Nanoparticle: is a small particle that ranges between 1 to 100 nanometres in size. Undetectable by the human eye, nanoparticles can exhibit significantly different physical and chemical properties to their larger material counterparts.

Biosynthesis of nanoparticles by fungi

The use of fungi as reducing and stabilizing agents in the biogenic synthesis of silver nanoparticles is attractive due to the production of large quantities of proteins, high yields, easy handling, and low toxicity of the residues. Furthermore, this synthesis process coats the nanoparticles with biomolecules derived from the fungus, which can improve stability and may confer biological activity.

various species of fungus have potential for use in biogenic synthesis, enabling the production of nanoparticles with different characteristics considering aspects such as their size, surface charge, and morphology.

The synthesis mechanisms have not yet been fully elucidated, although it is believed that fungal biomolecules are mainly responsible for the process.

. Silver nanoparticles synthesized using fungi enable the control of pathogens, with low toxicity and good biocompatibility. These findings open perspectives for future investigations concerning the use of these nanoparticles as antimicrobials in the areas of health and agriculture.

-Among the different types of metallic nanoparticles, silver nanoparticles can be highlighted for their broad-spectrum antimicrobial potential These nanoparticles adhere to the cell walls and membranes of microorganisms and may reach the cell interior. They damage the cellular structures, induce the production of reactive oxygen species, and alter the mechanisms of signal transduction Several studies report applications in which good results have been obtained using silver nanoparticles for the control of pathogenic microorganisms in the areas of health and agriculture The commonest method used to produce silver nanoparticles is chemical synthesis, employing reagents whose function is to reduce the silver ions and stabilize the nanoparticles. These reagent are toxic and can present risks to health and the environment which has led to increasing interest in biogenic synthesis methods. Such processes enable nanoparticles to be obtained that present lower toxicity, better physicochemical characteristics, and higher stability Biogenic synthesis of nanoparticles can be performed using organisms such as bacteria, fungi and plants, or the byproducts of their metabolism, which act as reducing and stabilizing agents These nanoparticles are capped with biomolecules derived from the organism used in the synthesis، which can improve stability and may present biological activity Biogenic synthesis is relatively simple, clean, sustainable, and economical, and provides greater biocompatibility in the uses of nanoparticles

Fungi have excellent potential for the production of many compounds that can be used in different applications. Around bioactive substances are known to be produced by microscopic filamentous fungi (ascomycetes and imperfect fungi) and other fungal species . These organisms are widely used as reducing and stabilizing agents, due to their heavy metal tolerance and capacity to internalize and bioaccumulate metals. Furthermore, fungi can be easily cultivated on a large scale ("nanofactories") and can produce nanoparticles with controlled size and morphology Fungi have advantages over other microorganisms, in that they produce large quantities of proteins and enzymes, some of which can be used for the fast and sustainable synthesis of nanoparticles .

The mechanism of biogenic synthesis of nanoparticles using fungi

1- intracellular

In the case of intracellular synthesis, the metal precursor is added to the mycelial culture and is internalized in the biomass. Consequently، extraction of the nanoparticles is required after the synthesis, employing chemical treatment, centrifugation, and filtration to disrupt the biomass and release the nanoparticles

2- extracellular.

in the case of extracellular the metal precursor is added to the aqueous filtrate containing only the fungal biomolecules، resulting in the formation of free nanoparticles in the dispersion.

This last method is most widely used, since no procedures are required to release the nanoparticles from the cell .

Nonetheless, the nanoparticle dispersion must be purified in order to eliminate fungal residues and impurities, which can be achieved using methods such as simple filtration, membrane filtration, gel filtration, dialysis, and ultracentrifugation.

Synthesis Mechanisms:

How Does Extracellular Synthesis of Silver Nanoparticles by Fungi Occur

Although many studies have been published concerning the biogenic synthesis of silver nanoparticles using fungi, the specific mechanisms involved have not yet been fully elucidated. It is known that extracellular synthesis of nanoparticles occurs according to reactions in which the enzymes present in the fungal filtrate act to reduce silver ions, producing elemental silver Ag^0 at a nanometric scale. After the reaction, the color of the filtrate changes and UV-visible spectroscopy can be used to observe surface plasmon resonance bands reflecting alteration of the optical properties of the material. The absorbance wavelengths of these bands vary in the range from 400 to 450 nm, with an absorbance peak at a longer wavelength indicating the presence of larger nanoparticles.

