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Myconanotechnology and application of nanoparticles in biology

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Abstract
To develop a new green approach for biosynthesis of nanoparticles, myconanotechnology has been represented as a novel field of study in nanotechnology. Several scientists have re-explored the fungi including yeasts and filamentous fungi as a biofactory for eco-friendly, cost-effective synthesis of nanoparticles. The advantageous of fungal-mediated biosynthesis of nanoparticles have turned the attention of scientists to the kingdom of fungi. The most notable benefits of applying fungi in nanoscience are their resistance to many harsh conditions as well as secretion of extracellular reductive proteins so that it makes the downstream processes easier. This review focuses on general introduction, synthesis of nanoparticles through fungi and its application in biology.

Keywords: Myconanotechnology, fungi, nanotechnology, nanoparticles, extracellular.

INTRODUCTION

Nanotechnology is a multidisciplinary science comprising various aspects of research and technology [1]. Nanoparticles are metal particles in the size range of 1-100nm and form building blocks of nanotechnology [2]. Metal nanoparticles like gold, silver and platinum have gained considerable attention in recent times due to their fundamental and technological interest. Myconanotechnology is the interface between '*Mycology*' and '*Nanotechnology*' and has considerable potential, partly due to the wide range and diversity of the fungi [3]. When focusing on the synthesis of nanoparticles using fungi, it was observed that nanoparticles of good monodispersity and well dimensions could be synthesized. As fungi are found to secrete high amount of protein they might result in the significant mass productivity of nanoparticles. The fungal proteins are capable of hydrolyzing metal ions. In addition to this, fungi are easy to isolate and culture. Moreover, the downstream processing and the handling of fungal biomass are less complex than the synthetic methods [4].
'Mycology' is the study of all aspects of fungi. Environmentally, fungi are of vital important. An attractive possibility of green nanotechnology is to use micro-organisms in the synthesis of nanoparticles. Recently, the utilization of biological systems, especially fungi, has emerged as a novel method for the synthesis of nanoparticles.

At the nanoscale level, the properties of matter are significantly different from their macroscopic bulk properties. Nanotechnology is also referred to the ability for designing, characterization, production and application of structures, devices and systems by controlling shape and size at the nanometer scale [5]. Nanoparticles are viewed as the fundamental building blocks of nanotechnology [6]. They are the starting points for preparing many nanostructured materials and devices.

Currently, there is a growing need to using environmentally friendly nanoparticles that do not produce toxic wastes in their process synthesis protocol. Certain bacteria, yeasts and now fungi play an important role in remediation of toxic metals through reduction of the metal ions. For example, environmentally friendly microorganisms could minimize the toxicity in the process of metallic nanoparticle production by reduction of the metal ions or by formation of insoluble complexes with metal ions (e.g. metal sulfides) in the form of colloidal particles [7].

Nanoparticle production through fungi:

Mycofabrication can be defined as the synthesis of metal nanoparticles using fungi. The fungal system in recent times has emerged as "Bionanofactories" synthesizing nanoparticles of silver, gold, platinum and CdS etc. Fungi can accumulate metal ions by physico-chemical and biological mechanisms including extracellular binding by metabolites and polymers, binding to specific polypeptides, and metabolism-dependent accumulation [8]. The possible use of fungi has gained much importance, as they are easy to culture in bulk. Also, the extracellular secretion of enzymes has an added advantage in the downstream processing and handling of biomass [9] when compared to the bacterial fermentation process which involves use of sophisticated instruments to obtain clear filtrate from the colloidal broth [10]. Moreover, fungi are excellent secretors of protein compared to bacteria and actinomycetes, resulting into higher yield of nanoparticles [10]. Thus, using these dissimilatory properties of fungi, it could be extensively used for the rapid and eco-friendly biosynthesis of metal nanoparticles.

In the biosynthesis of metal nanoparticles by a fungus, the fungus mycelium is exposed to the metal salt solution. The presence of hydrogenase in fungi, such as Fusarium oxysporum [11], Trichoderma reesei [12] and Trichoderma viride, was demonstrated with washed cell suspensions that had been grown aerobically or anaerobically in a medium with glucose and salts amended with nitrate. Many fungi that exhibit these characteristic properties, in general, are capable of reducing Au (III) or Ag (I) [13]. Extracellular production of gold, silver and bimetallic Au-Ag alloy nanoparticles by the fungus Fusarium oxysporum [14] was already observed. It has been also observed that the exposure of aqueous solutions of metal salts or a mixture of metal salts to Fusarium oxysporum resulted in extracellular formation of nanoparticles of dimensions 5–50 nm and alloy nanoparticles of dimensions 8–14 nm [15].

