 2 illustrates that the algae and plants are used to synthesize the different types of silver nanoparticles with their different applications.

3.2.4 Synthesis of AgNPs from Plants

The use of plants as formation groups for AgNPs has attracted due to its rapid, non-pathogenic, environmentally friendly, and economical protocol that offers a one-step biosynthetic procedure and contains important phytochemicals used as reducing agents for AgNP synthesis. Plants that promote the synthesis of AgNPs of different sizes have been described (Table 2) and briefly described in this review article. AgNPs biosynthesis was achieved by sonication using extract from 16 easily available plants, and antimicrobial assays were performed on bacteria (E. coli, Salmonella paratyphi, S. aureus, and B. subtilis) for AgNP biosynthesis. It exhibits excellent antibacterial activity[21]. The main pros of using plant extracts for the formation of AgNPs are that they are readily available, safe, non-toxic in most cases, contain many metabolites that can help recover silver ions, and are superior to microbes. It's quick to mix. plant-supported regeneration by secondary plant substances is considered a mechanism. The most important secondary plant substances are (terpenoids, flavones, ketones, aldehydes, amides and carboxylic acids). Flavones, organic acids and quinones are water-soluble phytochemicals that are responsible for the ion reduction. It is believed that phyto-chemicals are directly involved in ion reduction and AgNPs synthesis.

3.2.5 Synthesis of Metal Nanoparticles Using Different Parts of Plant

The use of different plants and their extracts is very famous due to its fast development, one-step method, inexpensive protocol, non-pathogenic and environmental friendly. Plant synthesis is faster than other microorganisms such as bacteria and fungi. Therefore, the use of plants extracts in green chemistry has given birth and is still being researched. It has been observed that, depending on the type of plant extract, metal nanoparticles can be produced in less time at room temperature. when the plant extract is used in a metal salt solution. Extract concentration, temperature, pH and metal salt are the most important factors after selecting plants extract. Apart from the conditions in which it was formed, the important factor is the plant from which the extract was obtained. The pros of synthesizer nanoparticles are that , they are easy to obtain, easy to maintain, and contain many active ingredients that help reduce Ag ions. leaves, stems, buds, bark, flowers, seeds, and their derivatives are used for nanoparticles biosynthesis. Noteworthy are the active ingredients they contain, which ensure stabilization and recovery, as well as the biomolecules that produce stable nanoparticle. Biomolecules such as amino acids, polysaccharides, alkaloids, and proteins are the main constituents affecting nanoparticle reduction and blocking of nanoparticles[47]. Plant nanomaterials are broadly used in different fields and are attracting attention. physicochemical properties. Nanoparticles of various metals like gold, silver, platinum, zinc, copper, titanium oxide, magnetite, and nickel have been synthesized from natural sources and have been studied extensively. Various plant parts like stems, roots, seeds, fruits, callus, bark, leaves, and flowers are used to synthesize metals NPs of various sizes and shapes through biological approaches as shown in Figure 4. The biosynthetic reactions can be modified at different concentrations. The number of metals and plant extracts in the rxn medium that can change the shapes and sizes of NPs.

Fig. 4 illustrates that the different parts of the plant are used to synthesize the different sizes of silver nanoparticles. [47]

3.2.5.1 Root

The roots extract contains various functional groups, particularly amine, carboxyl, and phenolic compounds. The researchers synthesized AgNPs using the aqueous rhizome extract of the Zingiber Officinale. Plant extracts of silver ions with nanoparticles of metallic Ag. Other functional groups are C=0 and C=N. Polypeptides are compounds responsible for capturing ionic species on metal NPs[20]. Formation of metal NPs with Medicago sativa is probably one of the first reported cases of AgNP production using plant parts as a medium. Alfalfa roots absorb reduced silver (from Ag to AgO) from the agar as a medium and transfer it to sprout in the same oxidation states (AgO). The Ag atoms in the crossbar then arrange themselves by bonding with each other and forming larger arrays to create NPs. SEM/TEM analysis shows the aggregation of Ag atoms in plant tissues subjected to nucleation and NP formation.[49]