The size depends on the synthesis conditions such as

1-fungus species,**2-** temperature, **3-**pH, **4-**dispersion medium,

Optimization of Silver Nanoparticles Synthesis

wide variety of fungi have potential for use in the synthesis, it is important to consider their individual characteristics and to optimize the synthesis conditions accordingly Parameters such as

1- agitation , 2-temperature,3- light,4- culture 5-synthesis times-

differ depending on the fungus used and can also be adjusted in order to obtain the desired nanoparticle characteristics. Control of nanoparticle size and shape requires adjustment of the parameters used for both cultivation of the fungus and the synthesis process

Studies have found that changes in temperature, concentration of the metal precursor, pH, culture medium, and amount of biomass can be used to obtain nanoparticles with different physicochemical characteristics.

Effect of Temperature

The temperature used in the synthesis of silver nanoparticles employing fungi can affect parameters such as the speed of the synthesis and the size and stability of the nanoparticles reported that 30◦C was the optimum temperature for production of high stability silver nanoparticles using *Isaria fumosorosea* The occurrence of synthesis of nanoparticles by some fungal species at high temperatures indicates that electrons can be transferred from free amino acids to silver ions. However، very high temperatures, between 80 and 100◦C, lead to denaturation of the proteins that compose the nanoparticle capping. This denaturation alters the nucleation of Ag+ ions، with the nanoparticles aggregating and increasing in size , unsuitable temperatures lead to increased nanoparticle size and loss of stability, due to the low activity of the enzymes involved in the synthesis.

Effect of pH

Adjustment of the synthesis pH can be used to control certain characteristics of the nanoparticles. Nayak et al. (2011) reported that the conformation of nitrate reductase enzymes could be altered according to the concentration of protons in the reaction medium, leading to alteration of the morphology and size of the nanoparticles. At higher pH, there is greater competition between protons and metal ions for establishing bonds with negatively charged regions, resulting in greater success of synthesis at alkaline pH, more alkaline pH resulted in a shorter synthesis time and smaller nanoparticle size distribution and polydispersity index values.

Effect of AgNO3 Concentration:

In most of the studies employing fungi for extracellular synthesis of silver nanoparticles, AgNO3 was used at a concentration of mM (millimolar) In some cases،
a lower metal precursor concentration resulted in a smaller nanoparticle size and an improved dispersion) other studies obtained smaller sizes when intermediate AgNO3 concentrations were used.

Effect of the Culture Medium:

It is known that microorganisms present different responses depending on the culture medium and the cultivation conditions. Changes in these conditions result in the synthesis of different metabolites and proteins In nanoparticle synthesis using fungi, a culture medium containing substrate specific for the enzymes that act in the synthesis can induce their production and release by the fungus, enhancing the reduction of silver and the formation of nanoparticles Fusarium oxysporum was cultivated in a culture medium modified to induce nitrate reductase enzyme activity (0.35% yeast extract, 1% peptone, 0.35% potassium nitrate, and 1.5% glucose, as well as in malt glucose yeast peptone (MGYP) medium without enzyme induction (0.3% malt extract, 1% glucose, 0.3% yeast extract, and 0.5% peptone). The nanoparticle dispersions produced using the filtrate from the fungus cultivated in the enzyme induction medium presented higher concentrations and smaller sizes of the nanoparticles, which was attributed to stimulation of the enzymatic activity by the nitrogen source in the modified medium, hence increasing nanoparticle production.

Effect of the Quantity of Biomass:

The amount of biomass used can affect the synthesis and characteristics of silver nanoparticles. Some studies have reported higher nanoparticle production using lower biomass concentrations, while others have found higher synthesis rates using higher concentrations.

APPLICATIONS:

Silver nanoparticles synthesized using fungi have various potential applications in the areas of health, agriculture, and pest control. There are no reports concerning the better or worse activities of biogenic nanoparticles synthesized from different sources, such as fungi, bacteria, or plants. However, synthesis based on fungi may be advantageous in terms of production, due to the

1- large quantities of metabolites produced.

2- The capacity of fungi to produce antibiotics that could be contained in the capping and act in synergy with the nanoparticle core

Many studies of biogenic synthesis of nanoparticles using fungi have shown results that are promising for the application of these systems in:

a- controlling pathogenic fungi and bacteria.

b-combating cancer cells and viruses.

c- providing larvicidal and insecticidal activities .

d- Health Applications.

e-Agriculture and Pest Control Applications ..