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Biomedical Applications of Marine Microbes for Metallic Nanoparticle Production

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Introduction

Nanotechnology is one of the most promising technologies being used in various disciplines of research. Nanotechnology multidisciplinary studies are exciting because of its vast range of applications in biology, chemistry, engineering, medical sciences, and so on. The biosynthesis of metallic nanoparticles has attracted increased attention in recent years as a potential platform for bionanotechnology and biomedicine. Metallic nanoparticles are a viable biological and scientific solution to problems in a variety of disciplines, including biomedicine, cosmetics, food packaging, and bionanotechnology. The prefix nano was derived from the Greek term Nanos, which means "dwarf," and was used to describe objects one billionth (10^{-9} metre) in size. Metallic nanoparticles are typically manufactured in two ways: top-down and bottom-up [1].

Different ways to metallic nanoparticle synthesis exist, with the top-down approach including physical methods and the bottom-up approach including chemical and biological methods. The use of high temperatures, pressure, and hazardous chemicals in physical and chemical methods of nanoparticle synthesis is harmful to the environment. Furthermore, due to their low biocompatibility and instability, chemically produced nanoparticles can only be used in biomedical applications. Bioreduction, also known as the green method for metallic nanoparticle synthesis, is a bottom-up approach in which plant extracts or microorganisms employed for metal salt reduction are converted into nanometre-sized metals. This approach produces nanoparticles that are harmless and stable.

Description

Nanotechnology has become one of the most in-demand technologies in a variety of scientific sectors. The creation of metallic nanoparticles utilising marine microorganisms has attracted worldwide attention due to its numerous uses in biomedical science. The utilisation of marine microorganisms for the manufacture of metallic nanoparticles is environmentally friendly, time efficient, and cost effective. To reduce waste and safeguard the environment, an eco-friendly solution is required. Marine microorganisms have recently been identified as an environmentally safe and efficient technique to use as prospective biofactories for the manufacture of metallic nanoparticles. In this paper, we explore and describe the potential uses of marine microorganisms such as bacteria, fungus, and microalgae for metallic nanoparticle manufacturing, as well as the applications of those nanoparticles as antibacterial and anticancer agents [2].

Aquatic microorganisms are microscopic creatures that dwell in the marine environment. Algae, yeast, fungi, bacteria, actinobacteria, and cyanobacteria are examples of cellular life forms. In industrial point of view, the marine microorganism is a very promising option for the synthesis of biologically essential metabolites. Microbes and their products have been used in a variety of industries, including agriculture, cosmetics, food production, fermentation, medications, and pharmaceuticals. Marine microorganisms have recently been identified as prospective biofactories for the environmentally benign and low-cost production of metallic nanoparticles. Furthermore, metallic nanoparticles biosynthesis is an important green chemistry process that integrates nanotechnology and microbial biotechnology [3].

Synthesis of nanoparticles

Prokaryotic and eukaryotic microorganisms living in a marine environment with different conditions such as alkaline, acidic, hypersaline, and variable temperatures include bacteria, fungus, and microalgae. They are either unicellular or multicellular and account for more than 90% of the sea's biomass. New material synthesis methods that are reliable, environmentally safe, and non-toxic for medical and healthcare applications are still being developed. Biosynthesis is the technique of creating nanoparticles by an enzymatic reaction or a biological mechanism. Researchers are currently interested in the production of metallic nanoparticles using marine microbes since it is a straightforward, cost-effective, and environmentally benign process. Furthermore, the nanoparticles created can be used in healthcare.

The precise mechanism of microbial intracellular synthesis of nanoparticles is unknown due to the involvement of various bacteria and microbial biomolecules with various metal ions. Theoretical intracellular manufacturing of nanoparticles is accomplished by trapping positively charged metal ions on the surface of the cell wall or in the cytoplasm containing negatively charged enzymes or proteins. The trapped metal ions are reduced to produce tiny nuclei, which then form various morphological nanoparticles. According to studies, Rhodococcus Spp. gold nanoparticle synthesis was found on the surface of mycelia and the cytoplasmic membrane in alkalotolerant actinomycetes. As a result, more gold nanoparticles were found on the cytoplasmic membrane than on the cell wall, indicating that the gold nanoparticles are created as a result of the interaction of the enzymes present on the cytoplasmic membrane. When the fungus Verticillium species biomass was exposed to Ag^+ ions, the silver nanoparticle was formed below the cell wall surface, presumably due to enzymes found on the cell wall membrane. In the case of Tetraselmis kochinensis, the biomass was introduced to the HAuCl4 solution and the production of gold nanoparticles was observed [4,5].

The extracellular creation of metallic nanoparticles is dependent on microbial proteins on the surface or enzyme secretion. For the construction of nanoparticles, biological templates such as DNA and proteins have been reported. The role of the enzyme nitrate reductase in the creation of metallic nanoparticles by reducing metal ions is well established. Many studies support this method; for example, the enzyme nitrate reductase from the fungus Fusarium oxysporum has been described for the creation of silver nanoparticles from $AgNO_3$. Finally, the electron is received by the gold ions, who reduce it to make gold nanoparticles. Ferreira and colleagues reported the extracellular production of silver chloride nanoparticles utilising the microalga Chlorella vulgaris. Silver nitrate was converted into silver chloride nanoparticles by the microalgae, and proteins are involved in the production and stabilisation of silver chloride nanoparticles. However, the precise process underlying the extracellular creation of metallic nanoparticles utilising algae is still unknown.

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To obtain purified nanoparticles, the intracellular nanoparticles synthesis method requires multiple steps, including lysis of microbial cells to collect the intracellularly synthesised nanoparticles, repeated washing and centrifugation to remove unnecessary cell debris, cellular components, and others. In general, metallic nanoparticles are biosynthesised using various reactants such as active biomass, cell-free supernatant or cell extract, and culture supernatants of marine microorganisms. The manufacture of several forms of metallic nanoparticles has been described using marine bacteria, actinobacteria, proteobacteria, and cyanobacteria. The biological manufacture of silver nanoparticles of 200 nm size using Pseudomonas stutzeri AG259 was first described; the species was silver resistant, isolated from a silver mine, and generated silver nanoparticles were accumulated in periplasm.

Researchers have recently focused their attention on the rapidly evolving field of nanotechnology, which uses marine microorganisms in the production and functionalization of metallic nanoparticles for biomedical applications. Metallic nanoparticles mediated by marine microorganisms are proposed as a revolutionary nanomedicine and have recently been studied for their potential applications in several domains.

Conclusion

Metallic nanoparticles mediated by marine microbes are non-toxic and environmentally benign. Marine microorganisms such as bacteria, fungus, and microalgae have recently been used in nanotechnology and biotechnology as a trustworthy resource for the development of environmentally acceptable methods for the synthesis of metallic nanoparticles and their biological and medicinal applications. The formation of nanoparticles is classed as extracellular or intracellular dependent on where the nanoparticles form. Metallic nanoparticles' shape and size can be modified by adjusting reaction parameters such as pH, duration, temperature, and reactant ratio. Furthermore, genetic and proteomic manipulation of microbes could be a wonderful way to optimise nanoparticle production.

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