ANTIMICROBIAL AND ANTICANCER ACTIVITY OF SILVER NANOPARTICLES FROM EDIBLE MUSHROOM: A REVIEW

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ABSTRACT

Biologically inspired nanoparticle synthesis is currently a rapid expanding area of research in nanotechnology. Nanoparticle synthesis utilizing the bioresources such as plants and microbes appears to be a viable, low-cost, and eco-friendly approach. Especially mushrooms can be used for large-scale synthesis of silver nanoparticles as mushroom produces many proteins that reduce the silver nitrate during the biosynthesis. Silver nanoparticles can be characterized using ultraviolet-visible (UV-VIS) spectroscopy, fourier transform infrared spectroscopy, X-ray diffraction, scanning electron microscopy, energy dispersive X-ray, and transmission electron microscope. Silver nanoparticles possess high antibacterial activity since silver in different forms has been extensively used as a medicine for curing diseases and promote wound healing. Silver nanoparticles have high surface specific area, which will lead to excellent antimicrobial activity as compared with bulk metallic silver. Further, the silver nanoparticles show anticancer activity against various cell lines such as human epidermoid larynx carcinoma (HEP-2), colon adenocarcinoma (HCT-116), breast adenocarcinoma (MCF-7), liver carcinoma (Hep-G2), and intestinal adenocarcinoma (Caco2) were well documented. This review intends to present green synthesis of silver nanoparticles and their application as antimicrobial and anticancer agents.

Keywords: Silver nanoparticles, Bioresources, Mushroom, Antimicrobial activity, Anticancer property.

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INTRODUCTION

Nanoparticles are the basic essential elements of nanotechnology and it exhibits fabulous advanced characteristics based on their properties such as size, morphology, and other size-dependent properties [1]. These unique features of nanoparticles may lead to play a crucial role in a variety of surprising and interesting uses in biomedical, energy science, optics, and other health-care applications [2,3]. Among the nanoparticles, nanosilver has potential applications in the field of biomedicine since silver have a disinfecting effect and has found uses in traditional medicines for a long time. Silver nanoparticles have high surface specific area, which will lead to excellent antimicrobial activity as compared with bulk metallic silver.

Originally, silver nanoparticles can be synthesized using various chemical and physical methods, but these approaches are not environmentally benign [4]. Each method has advantages and disadvantages with common problems being cost, scalability, wide size distribution [5] and decrease in the stability of the nanoparticles on application can be problematic since aggregation decreases the specific surface area lowering the antimicrobial and catalytic activity [6]. Furthermore, the presence of some toxic metals in the synthesis process may create some adverse effects in biomedical applications [7]. Thus, biosynthesis of nanoparticles emerged as an effective alternative to overcome the disadvantages of the classical methods.

The bio-route attracts a considerable interest because of its eco-friendliness and biocompatibility. A great deal of effort has been put into the biosynthesis of metal nanoparticles, using microorganisms such as bacteria [8,9], fungus [10,11], algae [12], and plants [13]. The use of macro-fungi especially mushroom in the nanoparticle synthesis is a new addition and holds a promising role in large-scale nanoparticle production in lesser time period. In fact, the mushroom fungi produce many proteins and extracellular enzymes involved in the reduction of silver nitrate during the synthesis of silver nanoparticles and are very simple to grow both in lab scale and industrial scale and also the yield is high.

This review intends to present a brief note on the biosynthesis of silver nanoparticles from edible mushroom extract, their characterization using various techniques, antimicrobial and anticancer activity.

Biosynthesis of Silver Nanoparticles from Edible Mushroom Extract

Mushroom extract was prepared by boiling cut pieces of edible mushroom (Pleurotus sp.) with sterile distilled water for 10 minutes and filtered. The extract was mixed with 1mM AgNO3 (Fig. 1). The mixture turned brown color which indicates the formation of silver nanoparticles. The nanoparticles are then pelleted and dried.

Characterization of Silver Nanoparticles

UV-VIS spectroscopy

Metal nanoparticles exhibit strong absorption of electromagnetic waves due to surface plasmon resonance in the visible range [14]. Thus, UV-VIS spectroscopy is used to investigate the formation and stability of metal nanoparticles in solution. Dark brown color indicates the production of silver nanoparticles in solution [15].

