Biosynthesis of metal nanoparticles and their application in the field of agriculture and biomedical sciences

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Abstract

The biosynthesis of metal nanoparticles has emerged as a sustainable and environmentally friendly approach, that offers unique advantages over conventional chemical synthesis methods. This procedure converts the metal ions into nanoparticles by using biological elements like plants, bacteria, and enzymes. The resultant nanoparticles have unique features and have a wide range of uses in industries including agriculture and the biological sciences. These green synthesis techniques are especially appealing for agricultural applications because of how cost-effective and environmentally friendly they are. The use of agro nanotechnology, which has applications from better food quality to reducing agricultural inputs, may significantly enhance crop productivity. Innovative methods like the detection and treatment of illness, the delivery of nanopesticides, the use of biopesticides and green pesticides, the gradual and continuous release of micronutrients, and fertilisers, etc. may be made possible by nanotechnology for the agro-food industry.

Keywords: - Nanotechnology, Fungi, Nanoparticles, Biosynthesis, Pesticides,

1. Introduction

The process of creating nanoparticls by utilizing biological agents, such as plants, bacteria, fungi, algae, or other biomolecules, is known as "biosynthesis of nanoparticles"[1]. Compared to conventional chemical and physical methods, this green synthesis strategy has a number of benefits, such as cost-effectiveness, the capacity to customize the characteristics of nanoparticles for particular applications, and environmental friendliness. Nanoparticle biogenesis has been investigated in a variety of biological systems [2]. A variety of bioactive substances, including polyphenols, flavonoids, and terpenoids, are present in plant extracts, particularly those from the leaves, stems, and roots. These substances are good reducing and stabilizing agents for nanoparticles. The reduction and stabilization processes are made easier by the enzymes and proteins that microorganisms like bacteria and fungi have. Algae and other biological agents have further demonstrated potential for nanoparticle production [3]. The synthesis of nanoparticles is in great demand nowadays as nanotechnology has emerged as a game-changing field with extensive applications in several sectors. The biosynthesis of nanoparticles and their potential use in agriculture is one of the most exciting and quickly developing fields of nanotechnology [4]. It is possible to increase nutrient absorption efficiency and decrease waste by the regulated and targeted administration of agrochemicals, such as fertilizers and pesticides, through nanocarriers, that can increase crop yield and minimize environmental pollution [5].

2. Nanoparticles

Nanoparticles are extremely small particles that generally vary in size from 1 to 100 nanometres (1 nanometre is equivalent to one billionth of a meter). Since they are so little, they display special traits and behaviour that set them apart from their bulk counterparts. Nanoparticles can be synthesized from various materials, such as metals, metal oxides, polymers, and carbon-based materials [6].

Nanoparticles are referred to as being "biosynthesized" when microorganisms extract target ions from their environment and change those metal ions into the element metal utilizing enzymes created by cell processes [7]. Production may be classified as intracellular or extracellular depending on where nanoparticles are produced. Delivering ions within the microbial cell, where they mix with enzymes to generate nanoparticles, is the intracellular strategy [8]. Nanoparticles are created extracellularly by trapping reducing ions in the presence of enzymes and metal ions on cell surfaces. The biosynthesized nanoparticles have been applied in a wide range of sectors that covers biosensors, speeding reaction speeds, separation research, cancer treatment, gene therapy, targeted administration of medicine, agriculture, pharmaceutical carriers, DNA analysis, antimicrobial compounds, and MRI [9].

Since the beginning of life on Earth, inorganic substances and biological ones have been interacting constantly. This continuous interaction made it possible for life to coexist with a well-organized mineral deposit on this planet [10]. Scientists' interest in the interactions between inorganic substances and living things has increased recently. Numerous bacteria can create inorganic nanoparticles via extracellular or intracellular pathways, according to studies. This section covers the categories of oxide nanoparticles made up of magnetic and nonmagnetic oxide nanoparticles, sulfide nanoparticles, and other ad hoc nanoparticles [11]. It also discusses the synthesis of various nanoparticles via biological processes. The topic also includes metallic nanoparticles like gold, silver, alloy, and other metal nanoparticles [12].

Fungi may be utilized to make a variety of nanoparticles, which include gold, silver, zinc oxide, and others [13]. Although nanoparticles have been utilized since the fourth century, Michael Faraday first scientifically characterized them in his study "The Experimental Relations of Gold and Other Metals to Light" published in 1857. These are of enormous scientific interest because they serve a significant role in acting as the connecting link between bulk materials, and atomic, or molecular structures. American physicist Richard Feynman's presentation, "There's Plenty of Room at the Bottom," delivered on December 29, 1959, at a conference of the American Physical Society held at Caltech is widely credited for inspiring the development of the area of nanotechnology. This talk marked the official beginning of nanoparticle research [14].

