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Silver nanoparticles: A new Era of nanobiotechnology

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Abstract
Nanotechnology is a fast emerging field in physics, chemistry as well as in biology. In view of the tremendous applications of nanotechnology, scientists are in flick to carry out research in this vital discipline. Chemists are highly interested in synthesizing nanoparticles of different dimensions employing many of the precious metals. Now a days scientist have started the exploitation of bio-based synthesis of nano-particles using leaf extracts and microorganisms. The development of eco-friendly procedures for the metal nanoparticles synthesis through biological process is evolving into an important branch of nanobiotechnology. Generally, nanoparticles are synthesized by chemical and physical methods, which are not eco-friendly so it is necessity to synthesized nanoparticles using plant extracts or from the plant source. Nanotechnology is gaining tremendous impetus in the present century due to its capability of modulating metals into their nanosize, which drastically changes the chemical, physical and optical properties of metals. Metallic silver in the form of silver nanoparticles has made a remarkable comeback as a potential antimicrobial agent.

Keywords: Nanotechnology, nanoparticles, phytonanoparticles, metallic silver, biogenesis, silver nanoparticles, mechanism of action of silver nanoparticles, application of nanoparticles

1. Introduction

1.1 Nanotechnology

One of the important characteristics of biological system is their ability to change important properties in response to small environment signals. Till recent times Nanotechnology has been a domain of physics, chemistry, electrical engineering and material sciences. Nanotechnology is now creating a growing sense of excitement in the life sciences especially biomedical devices and Biotechnology.

Nanotechnology refers broadly to a field of applied science and technology whose unifying theme is the control of matter on the atomic and molecular scale[1]. Nanotechnology refers to the study of compounds of 100 nanometers or smaller in one dimension. Nanotechnology has a variety of applications in fields such as optics, electronics, bio-medicine, mechanics, catalysis and the energy science, etc. Thus, development of different branches of nanotechnology results in developing the related sciences, and is a consequential goal of scientific word. The bio - molecules from various plant components and microbial species have been tremendously used as potential agents for the synthesis of silver nanoparticles (AgNPs) [2].

Nanotechnology is usually represented by two different approaches: 'top-down' and 'bottom-up'. 'Top-down' refers to making nanoscale structures through the use of lithographic techniques, whereas 'bottom-up', or molecular nanotechnology, is related to building organic and inorganic materials into defined structures, atom-by atom or molecule-bymolecule, often by self-assembly or self-organization. Bionanotechnology has emerged up as integration between biotechnology and nanotechnology which is the eco-friendly technology for synthesis of nanomaterials.

1.2 What are nanoparticles

Nanoparticles (matter having nanometre dimensions, (1 nm = 10^{-7}). Metal nanoparticles emerging as new field and have received considerable attention in recent years because of their potential applications in catalysis [3], optoelectronics [4], biosensor [5, 6] and pharmaceutical applications [7]. Their performance depends critically on their size, shape and composition. Chemical synthesis methods are available for the synthesis of metal nanoparticles, many of the reactants and starting materials used in these methods are toxic and potentially hazardous in concern with biological applications [8]. The synthesis of inorganic nanoparticles by biological systems makes nanoparticles more biocompatible and environmentally benign.

1.3 What are phyto nanoparticles
The biological synthesis of gold or silver nanoparticles using a phytochemical is called phytonanoparticles.

1.4 Metallic silver
Silver antimicrobial property is related to the amount of silver and the rate of silver released. Silver in its metallic state is inert but it reacts with the moisture in the skin and the fluid of the wound and gets ionized. The ionized silver is highly reactive leading to cell distortion and death, as it binds to tissue proteins and brings structural changes in the bacterial cell wall and nuclear membrane. Also, silver binds to bacterial DNA and RNA by denaturing and inhibits bacterial replication [9, 10].

2. Biogenesis of metal nanoparticles
2.1 Bacteria
Magnetotactic bacteria are a group of gram-negative prokaryotes that are diverse with respect to morphology and habitat. They have the ability to synthesize fine (50-100nm) intracellular membrane bound ferromagnetic particles composed of magnetite (Fe_3O_4) or greigite (Fe_3S_4) which are covered with an intracellular phospholipids membrane; the structures thus formed are called magnetosomes [11].

2.2 Higher Plants
Armendariz and co-workers studied Oat (*Avena sativa*) biomass as an alternative to recover Au (III) ions from aqueous solutions and for its capacity to reduce Au_3+ to Au^+ forming Au nanoparticles. To study the binding trend of Au_3+ to oat and the possible formation of Au nanoparticles, the biomass and a solution of Au_3+ were reacted for a period of 1 hr at pH values ranging from 2 to 6.The results demonstrated that Au_3+ ions were bound to oat biomass in a pH-dependent manner, with 80% adsorption at pH 3. HRTEM (High Resolution Transmission Electron Microscopy) studies showed that oat biomass reacted with Au_3+ ions formed Au nanoparticles of FCC (face centered cube), tetrahedral, decahedral, hexagonal, icosahedral multi-twined, irregular and rod shape [12]. These studies also showed that the pH of the reaction influenced the nanoparticle size. The smaller nanoparticles and the higher occurrence of these were observed at pH values of 3 and 4, whereas the larger nanoparticles were observed at pH 2.

