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Algal production of nano-silver and gold: Their antimicrobial and cytotoxic activities: A review

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Abstract The spreading of infectious diseases and the increase in incidence of drug resistance among pathogens have made the search for new antimicrobials inevitable, similarly is the cancer disease. Nowadays, there is a growing need for biosynthesized nanoparticles (NPs) as they are one of the most promising and novel therapeutic agents of biological origin. The unique physico-chemical properties of the nano silver (Ag-NPs) as well as nano gold (Au-NPs) when combined with the growth inhibitory capacity against microbes lead to an upsurge in the research on NPs and their potential application as antimicrobials. The phytochemicals of marine algae that include hydroxyl, carboxyl, and amino functional groups can serve as effective metal reducing agents and as capping agents to provide a robust coating on the metal NPs. The biosynthesis of Ag-NPs and Au-NPs using green resources is a simple, environmentally friendly, pollutant-free and low-cost approach. The biosynthesized NPs using algae exerted an outstanding antimicrobial and cytotoxic effect.

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1. Introduction

Nanotechnology is a modern technology that studies nanometer sized objects [89]. It is expected that nanotechnology will be developed at different levels such as materials, medical devices and systems. Generally, the synthesized silver nanoparticles have applications in the field of nanomedicines and this opens the way to develop AgNPs synthesized by different microbes against various human pathogens [3].

The progress in nanotechnology research is starting to have an impact in the biomedical and industrial fields. Not only does this progress raise hopes in patient populations regarding improved specificity and lower doses, but it raises concerns in environmental and occupational fields due to a lack of toxicity studies and other unwanted side effects as well. Nano-Ag particles, with dimensions ranging from tens to hundreds of nanometers, have unique features that differ from bulk material properties. The increased relative surface area of nanoparticles (NPs), compared with fine and ultrafine particle bulk material, can lead to changes in its physical, chemical, mechanical, thermal as well as electrical, magnetic, and luminescent properties [91].

Over the past few contracts, inorganic NPs, whose structures exhibit novel functionality and improved physical as well as chemical and biological characteristics due to their nano scale size, have released much interest. To date, metallic NPs are usually prepared from noble metals, i.e., Ag, Pt, Au and Pd [96]. Among inorganic agents, silver is the metal of choice in the fields including biological systems as well as living organisms and medicine [102] because it has been used most extensively since ancient times to fight infections and control blighter. Silver NPs (Ag-NPs) have gained special interest over other metal NPs (e.g., gold and copper) because the surface plasmon resonance energy of it is located away from the inter band transition energy. Tremendous applications were found by the Ag-NPs in the fields of catalysis, optoelectronics, detection and diagnostic, antimicrobials and therapeutics. The Ag-NPs can be exploited in medical and pharmaceutical due to their low toxicity to human cells and high thermal stability [122].

The Macedonians were the first to use the application of silver plates to achieve better wound healing, perhaps it was the first try to prevent or treat surgical infections. Hippocrates used silver preparations for the treatment of ulcers and promoted them medically because it was mentioned in a pharmacopeia published in Rome in 69 B.C.E. [48]. Various silver compounds and their derivatives have been used to treat burns, wounds and infections as antimicrobial agents [2]. Its risk benefit ratio is advantageous. Various silver compounds and their derivatives have been used to treat burns, wounds and infections as antimicrobial agents.

The use of gold in medicine (Chrysotherapy) has been used since antiquity. Gold was used to treat diseases in ancient cultures in Egypt, China and India. They treated diseases such as small pox, syphilis, skin ulcers, and measles [50,110,45,68]. In the past few decades, several organo-gold complexes have emanated with hopeful antitumor, antimicrobial, antimalarial, and anti-HIV activities [45,129].

Nano scaled-Ag and Nano scaled-Au are not new and it was likely created in the 4th century A.D. In the 1990s, researchers at the British Museum determined the average diameter of the gold and silver particles in the glass to be 70 nm. The Lycurgus Cup therefore represents what is likely one of the first uses of Ag- NPs and Au-NPs [37].

Faraday in 1857 was the first who described the chemical reduction of transition metal salts to generate zero-valent particles; following this early detection, Lea [75], described the reduction of silver nitrate ($AgNO_3$) in the presence of trisodium citrate, which was subsequently extended to gold NPs by reducing chloroauric acid with sodium citrate [132].

The Ag-NPs and Au-NPs particles play an important role in nanobiotechnology and biomedicine to control the drug renitent bacteria. It was evident that people that become infected with drug renitent microorganisms usually spend more time in the hospital and require a form of treatment that use two or three different antibiotics and is less efficient, more toxic, and more expensive. The Ag-NPs are preferred option because they are nontoxic to the human body at low concentrations and have broad spectrum antimicrobial properties [115,28,52,104]. The Ag-NPs have been studied as an ambience for antibiotic delivery, and for the production of disinfecting filters and coating materials [80,64].

Singaravelu et al. [123] made a novel extracellular synthesis of monodisperse Au-NPs using marine alga, *Sargassum wightii* Greville. This report is the first in which a marine alga has been used to synthesize highly stable extracellular Au-NPs in a relatively short time period compared with that of other biological procedures. As a matter of fact, 95% of the bioreduction of $AuCl_4$ ions happened within 12 h at stirring condition. Kaushik et al. [61] concluded that the alternative and eco-friendly process for synthesis of metallic NPs is a critical need through using biological systems. There are many recent studies which specified the antimicrobial activity of the biosynthesized Au-NPs using seaweeds [107,35,134].

2. Characterization of the metal nanoparticles

Characterization of the metal NPs is performed using a variety of analytical techniques as transmission or scanning electron microscopy (TEM, SEM), atomic force microscopy (AFM), dynamic light scattering (DLS), X-ray photoelectron spectroscopy (XPS), powder X-ray diffractometry (XRD), Fourier

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