3.2.5.2 Fruits

According to the literature data, the fruits play a vital role in ecological formation of AgNP. AgNPs were reconstituted and encapsulated using fruit extracts from the Solanum xanthocarpum plant Known as Indian chestnut or yellow chestnut, this thorny plant grows in different parts of the India Pakistani subcontinent. This fruit is the source of apigenin glycosides, quercitrin, and flavonoids, and their extracts have antibacterial, antioxidant, and antiparasitic properties. This research showed that molar ratio, pH, and temp. of AgNO3 and S. xanthocarpum (SXE) extract affect Ag reduction and AgNP size. The resulting particles contain urease and anti-H inhibitors. pyloric activity; Thus, this study demonstrated the good antibacterial and urease-inhibiting activity of AgNPs[50]. The researchers used fruit extracts from the plant Tribulus Terrestris, to which silver nitrate solutions were added at various molar concentrations, to synthesize environmentally-friendly AgNPs with exact morphologic properties. The extracts contain active phytochemicals responsible for a one-step reduction reaction. Spherical AgNPs obtained from T. Terrestris extract have excellent antibacterial activity. Similar reports on the uses of grape polyphenols for the synthesis of palladium nanoparticles are effective against bacterial diseases.

3.2.5.3 Seeds

Seeds contain active products recovery of chloroauric acid with a strong reducing agent. Fenugreek seed extract acts as the best surfactant. The seed extract contains carboxyl groups, "C=N, and C=C" functional groups. Metabolic functional groups act as surfactants of AuNPs, and "flavonoids can stabilize the electrostatic stabilization" of AuNPs. To describe AgNPs synthesis using plants seeds, a research describes the production of green silver nanoparticles using jatropha seed extract, noting that key plant components including curtain (an enzyme), curca cyclin A (cyclic octapeptide), and curca cyclin B (cyclic nonapeptide) can act as restorative and limiting agents. The resulting NPs were characterized using XRD, SEM, and UV-visible spectra. As a result of the analysis, the Ag nanoparticles had a spherical shape range of 21–45 nm, while the remaining particles were larger and had two wide distributions of irregular shape. In addition, it was observed that cyclic peptide cavities (curcacycline A and curcacycline B) stabilizes small nanoparticles while large ones are stabilized by curcain enzyme.[51]

3.2.5.4 Leaves

Plants leaf extracts used as a source to synthesize NPs were recorded. Leaves of *Centella Asiatica, Murraya koenigii, Alternanthera sessiles* and other plant's leaves extract had been studied. P. nigrum leaves contains an important bioactive compound that was synthesized by the environmental supporter method[52]. According to the literature, plant extracts of *Ocimum Sanctum* (Tulsi) are a better source of stabilizer and biological reducing agents. Research shows that the glycosides, alkaloids, saponins and tannins present in the extracts can diagnose diarrhea, headaches, parasitic infections and coughs.A researcher used a green synthesis strategy to develop stable AgNPs using quercetin and tulsi leaf extract. TEM images of AgNP show NP spherical and amorphous dimensions using quercetin (11.38nm) and tulsi (14.69 nm) as reducing and limiting agents. For quercetin, the nanoparticle size increases from 10.40 to 19 nm as the pH increased to 9.5.[53]

Table 3: Synthesis of Silver nanoparticles using different parts of plant[48]

Plant	Size of AgNPs (nm)
Cassia angustifolia	9-31
Leaf of Curcuma longa	10-30
Ocimum tenuiflorum	25-40
Peels of Punica granatum	10
Alstonia scholaris	30-50
Flower of Calotropis procera	35
Leaf of Catharanthus	5-10
Chenopodium album	10-30
Rhizome of Dioscorea batatas	10-40
Leaf of Eclipta prostrate	10-20
Gelidilla acerosa	16-40
Mentha piperita	57
Leaf of Piper longum	18-41
Leaf of Polyalthia longifolia	15-50
Leaf of Polyalthia longifolia	58
Flower of Rosa damascene	10-30
Leaves of Vitex negundo	18.2

Table 3 illustrates the different parts of the plant like root, stem, leaves are used to synthesize the different sizes of silver nanoparticles.