2.3 Fungi – as model systems for nanoparticles biosynthesis
For large-scale biosorption of metals, fungi possess unique advantages over bacteria:
1. Most fungi have a very high wall-binding capacity as well as intracellular metal uptake capacities [13].
2. They are easy to culture on a large scale by solid substrate fermentation, thus making a large amount of biomass available for processing.
3. Fungi can grow over the surface of inorganic substrate during culture. This leads to the metal being distributed in a more efficient way as a catalyst.
4. Fungi produce large amount of enzymes per unit biomass.
5. The use of specific enzymes such as reductases secreted by fungi opens up exciting possibilities of designing a rational biosynthesis strategy for metal nanoparticles of different chemical composition.

2.4 Silver nanoparticles
Silver nanoparticles are mostly synthesized through various colloidal processes of surfactant-stabilized silver nanoparticles in liquid phases through chemical reductions of silver salts in aqueous solutions. With some exceptions, most of the chemical synthetic approaches are based on the reduction of water-soluble silver salt precursors, $AgNO_3$ and its derivatives by boron hydrides, alcohols, citrates and alkyl sulfates. The stability of the synthesized nanoparticles has been problematic, as they aggregate and precipitates out over time in aqueous solution [14].

2.5 Synthesis of silver nanoparticles using plant extract
Primarily the plant parts such as leaf washed and the clean leaves have to dry with water absorbent paper. Then cut it into small pieces (but do not grind it) and dispensed in sterile distilled water and then boiled for one hour at 80 ^{0}C. Then collect the extract in separate conical flasks by standard filtration method. Add silver nitrate solution in the extract and keep the extract for incubation till 28 hrs. The color changes from pale green to dark brown. This indicates the synthesis of silver nanoparticles and finally they assess for the antimicrobial activity [15].

2.6 Mechanism of action of silver nanoparticles
As compared to other salt, silver nanoparticles shows efficient antimicrobial property due to their extremely large surface area and provides better contact with the microorganisms as it attached to the cell membrane and also penetrate inside the bacteria. The bacterial membrane contains sulfur-containing proteins and the silver nanoparticles interact with these proteins in the cell as well as with the phosphorus containing compounds like DNA. As silver nanoparticles enters the bacterial cell it forms a low molecular weight region in the center of the bacteria to which the bacteria conglomerates thus, protecting the DNA from the silver ions. These nanoparticles mostly attack the respiratory chain, cell division finally leading to cell death. The nanoparticles release silver ions in the bacterial cells, which enhance their bactericidal activity [16-18].

3. Applications of nanoparticles
3.1 Agriculture
Agriculture is the backbone of most developing countries, with more than 60% of the population reliant on it for their livelihood. Rickman and co-workers reported the application of nanotechnology in precision farming to enhance crop yields (outputs) through minimizing input (fertilizers, pesticides, herbicides). Precision farming made use of computers, global satellite positioning systems, and remote sensing devices (biosensors) prepared by using different nanomaterials to measure highly localized environmental conditions, in order to determine whether crops were growing at maximum efficiency. Nanopesticides and nanoherbicides were being extensively used in the agriculture for making formulations which contain 100–250 nm nanoparticles that are more soluble in water thus increasing their activity. Other companies employed nanoemulsions of nanoscale particles, which could be either water or oil-based and contained uniform suspensions of pesticide or herbicide nanoparticles of 200–400 nm [19].

3.2 Medicinal and health care
Nanoparticles have been recently used to improve the

techniques for *in vivo* diagnosis of biomedical disorders. Iron oxide nanoparticles are currently being used for patients diagnosis and therapy [20]. There have been several reports regarding the use of AgNPs as therapeutic agents, as glyconano sensors for disease diagnosis [21].

3.3 Textile Industry
Now a days silver nanoparticles have been used to produce ‘‘anti-odour’’ clothes, automotive interiors, household products such as kitchen cloths, sponges, towels, bed lines or reusable surgical gloves and masks [22]. Nanosilver-based disinfectant solutions mostly useful for the surface decontamination, tools in kindergartens, schools, workplaces, for different types of equipment and computers, toys, all kinds of furniture and the like, in industrial and domestic, and public utilities. This will open new opportunities to develop nanosilver-based consumer products for surface disinfection such as spray bottles, disposable wipes for disinfecting hands and to maintain daily personal hygiene, etc. In this way, nanosilver based products can be sprayed on surfaces and materials in order to inhibit the pathogen development and to improve human health and safety [23].

3.4 Preservative agent
The use of anodic silver as preserving agents in cosmetics was also tested by challenge test in a set of cosmetic dispersions with the addition of known preservative inhibitors or microorganism growth promoters such as humectants, hydro soluble collagen as well as for vegetable extracts.

3.5 Other uses
Silver nanoparticles can be used for water filtration [24], DNA can be delivered to plants using nano-particles in genetic engineering, nano-capsules can be used for delivery of pesticides, fertilizers and other agrichemicals more efficiently, soil conditions, soil health status and crop growth can be monitored with the help of nano-sensors, for monitoring plant microenvironment and its changes and in green house production of protected cultivation.

3.6 Conclusion and future prospects
In summary, it can be conclude, that among the different antimicrobial agents, silver has been most extensively studied. The antibacterial, antifungal properties of silver nanoparticles have been extensively studied. The silver nanoparticles with their unique chemical and physical properties are proving as an alternative for the development of new antibacterial agents. The silver nanoparticles have also found diverse applications in the agriculture as nanopesticides and nanoherbicides, in medical sector, in textile industry and also as a preservative agent. The advantage of using silver nanoparticles for impregnation is that there is continuous release of silver ions and the devices can be coated by both the outer and inner side which enhances its antimicrobial efficacy. The burn wounds treated with silver nanoparticles shows better cosmetic appearance and scar less healing. Thus, it can be concluded that metallic silver has been in use since ancient times.

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