Applications

The unique properties of nanomaterials encourage belief that they can be applied in a wide range of fields, from medical applications to environmental sciences. Studies conducted by nanotechnology experts mapping the risks and opportunities of nanotechnology have revealed enormous prospects for progress in both life sciences and information technology [16]. Medical applications are expected to increase our quality of life through early diagnosis and treatment of diseases, and prosthetics, among others.

Imaging

1) Scanning microscope imaging. SWCNTs have been used as probe tips for atomic-force microscopy imaging of antibodies, DNA, etc. [17]. Nanotubes are ideal probe tips for scanning microscopy due to their small diameter (which maximizes resolution), high aspect ratio, and stiffness.

2)Molecular-recognition AFM tips. SWCNTs with attached biomolecules are attached to AFM tips, and used for "molecular-recognition" in order to study chemical forces between molecules [17].

Biomedical applications

1) Nanoscaffolds. Nanofiber scaffolds can be used to regenerate central nervous system cells and possible other organs. Experiments performed on a hamster with severed optic tract demonstrated the regeneration of axonal tissue initiated by a peptide nanofibers scaffold [18].

2)Antimicrobial nanopowders and coatings. Certain nanopowders, possess antimicrobial properties [19], [20]. When these powders contact cells of *E. coli*, or other bacteria species and viruses, over 90% are killed within a few minutes. Due to their antimicrobial effect, nanoparticle of silver and titanium dioxide (<100nm) are assessed as coatings for surgical masks [21].

3) Bioseparation. Nanotube membranes can act as channels for highly selective transport of molecules and ions between solutions that are present on both side of the membrane [22]. For example, membranes containing nanotubes with inside diameters of molecular dimensions (less than 1 nm) separate small molecules on the basis of molecular size, while nanotubes with larger inside diameters (20–60 nm) can be used to separate proteins [23].

4) Drug delivery. The ability of nanoparticles to target and penetrate specific organs and cells contributes to their toxicity, however, this ability may be exploited in nanomedicine. Nanospheres composed of biodegradable polymers can incorporate drugs, allowing the timed release of the drug as the polymer degrades [24]. When particles are set to degrade in an acid microenvironment, such as tumor cells or around inflammation sites, this allows site-specific or targeted drug delivery.

5) Gene transfection. Surface-functionalized nanoparticles can be used to permeate cell membranes at a much higher level than nanoparticles without a functionalized surface [25]. This property can be used to deliver genetic material into living cells, a process called transfection. For example, silica nanospheres labeled on their outer surfaces with cationic ammonium groups can bind DNA (a polyanion) through electrostatic interactions [26]. Then nanoparticles deliver the DNA into cells.

6) Medical imaging. A variety of techniques currently called "non-invasive" have been used for more than a quarter of a century in medical imaging, for example super paramagnetic magnetite particles coated with dextran are used as image-enhancement agents in magnetic resonance imaging [27]. Intracellular imaging is also possible through attachment of quantum dots to selected molecules, which allows intracellular processes to be observed directly.

7) Nasal vaccination. Nanospheres carriers for vaccines are in development. Antigen-coated polystyrene nanospheres, used as vaccine carriers targeting human dendritic cells, have been researched for nasal vaccination [28]. Nanospheres had a direct effect on human dendritic cells, inducing transcription of genes important for, e.g., phagocytosis as well as an immune response.

8) Nucleic acid sequence and protein detection. Targeting and identifying various diseases could be made possible by detecting nucleic acid sequences unique to specific bacteria and viruses, or to specific diseases or abnormal concentration of certain proteins that signal the presence of various cancers and diseases [29]. Nanomaterials-based assays are currently evaluated as well as more sensitive proteins detections methods. Nucleic acid sequences are currently detected with polymerase chain reaction (PCR) coupled with molecular fluorophore assays. Despite high sensitivity, PCR has significant drawbacks, such as: complexity, sensitivity to contamination, cost, and lack of portability [29]. Current protein detection methods, such as enzyme-linked immunoabsorbent assay (ELISA), allow the detection of proteins concentrations at which the disease is often advanced. More sensitive methods based on nanomaterials would revolutionize physical treatment of many cancer types and diseases [29].

9)Smart nanophase extractors. Differentially functionalized nanotubes are used as smart nanophase extractors, with molecular-recognition capabilities, to remove specific molecules from solutions [23].

10) Treatment for local anesthetic toxicity. Local anesthetic can be sometimes very toxic, ranging from local neurotoxicity to cardiovascular collapse and coma. In addition to conventional therapies, drug-scavenging nanoparticles have shown to increase survival rate from no animals in the control group to all animals in the treated group [30], [31].

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