The biogenesis of nanoparticles includes two important categories.

The first process is called "Bioreduction" (in which metal ions are chemically reduced by living things into more stable forms), while the second is called "Biosorption" (in which nanoparticles from the environment adhere to living things) [15]. Numerous creatures with the potential to produce nanoparticles have not yet been fully investigated. In this work, we are aiming to identify fungi that can produce these nanoparticles as well as how to characterize them.

2.1. Trends for formulation of Nanoparticles:

There are basically two important trends in nanoparticle production [16]. these are the following: -

i. **Top down approach:**
   In a top-down technique, a bulk material is sliced into smaller and smaller pieces until a nano-sized particle is obtained. Typically, this approach is used in the physical production of nanoparticles [17].

ii. **Bottom up app approach:**
   In the bottom up technique, the substance is built up from the bottom up, or "bottom up." The creation of clusters or molecules as a result of atom-by-atom deposition results in the production of clustered monolayers on the surface of the substrate. It is usually done using chemical and biological methods [18].

2.2. Methods used for nanoparticle fabrication:

i. Physical methods:

The nanoparticles are synthesized using physical or mechanical processes are referred to as physical methods. Some of the important procedures include mechanical ball milling, vapor condensation, thermal decomposition, arc discharge, photo irradiation, laser ablation, ultrasonication etc [19].

ii. Chemical methods:

The production of nanoparticles by the action of various chemical processes are referred to as chemical methods. Some of the chemical methods include sol gel method, solvothermal process, electrochemical process, sonochemical process, thermal plasma synthesis etc [20].

iii. Biological method:

"Biosynthesis of nanoparticles" refers to the method of making nanoparticles with biomedical applications that utilizes microbes and plants. This approach is cost-effective, secure, compatible with biological systems, environmentally friendly, and secure [21]. The term "green synthesis" refers to synthesis that involves the use of plants, bacteria, fungi, algae, etc. They make it possible to produce industrial-scale, large quantities of pure ZnO NPs [22]. When NPs are produced via a biomimetic method, which also lessens the requirement for costly and hazardous chemicals, more catalytic activity may be seen [23]. The biogenic enzymatic method is more preferred in comparison of chemical methods in a number of aspects for producing nanoparticles. Although the latter methods may quickly create huge quantities of nanoparticles with certain sizes and shapes, they are challenging, antiquated, costly, and ineffectual, and they produce dangerous toxic wastes that are terrible for the environment as well as the human health [24]. Enzymatic processes reduce the need for pricey chemicals, and the more socially acceptable "green" alternative uses less energy and is better for the environment.

3. Methodology

There are so many methods for the biosynthesis of nanoparticles. Here we have preferred biosynthesis of nanoparticles using fungi. Soil samples has been collected from the mining area. The soil present in mining area is capable of degrading more variety of metals so it can be used for various metals degradation [25]. Isolation of fungi by serial dilution method has been performed. For this, take 1 g of soil, weighed, should be added to a test tube with 10 ml of distilled water and thoroughly mixed. Prepare five test tubes with a 9 ml capacity each for distilled water. Take now 1/11 of a ml of Stoke into the first tube for the initial dilution. Take 1 ml of the first dilution once more and add it to the second tube, which will contain the second dilution. For the remaining three test tubes, which will represent the third, fourth, and fifth dilutions, repeat this procedure. Now Place 1 ml of each filtrate dilution in a Petri plate, add the culture media, and then tilt the dish to evenly distribute the sample and media [26]. Perform the Identification of fungi by morphology and molecular method. The morphospecies of fungi will initially be determined from their cultures. Depending on their capacity for sporulation, the selected cultures will be injected on various medium. On PDA (Potato dextrose agar)-containing Petri plates, the isolates are inoculated and incubated at 24 ± 2^{0}C for around one week. Lactophenol cotton blue staining was used to identify fungi growing out of the explants when they were in the sporulation stage. In molecular method, for acquiring the fresh mycelia for DNA extraction, liquid cultures of fungal isolates were created using 50 mL of Potato Dextrose Broth medium (Hi Media, pH 7.3) in 100 mL Erlenmeyer flasks. Centrifugation at 8,000 rpm and 40C for 10 min was used to separate the mycelia. Mycelia were gathered and physically crushed in liquid nitrogen. From 100 mg of fungus mycelia, genomic DNA was isolated [27]. Screening of potential fungi for nanoparticle production has been done once the identification is done. Screening is the process of choosing and assessing various fungal species according to how well and quickly they can synthesize nanoparticles. This screening procedure helps in the discovery of fungi that might be good candidates for the manufacture of green nanoparticles [28]. Now metal nanoparticles from the fungi has been synthesized. 1 g of metal hexahydrate was dissolved in 2–10 mL of fungal extract. After being extensively swirled with the use of a magnetic stirrer and kept in a pre-heated muffle furnace maintained at t 400±10°C for two hours, the completed product was then further calcined at 700°C. So, it was also necessary to undertake a structural study on the synthesized metal NPs [29]. The size and architectures of the metal nanoparticles determine how much energy is required for the nucleation and growth of a supersaturated arrangement throughout various processes including coarsening, focused connection, and accumulation. Lastly, Purification and characterization of metal nanoparticles by spectroscopic and microscopic methods. (UV Visible spectroscopy, SEM, TEM, XRD) has been done. In a conventional UV-Vis spectrophotometer, one-half of a light beam is sent through a transparent cell holding a solution of the material being tested, and the other half is directed through a cell that is similar to the sample cell but contains the solvent instead of the substance. The device is designed to travel throughout the required wavelength range, allowing comparison of the intensity of the two beams [30]. If the substance absorbs light of a specific wavelength, the intensity of the sample beam (IS) will be lower than the intensity of the reference beam. The production of the spectrum involves measuring the absorption of radiation by a sample at various wavelengths and recording the findings. The wavelength of the whole area is plotted against the absorption (A) of light at each wavelength to form the spectrum. The graph between (hv versus h) may also be plotted along the x-axis to determine the sample's band gap. Calculating the quantity of a component known to be present in the sample using UV-Vis spectrometry is almost exclusively employed for quantitative analysis. Usually, a solution is used to analyze the substance [31].