3.2.6 Role of AgNPs in Abiotic Stress Tolerance

Plants are naturally exposed to various abiotic stresses like low temperature, heat, salinity, drought, salinity and the incidence of these stresses in the global environment is increasing. Recently, nanotechnology has attracted the attention of researchers in various fields. Due to their extremely small size, nanoparticles have acquired several unique properties that distinguish them from their larger counterparts. Nanoparticles have greater solubility, surface area, and reactivity than bulk materials. Therefore, they can play a promising role in reducing the harmful effects of biotic stress and contributing to the goals of sustainable agriculture worldwide. The use of (AgNPs) in agriculture is gaining popularity due to their effect on stress tolerance. Various forms of AgNPs have been investigated for their potential role in reducing abiotic stress. These silver nanoparticles have been shown to compensate for nutrient deficiencies, enhance enzymatic processes, and increase plant stress tolerance by promoting the attachment of growth-promoting bacteria to plant roots under abiotic stress conditions. These early results are encouraging and also mark a new era of using nanoparticles to improve yields under harsh environmental conditions. [54]

3.2.7 *Biological Reducing Agents*

Reducing agents are commonly used in organic systems. AgNPs are synthesized using the 4 kingdoms of the 5 kingdoms of living species, i.e. different organisms. To our knowledge, there is no data on the use of animal materials for AgNPs synthesis. Because of these limitations, green AgNPs synthesis is discussed below the heading of plants, microorganisms, and biopolymers. Green synthesis of AgNPs was carried out by using the plant extracts, culture media, and biopolymer. Plants used to synthesize AgNPs range from [1-100nm]. However, reports of sub plants are limited, and angiosperms are the most appropriate choice. AgNPs have been synthesized using parts such as leaves, bark, roots, and stems. Medicinal plants such as ("Boerhaavia diffusa, Tinospora cordifolia, and Aloe vera").[55–57] Some exotic weeds, such as Parthenium hysterophorus which grow uncontrollably due to the lack of usual enemy and cause health diseases, are also used for AgNPs synthesis. Another collection includes plants producing alkaloids (Papaver somniferum) and essential oil (Mentha piperita). All herbals extract act as potential reducing agents and stabilizers. An exception is when external chemicals such as sodium decyl sulfate are used to stabilize AgNPs. Proteins, metabolites, and chlorophyll presented in plant extract act as ribbons for synthesized Ag NPs.[58] When extracting the reducing agent from plants, the preferred solvent is mainly water, but there are many reports of the uses of organic solvents such as ethanol, methanol, and ethyl acetate.[59] Some research scholars pretreat plant material with salt or acetone.The atmosphere before extraction. Although extraction solvents vary, nanoparticle suspensions are usually prepared only in an aqueous medium.[60] The Synthesis using plant extract made it possible to obtain NPs with good size, shape, and structure, as compared to nanoparticles in bark, tissues, and whole plants.[61] The synthesis of AgNPs by microorganisms is more intensive than using plant extract and biopolymer as reducing agents and capping agents, mainly due to the difficulties of growth and maintenance of culture, and standardization of seed sizes.[62] Several species of Microorganisms synthesize AgNPs intracellularly and extracellularly. [63]Intracellular AgNPs synthesis has been observed by several researchers.

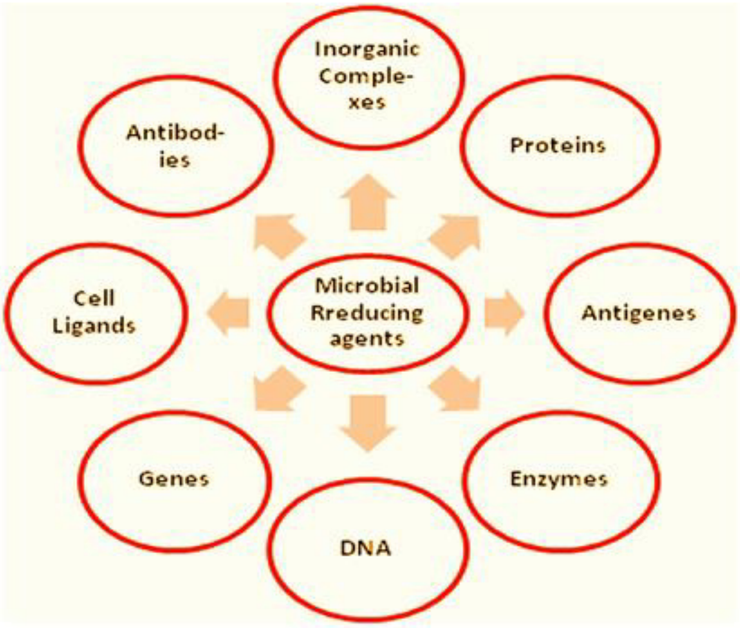

Fig. 5 Biological reducing agents [24]