Fourier transform infrared spectroscopy (FTIR)

When infrared radiation is passed through a sample, specific wavelengths are absorbed which causes the chemical bonds present in the material to undergo vibrations such as stretching, contracting and bending. Thereby, FTIR can be used to determine the functional groups of the biomolecules in the extract which are responsible for the reduction of the silver ions.

X-ray diffraction (XRD)

XRD is a conventional technique used to establish the crystalline nature, domain size, and structure of the nanoparticles [16]. It can be used to look at a single crystal or polycrystalline materials.

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Scanning electron microscopy (SEM)

SEM is a direct visualization technique used for the morphological examination of nanoparticles. Surface morphology and size of the nanoparticles can be examined; however, this technique provides limited information about the size distribution.

Energy dispersive X-ray spectroscopy (EDX)

EDX spectroscopy is used for the elemental analysis or chemical characterization of nanoparticle samples. EDX confirms the formation of silver nanoparticles by recording the strong signal of elemental silver.

Transmission electron microscope (TEM)

TEM is used to study the size and shape of the silver nanoparticles. It is a direct imaging technique, provides higher resolution than SEM. The synthesized silver nanoparticle solution is dropped on carbon-coated TEM grids, dried and viewed for determining the particle size [16]. The sample preparation for TEM is complex and time-consuming because of its requirement to be ultra thin for the electron transmittance under high vacuum.

ANTIMICROBIAL ACTIVITY OF SILVER NANOPARTICLES

Since several years silver has been known as a strong disinfecting agent and has found many uses in traditional medicinal practices. Several silver-based compounds have been utilized effectively as antimicrobial specialists [17]. Compounds of silver are also used in the medical field to treat burnt wounds and various other types of infections. Nanoparticles of silver have aptly been investigated for their antibacterial property because the silver nanoparticles have high specific area than their volume, which will lead to excellent antimicrobial activity as compared with bulk silver metal [18-21].

Silver nanoparticles showed potential antibacterial activity against Gram-positive bacteria such as Staphylococcus aureus and Bacillus subtilis [22] and Gram-negative organisms such as Klebsiella pneumonia [22] and Salmonella typhus [23]. Praiseworthy endeavors have been made to investigate this property utilizing electron microscopy, which has uncovered size-dependent interaction of silver nanoparticles with microorganisms [19]. However, the inhibitory mechanism of silver nanoparticles is only partially understood. There are different speculations on the activity of silver nanoparticles on microorganisms to bring about the microbicidal impact.

Silver nanoparticles attach with the microbial cell wall membrane by electrostatic attraction [24,25] and subsequently penetrate it, thereby changing the permeability of the cell membrane and causes cell death. Sondi and Salopek-Sondi [26], stated that the nanoparticles associated with the bacterial cell wall form “pits,” thereby affects the permeability and causes cell death.

Electron spin resonance spectroscopy studies proposed that there is the development of free radicals by the silver nanoparticles that might be thought to be another mechanism by which the cells die. At the point when the free radicals formed by the silver nanoparticles are in close contact with the bacteria, they can harm the cell membrane and make it permeable which can at last prompt to cell death [27,28]. It was suggested that there can be release of silver ions by the nanoparticles, which acts on the thiol groups of many crucial enzymes and make them inactive, thereby repress several cellular activities and harm the cells [29].

Another reality is that the DNA has sulfur and phosphorus as its important constituents which are soft bases. Silver being a soft acid can act on these soft bases and destroy the DNA which would definitely lead to cell death [19]. The interaction of the silver nanomaterials with the sulfur and phosphorus of the DNA can prompt to issues in the bacterial DNA replication and thus terminate the microscopic organisms (Fig. 2). However, further research is required to thoroughly establish the bactericidal mechanism.

ANTICANCER ACTIVITY OF SILVER NANOPARTICLES

Nanotechnology plays a tremendous role in overcoming many of the problems that conventional methods face in the treatment, diagnosis, and detection of cancer [31]. The primary feature of these nanoparticles is that their surfaces can be functionalized, exploiting reactive terminal groups, with particular proteins, peptides or monoclonal antibodies that are capable specifically to bind at a site of action or a specific targeted tissue, without interacting with other cells [32]. Therefore, the use of nanotechnology in cancer treatment offers exciting possibility of destroying cancer cells with minimal damage to healthy tissues and organs.