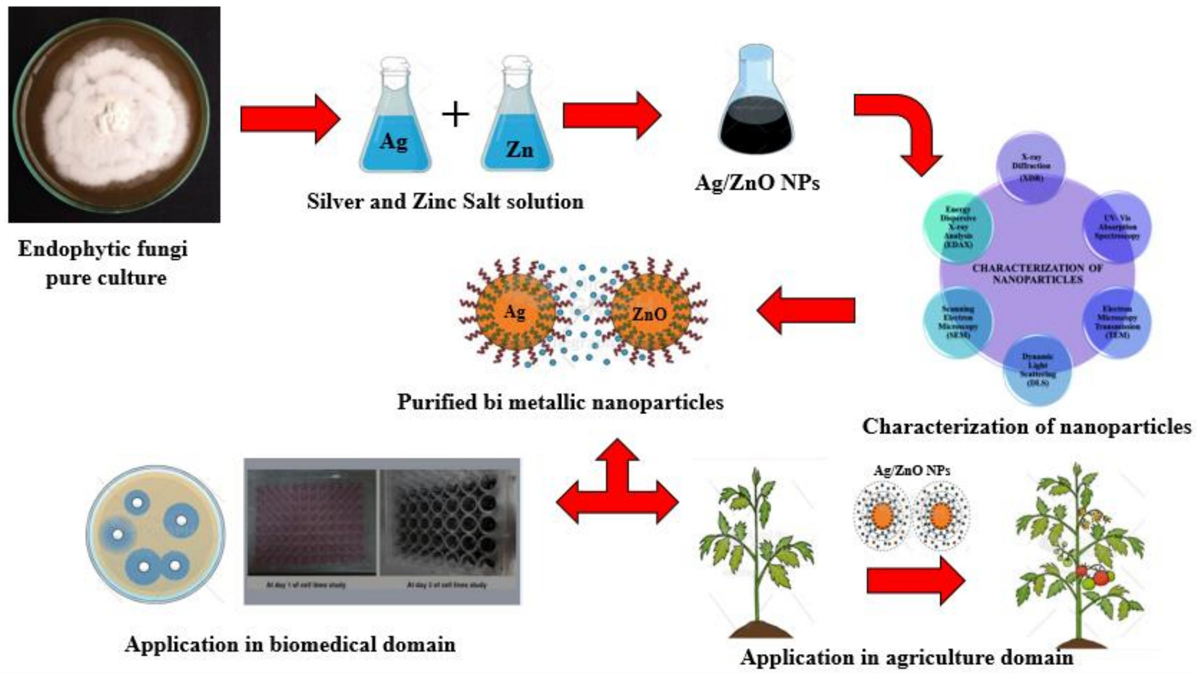

Figure 1: Schematic representation of applications of metallic nanoparticles

4. Applications

Due to their distinctive characteristics and variety of capabilities, metal nanoparticles have a wide range of applications in a variety of sectors. Fig 1. Shows some of the applications of nanoparticles of metal nanoparticles in various fields.