3.2.8 *Characterization of Green Synthesized AgNPs*

3.2.8.1 *UV/Visible Spectroscopy*

UV/Vis spectroscopy helps analyze the relationship between metal ion concentration, pH and extract the content and the type of AgNP formed. The appearance of yellow or light brown-yellow color in a colorless mixture usually indicates the formation of Ag NPs. The properties depend on the sizes and shapes of the particles. In the UV spectra, the characteristic peak of AgNPs is usually observed at about 435 nm. It is already mentioned, that many factors influence the location of peaks. The change in the reaction mixture (solution of metal ions and plant extract) was recorded by visual observation. The biological reduction of Ag in an aqueous solution was observed by measuring the spectrum of the solution using a UV-Vis spectrophotometer and a water-based quartz cuvette. Inorder to study the stability of solutions of colloidal nanoparticles, the solutions were stored at room temperature for one week. During this time, the UV-visible spectra of the solution were measured at different intervals. 30 minutes, 24 hours and a week later. [64]

3.2.8.2 *FTIR Spectroscopy*

FTIR analyzes metabolites or functional group (capping/stabilizers) used on NP surfaces. The presence of amino, carboxyl, hydroxyl, and carbonyl groups after FTIR irradiation of AgNPs synthesized from Spirogyra macroalgae variants. The FTIR spectrum shows several peaks assigned to various functional groups, including strong and broad O-H deformation bands around the carboxyl/phenol stretch band at about 2927 cm-1 and quinine O-H at about 1515 and 1429 cm-1. respectively. After the synthesis of AgNP, it was found that the characteristic peak of the protein was shifted in the region of 1644 cm–1. The IR spectrum of Ag NPs synthesized from marine Streptomyces rochei MHM13 shows an absorption band in the range of 400–4000 cm-1. Typical intense peaks at 3420.14, 2932.23, 2362.37, 1639.20, 1430.92, 1115.62 and 613.252 cm-1 indicate their presence.[65]

3.2.8.3 *XRD*

XRD studies have been used to determine the crystal structure of nanomaterials. It is also used to denote the size and shape of a unit cell in a translationally symmetric knot. This method is mainly used to study the inner chamber and structure of gemstones. Perception depends on the precious impedance of a translucent sample and monochromatic X-rays produced by a shielded cathode ray tube to produce monochromatic radiation. This strategy, along with size estimation, helps to understand the gem design and nucleation properties of embedded AgNPs. According to fields (111), (200), four distinct and significant commodity peaks at 38.2°, 44.5°, 64.7°, and 76 .5°., (222) and (310). All peaks in the diffraction pattern can be effectively assigned to a rectangular structure focused on a silver plane.[66]

3.2.9 *Applications of Silver Nanoparticles*

AgNPs are finding wider applications in various fields, including biomedicine, materials science, and catalysis. This is due to its unique properties compared to bulk materials.

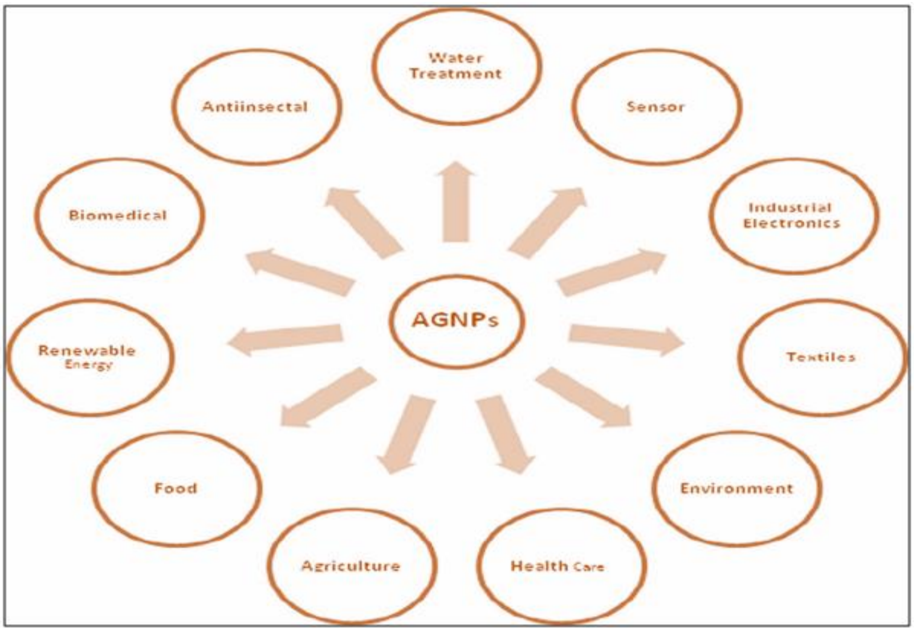

Fig. 6 Various applications of silver nanoparticles [2]