Nanoparticles can be used in the detection and elimination of cancer cells before they form tumors. Nanoparticles can also be designed to carry drugs and release them at the targeted site. These particles can make it permeable which can at last prompt to cell death [27,28]. It was important constituents which are soft bases. Silver being a soft acid can act on these soft bases and destroy the DNA which would definitely lead to cell death [19]. The interaction of the silver nanomaterials with the sulfur and phosphorus of the DNA can prompt to issues in the bacterial DNA replication and thus terminate the microscopic organisms.

Silver nanoparticles, which have gained prominence in the field of nanomedicine because of their exceptional properties and problems that conventional methods face in the treatment, diagnosis, and detection of cancer [31]. The primary feature of these nanoparticles is that their surfaces can be functionalized, exploiting reactive terminal groups, with particular proteins, peptides or monoclonal antibodies that are capable specifically to bind at a site of action or a specific targeted tissue, without interacting with other cells [32]. Therefore, the use of nanotechnology in cancer treatment offers exciting possibility of destroying cancer cells with minimal damage to healthy tissues and organs.

Nanoparticles will have a lethal effect on the cell wall of the cancer cells [33]. Water soluble organic moieties in the nanoparticles induce a synergistic antiproliferative effect in various cancer cell lines, thus prove to be useful in various types of cancer control system (Fig. 3).

Nanoparticles have been found to induce the apoptotic pathway in vitro through free oxygen radical generation, which showed antitumor, antiproliferative and antiangiogenic effects in-vitro [34]. Compounds having antiangiogenic properties are known for their potential capacity to hinder the action of abnormally expressed signaling proteins, for example, Ras and Akt, subsequently, exhibit a reliable antitumor effect [35].

Cytotoxic activities of silver nanoparticles are documented in the following research works. Asharani et al. [36] reported that silver nanoparticles exhibited antiproliferative effect on human glioblastoma cells. Franco-Molina et al. [37] evaluated the effects of colloidal silver on...
MCF-7 human breast cancer cells. Sanpui et al. [38] demonstrated that nanosilver not only disrupted normal cellular function but also affected membrane integrity, inducing various apoptotic signaling genes of mammalian cells, leading to programmed cell death. Hsin et al. [39] reported that nanosilver induced apoptosis in murine embryonic fibroblast cells (NIH 3T3) by increasing the generation of reactive oxygen species and activating the c-Jun N-terminal kinase pathway, leading to mitochondria-dependent apoptosis. Silver oxide nanoparticles displayed antitumor properties in transplanted Pliss lymphosarcoma tumor models when given through intravenous injection in aqueous form [40]. Silver nanoparticles have shown anticancer activity against some of the human cancer cell lines such as colon carcinoma (HCT-116), breast carcinoma (MCF-7), liver carcinoma (Hep-G2), and intestinal carcinoma (Caco2) as stated by Shawkey et al. [41]. The cytotoxicity of nanosilver is the consequence of dynamic physicochemical interaction of silver particles with the functional groups of intracellular proteins, as well as with the nitrogen bases and phosphate groups of DNA [42].

Silver nanoparticles serve as antitumor agents by decreasing progressive development of tumor cells. This might be because of their inhibitory actions in several signaling cascades liable for the development and pathogenesis of cancer. Taken together, these informations recommend that silver nanoparticles can actuate cytotoxicity on cancer cells and hindering tumor progression without lethality to normal cells.

CONCLUSION

Biologically prepared silver nanoparticles tend to be biocompatible and cost-effective. Thus, they are handy in wide variety of nanobiotechnology applications. Silver nanoparticle is a good alternative in antibacterial treatment with less side effect and potential action. More research is needed to study the anticancer activity of silver nanoparticles in detail. Under this backdrop, the edible mushroom will be a suitable source for green synthesis of silver nanoparticles having potential anticancer properties. Care has to be taken to utilize this marvel well and in a good, effective and efficient way for human betterment.

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