4.1. Agricultural applications

4.1.1. Nanoparticle's interaction with the plants

The agricultural industry benefits from advances in science and technology, which provide us with fresh ideas and solutions to difficult issues. With the development of nanotechnology, more effective and contaminant-free nanoformulations for sustainable agriculture are constantly being developed [32]. These novel compounds can affect plant physiology immediately after entering the complicated plant-soil system, which may be easily exploited to understand the consequences. Furthermore, crucial information on the interaction of these NMs with plants, whether positive or negative, is necessary for the regulated delivery of active chemicals. As a result, they may open up new opportunities for manufacturing superior nanomaterial-based goods. It is also thought that the concentration of NMs in the natural environment is substantially lower than levels considered harmful [33].

- Size-Dependent Uptake of NPs
- Surface Charge-Dependent Uptake of NPs
- Anatomical Difference and Mode of Application-Related NP Uptake
- Methods to Study Uptake, Quantification, and Translocation of NPs

4.1.2. NPs for Plant Growth and Seed Germination

The absorption of NMs within plants is heavily influenced by the size, chemical content, and functional groups on their surface, as well as the kind of coating. The interaction and absorption of NMs cause molecular changes that alter plant physiology overall . The potential impact of multi-walled carbon nanotubes (MWCNTs) on tobacco cell development (55-64% increase) is due to a novel molecular mechanism. The bulk of the genes that have been activated are involved in cell division (CycB), cell wall expansion (NtLRX1), and tobacco aquaporin (NtPIP1) [34]. The capacity of NMs to penetrate the hard layer of seeds and enable water importation determines improved development and vigor. Furthermore, the seed priming technique using nanotechnology is a promising strategy; before planting, it confirms the potential of high-yield value crops [35]. The use of MWCNTs has an impact on the development of various essential crops, including barley, soybeans, and maize. Raman spectroscopy and TEM imaging demonstrated that MWCNTs congregate inside the endosperm of exposed seeds. The nanoparticles were delivered to various regions of the plant and interacted with cellular machinery, boosting plant development. Mesoporous silica nanoparticles (MSNs) can promote photosynthesis by interacting with chloroplasts, resulting in higher seed germination, total protein, and chlorophyll content. MSNs at the greatest concentration (2,000 mg/l) did not cause stress in any of the plants, indicating a safer application as a smart delivery method [36]

4.2. Role in Biomedical Sciences

4.2.1. Drug delivery

Drug transfer to particular places is important in biological and medical science because it allows medications to be delivered to the desired spot while avoiding injury to normal cells in the surrounding environment. Biological components such as carbohydrates, protein, phenols, receptors, and medicines might be coupled with endophytic fungal-generated silver-zinc oxide NPs via surface alternation of green-produced nanoparticles. This alternative describes a specific role of bionanoassembles that allows them to be used in medicine for specific medication delivery [37]. As a result, it is appropriate to precisely target tumor cells using endocytosis, a lively targeting approach. Similarly, the outer surface of green processed nanomaterials is surrounded by biological chemicals derived from plant extract, which may be transmitted. Meanwhile, bimetallic nanoparticles are known for their exceptional assembly capability due to their enhanced surface area, which allows them to bond with a wide range of chemical compounds such as biological molecules and medicines. Thus, plant-based metal nanoparticles may be taken up or function by fungal extract biomolecules, which can be used as a natural linker for drug delivery to the appropriate places [38]. The biostability of biosynthesized silver-zinc oxide bimetallic nanoparticles in healthy and diseased cells makes them more reliable as a drug delivery vector. The enhanced activity of the drug delivery system might be attributed to the bimetallic nanoparticles' extra targeted effects, greater penetrability, and retaining properties. Analyzing the biocompatibility of fungal-derived metal nanoparticles, it is simple to predict the utility of biologically produced manufactured metal NPs as a competent vehicle for cancer-targeted drug administration in the future [39].