3.2.10 *Human Health*

Nanoparticles affect human health differently depending on the material from which they are made. Increasing the biological activity of NPs can be "beneficial, detrimental, or both". Many NPs are capable of reaching the skin, lungs, and brain.The impact of metal-containing NPs on human lung epithelial cells leads to reacting oxygen species forming, which causes oxidative stress and cell damage. Due to their rapid development and transparent body structure, research on the toxic effects of AgNPs was carried out in a zebrafish model. The results show the deposition of particles in the organ and a significant effect on development.

3.2.10.1 Antimicrobial Property

AgNPs have been shown to exhibit a good antimicrobial activity. Therefore, the research scholars used several new methods to identify and measure the antimicrobial activity of Ag nanoparticles.

a. Disk/well diffusion method

The common used methodology for assessing the antimicrobial activity of liquids, is the disk diffusion method, that has been used by researcher scholars to confirm the antimicrobial activity of AgNPs solutions.[69] In this methodology, a plate of absorbent materials of the same size is immersed in an increasing concentration of AgNPs and placed on the surface of an inoculated target.[70] The formation of the inhibitory zone around the disc reflects the antimicrobial effect of nanomaterial and its diffusion. In this method, as an alternative to using a disc, a small disc hole is made in the agar plate to fill the test solution. In both methods, microbially inoculated plaques were incubated under ordinary conditions to form a clear zone of inhibition. The radius of the inhibition area around disc directly correlates with the effects of AgNP on selected microbes.[71]

b. Minimum Inhibitory Concentration (MIC)

MIC can be described as the minimum concentration of the analyte that inhibits the growth of the target microbial visible by 100% after 24 h. MIC was measured by monitoring bacteriological development in a culture tube immunized with an equal number of microbial cultures but an increase in conc. of AgNPs in medium. The lowest conc. of AgNPs that regulate bacterial growth is known as the minimum inhibitory concentration.[70] To determine MBC, a particular concentration of AgNPs exceeding the MIC value was added which contains the culture medium of growing microbial inoculum, bacteriological growth was observed by using UV-visible spectra. The broth test was also used to perform MBC and MIC analyses, comparing results with standard data after experiments.[71,72]

c. Analysis of TEM and SEM images.

TEM and SEM analyzes were used to track variations in bacterial cell character before and after AgNPs treatment. Marked changes in cell shape and cell-wall perforation have been recorded, and some operators have been used as an indication of AgNPs antimicrobial activity.[72]

3.2.10.2 Antibacterial Property

AgNPs were obtained from Gram (+) bacteria “Lactobacillus fermentum” and Gram-negative bacteria, E. coli, the antibacterial activity of AgNPs against Gram (+) and Gram (-) bacteria are not similar and compete with each other.[70,72] Many conflicting reports of antibacterial activity against gram-positive and negative bacteria are present. While some research scholars have reported that Gram (-) bacteria are more sensitive to AgNPs than Gram-positive bacteria, others have observed the opposite. The different susceptibility of the two reported bacterial species may be due to differences in the characteristics of the bacteria species[69]. The antibacterial activity of Ag nanoparticles is very tough and little studied. The mechanism is only partially disclosed. The antibacterial activity of AgNPs can be divided into 2 types: bactericidal and inhibitory activity. The first strategy kills bacterial cells under the action of AgNPs, while the second strategy prevents the division without the death of bacterial cells. The mechanism of antimicrobial action of AgNPs is summarized. Silver nanoparticles with a high affinity for phosphorus- and sulphur-containing compounds present in membranes, DNA penetrate, protein, and respiratory enzymes and destroy cell - walls and plasma membranes and cause protein denaturation by scattering protons. Respiratory depression, intracellular ATP deficiency, and DNA damage. This mechanism is consistent with the report of many research scholars.[71]