4.2.2. Antioxidant Use

The endophytic fungal Ag/ZnO alloy NPs are being acknowledged for carrying antioxidant use as compared to metallic NPs. DPPH free radicals indicate antioxidant action depending upon quantity at an optimal concentration of synthesized NPs compared to ascorbate (standardized antioxidant anion). Additionally, solution change of color is due to NPs observed. Researchers showed that the combination of silver with zinc oxide forming plant-based nanomaterials increases their antioxidant capacity and their anti-proliferative behavior causes the elimination of free radicals [40]. Metal NPs as an antioxidant agent could be additionally applicable against vital fights like liver problems and cancer. The greatest barrier to bacterial tolerance in the surrounding environment is cell walls and plasma membranes. The absence of a peptidoglycan coating in the cell wall of gram-negative bacteria increases bacterial activity on them [41]. Because of their greater surface-to-volume ratio, NPs generate more reactive oxygen species. However, anions such as hydroxide and superoxide that stay on the cell wall of bacteria undermine comprehensiveness, potentially leading to cell wall breakdown and the release of intracellular contents, ultimately leading to cell death. While a molecule like H2O2 is detrimental to cell respiratory enzymes. The roughness of the nanoparticle's surface produced cell wall destruction, resulting in enhanced plasma membrane penetrability to metallic ions present on nanoparticles, culminating in bacterial toxicity [42]. Metal nanoparticles are more effective antibacterial agents than other nanoparticles such as titanium oxide-zinc NPs. Finally, it has been determined that the generation of ROS species on the surface of bacterial cell walls causes cell wall rupturing as the negatively charged cell wall absorbs positively charged silver and zinc ions, causing an alternation in electrodynamic interaction that eventually leads to death [43]. The use of Metal NPs against pathogenic bacteria and organisms in plants has received little attention. Meanwhile, the globe faces malnourishment and food scarcity, with these hazardous organisms playing a role in crop destruction; hence, this might be a primary area of concern for revolutionary research on metal nanoparticles, raising the relevance of these NPs in their applicability [44].

4.2.3. Antimicrobial Use

Endophytic fungal-derived metal alloy nanoparticles were successfully described as an agent that inhibits microbial development by destroying it. When compared to monometallic nanoparticles, these alloy NPs demonstrated enhanced antibacterial activity. Because of their tiny size and photocatalytic capabilities, metal NPs have demonstrated action against Micrococcus luteus and E. coli [45]. Furthermore, the antibacterial activity of metal NPs against S. aureus, P. aeruginosa, S. epidermis, B. subtilis, K. pneumonia, and P. aeruginosa. As a result, among other nanomaterials, metal NPs were used to evaluate their impact on microorganisms [46]. These nanoparticles have shown significant effectiveness against infective gram-positive and gram-negative bacterial strains.

4.3. Other applications

Agriculture	Food processing	Food packaging	Supplements
Nanocapsules used to deliver pesticides, fertilizers and other agrichemicals more efficiently	Nanocapsules improve bioavailability of neutraceuticals in standard ingredients such as oil	Fluorescent nanoparticles detect foodborne pathogens	Absorption of nutrients can enhanced by nanosize powder
Nanosensors used to monitor soil conditions and crop growth	Nanoparticles used as gelation and viscosifying agents	Nanosensors used to maintain temperature and time	Cellulose nanocrystals used as drug carrier
Detection of animal and pathogen can be detect by nanosensors	Nanoemulsion and particles are good for nutrients availability and dispersion	Nanoclays and nanofilm used to prevent food spoil	Better absorption and stability by nanoencapsulation
Nanocapsules use for vaccine deliver	Nanocapsules enhance flavor	Nanoparticles can used for antimicrobial and antifungal property	Deliver nutrients without affection color and taste of food
DNA delivery can be done by using nanoparticles	Nanoparticles can bind and remove pathogens and chemicals from food	Modified permeation behavior of foils	Nanodroplets for better absorption

5. Conclusion

The synthesis of metallic nanoparticles with the help of fungi was employed in this study to make compacts utilizing a low-combustion method. Ultraviolet-visible spectroscopy, FT-IR, SEM with EDX, DLS, and TEM with SEAD will be used for the characterization of the produced nanopowder to show the production of the nanoparticles. This research will focus on the fungi-mediated synthesis of metallic nanoparticles in a simple and environmentally acceptable technique that is innovative, nontoxic, and cost-effective when compared to physical and chemical production. The green synthesis techniques provide a number of benefits over conventional chemical and physical procedures, including the use of plant extracts, microbes, fungi, or other biomolecules. Improved nutrient absorption efficiency, reduced waste, and reduced environmental effect are the results of the controlled and targeted dispersion of agrochemicals that use nanocarriers, including as fertilizers and pesticides. Because of the increased demand from the application point of caution tests, large-scale research, and the development of vaccine and home-derived applications, fungal-derived synthesis can provide a valuable and monetary outlet for these NPs. As a result, wide study studies on manufacturing and changing fungal-generated metal NPs to cope with the potentials typically provided by chemically manufactured metal NPs are unquestionably necessary.

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