3.2.10.3 Antifungal Property

AgNPs have antifungal activity against different fungi. The mechanism of antifungal activity is incomplete.[61] Disruption of cell membrane structure by disrupting its integrity and thereby inhibiting budding processes is related to the antifungal effect of AgNPs on C. albanicans. The form of AgNP has a significant impact on antimicrobial activity. Mortality from fungal infections is known to be high and continues to increase due to the emergence of strains resistant to a limited no. of new antifungal agents and the development of prophylactic antifungal agents. The antifungal agent can be adsorbed onto the surface of live Ag, possibly facilitating the delivery of the antifungal. Green Ag nanoparticles also exhibited antifungal activity due to their biological encapsulation activity, which complements their convenient size. The synthesized green AgNPs have strong antifungal activity against Cryptococcus and Candida species. AgNPs were grown using Pilimelia columellifera subsp. pallida SL19 showed activity against fungi that cause superficial mycoses, namely M. furfur and C. albicans. AgNPs synthesized with Mentha pulegium aqueous extract showed important activity against fluconazole-resistant Candida albicans.[73]

3.2.10.4 Anti-parasitic Property

AgNPs showed larval activity against Culex quinquefasciatus, dengue vector Aedes aegypti, malaria vector A. subpictus, thread vector C. quinquefasciatus, Aedes aegypti, A. subpictu, and other parasites. The exact mechanism is still unknown, denaturation of sulfur-containing proteins and phosphorus-containing DNA by AgNPs leads to further denaturation of enzymes, organelles, etc. Someone who can be responsible for the activity. Leishmaniasis is a disease caused by parasites of the genus Leishmania. The current situation is worrying because of the Low availability and high cost of antimanic drugs. However, these parasites are susceptible to AgNPs due to formation of ROS. Nanoparticles showed related activity against Leishmania tropica in UV light. In addition, green AgNPs doped with miltefosine increased activity against Leishmania. [74]

2) Cardiovascular implants

The first cardiovascular device coated with elemental silver were silicone artificial heart valves to reduce the incidence of endocarditis. It has been proposed to use this Ag to avoid the microbe's contamination of silicone valves and reduce the inflammatory response of the heart. In clinical trials, heart valve antigen tests have been found to cause allergic reactions, suppress normal fibroblast function, and cause perivalvular discharge in patients. Therefore, efforts are focused on integrating Ag NPs into medical devices to create safe, non-toxic and antimicrobial coatings. Other advances in nanocomposites containing Ag-NP and diamondoid carbon as surface coatings for "heart valves and stents demonstrate" antithrombotic and antibacterial properties. The incorporation of nanostructured material into the "polymer base of polymeric heart valves improves biocompatibility, calcification resistance, and strength".[75]

3) Catheters

Catheters used in hospitals are more likely to be contaminated and may lead to unwanted complications. Ag nanoparticles are used to reduce biofilm formation in catheters. Polyurethane catheters have been modified with Ag-NP coatings to provide effective antibacterial catheters. Catheters coated by using AgNPs can reduce bacteria for up to 75 hours in animal models and are non-toxic.. In a pilot clinical research, the prevention of catheter-associated ventritis (CAV), 19 patients treated with Ag-NP coated catheters did not develop CAV and all CSF cultures were negative.[76]

4) Wound dressings

Ag dressings are used for clinical management of various injuries such as burns, chronic ulcers, pemphigus and toxic epidermal necrolysis. Ag-nanoparticles used in wound dressing shortened wound healing time by 3.25 days while increasing the microbial clearance from contaminated wounds without side effects compared to Ag-sulfadiazine and standard gauze dressings. Compared with traditional 1% Ag sulfadiazine cream or simple petroleum jelly gauze, Ag NP used in wound dressing can enhance the therapeutic effect on superficial burns, and has no effect on therapeutic burns, accelerates re-epithelialization, although the new tissue does not. not formed, namely angiogenesis and expansion. Chitosan-Ag nanoparticles use in wound dressings showed significantly improved wound healing compared to 1% Ag-sulfadiazine, along with less Ag deposition.[77]

5) Orthopedic and orthodontic inserts and obsessions

Embed-related and joint replacement bacterial defilements are high at 1.0-4.0% and are the most certifiable intricacies in muscular medical procedure considering the way that they are difficult to treat and results in expanded dreariness and more regrettable outcomes. Ag-NPs have been integrated into plain poly bone build-up, used for safe association of joint prostheses hip and knee replacement medical procedure, as a way to deal with decline bacterial obstruction.[78]

6) Dentistry

AgNPs have been used in dental instruments and gauze. The incorporation of AgNPs into orthodontic adhesives can increase or maintain the shear bond strength of orthodontic cements while increasing protection against microorganisms. AgNPs in dental composites can reduce microbial colonization of the coating and affect its antifungal ability. AgNPs associated with root canal fillings exhibit delayed antimicrobial activity against Streptococcus milleri, Staphylococcus aureus, and Enterococcus faecalis.[79]

7) Environmental

Environmentally friendly AgNPs are essential for wasted water treatment plants and biological systems. The inhibition effect of AgNPs on bacterial growth was evaluated in a medical facility using well-established breath measurement methods. Nitrifying bacteria can be inhibited by AgNPs, which can adversely affect microorganisms in wastewater treatment. Recently the environmental risk of AgNPs was investigated by measuring the silver released from clothing. Nutrient materials and washing water contain AgNPs with a diameter of 10 to 500 nm.[80]

8) Catalytic Action

The high surface energy and large surface area make metals NPs a good catalytic medium. Growing fine AgNPs proved a more efficient catalyst than stable colloidal particles. These growing particles catalyze the reduction of some organic dyes with borohydride. The reduction rate catalyzed by the growing particles was much faster than the larger and more stable particles of silver, the end product of the growing particles. Catalysis is based on efficient electron transfer by particles from BH4 ions to the dye. The catalytic activity of a particle depends on its size, dye E1/2, and dye interaction. Since the redox potential depends on sizes of NPs.[81]

3.2.11 Potential Application of AgNPs

Most industries today use unique characteristics of Ag material in the products such as fans, water filters, antibacterial spray, cosmetics, detergents, food additives, mobile devices, telephones, laptops, and keyboards. AgNPs are also broadly used in surgery instruments, dressing, composite prostheses, electronics, heart valves, and biosensors. AgNPs are also applied to or on different fabrics, room spray, water purifiers, nanodevices, and food containers. [82] Topical cream and ointments containing Ag to prevent infections in burn and open wounds are e.g. of the medical industry with the well-known use of silver and AgNPs. AgNPs have potential antibacterial activity against organisms like E. coli. Moreover, due to their functionalized surfaces, noble metal NPs such as AgNPs are an impactful and promising tool in terms of drug delivery applications.[83] That is the unique property of AgNPs such as the surface area to vol. ratio, apparent absorption, surface functionalization, and control drug released, are of importance in human life studies. AgNPs ensure food safety and extend shelf life by killing microorganisms when used in packaging. In addition, AgNPs-containing packaging films and coatings can absorb and degrade ethylene, a plant hormone is produced during aging. Eliminating ethylene from the center of the package increases shelf life of fresh fruit and vegetables. Addition of the applications related to human lives, the physical and chemical properties of NPs make them particularly appropriate for other high-technology applications. The development of new and better sensor devices, in particular electrochemical sensors and biosensors.[84] AgNPs have been used for electrical analysis by classification of biomolecules. AgNPs have better electrical conductivity and they act like electron transfer agents between protein and electrode. In addition, studies have shown that the AgNPs can be used as electrical bridges for electron transfer between electrodes and cytochrome-c.

4. CONCLUSION

Natural resources can reduce the content of Ag ions in AgNPs. The various biological compounds present in the plant extract can act as stabilizing and reducing agents for AgNPs synthesis. Plant-mediated AgNPs have more stability because of natural banding agents like proteins that prevent particle aggregation. The green synthesis of AgNPs using plant extract has a number of pros such as being environmentally friendly, biocompatibility, and economical. In conclusion, AgNPs play a vital role in many processes due to their unique properties based on nanotechnology. AgNPs have a wide range of important pharmacological properties and represent a cost-effective alternative to topical preparations. In addition to plant-mediated green synthesis, thereare particular focus on various biological assays that demonstrate AgNPs. This review paper will help research scholars develop new AgNPs -based drugs using environmentally friendly technologies.

5. AUTHORS CONTRIBUTION STATEMENTS

Mr. Akshay: Akshay carried out the literature survey and designed the manuscript. Dr. Rajeev Garg: This idea was conceptualized by Rajeev Garg. Anchal Verma and Akshay Saroha: Anchal Verma formatted and carried out a plagiarism check and Akshay Saroha reviewed the prepared manuscript.

6. CONFLICT OF INTEREST

Conflict of interest declared none.

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