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GREEN SYNTHESIS OF METAL NANOPARTICLES USING MICROALGAE: A REVIEW

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ABSTRACT

Nanometallic materials are metals and alloys that form nanocrystalline grains with particle size of about 5 to100 nm. In materials science, "green synthesis" has become a reliable, sustainable, and eco-friendly protocol for synthesizing a wide range of materials such as metal oxides, hybrids, and bio-inspired materials. Nowadays, a wide range of physico-chemical methods are used for the synthesis of nanoparticles. Green synthesis is found to be superior over physical and chemical method as it is economically feasible, environmentally friendly, scaled up for mass-scale production without any complexity. Several biological approaches, including the utilization of plant extracts, enzymes, bacteria, fungi, and algae, are being studied in order to enable a more environmentally sound synthesis of nanoparticles. Because these techniques are regarded as safe and environmentally responsible for the production of nanomaterials as an alternative to conventional methods, the development of green methods for the synthesis of nanoparticles is developing into a significant area of nanotechnology.

KEYWORDS: microalgae, silver nanoparticles, eco-friendly

1. Background

In order to lessen the negative impacts of nanoparticles frequently utilized in laboratories and industry by conventional synthesis methods, green synthesis is seen as a crucial instrument [1].

Over the last decade, the field of processing algal biomass under catalytic conditions has received a lot of interest. Algae could be considered as a "bio-factory" for synthesis of metallic nanoparticles. Also, algae are well known for their ability to hyper-accumulate heavy metal ions and remodel into more malleable shapes [2].

Algae are a group of autotropic organisms with economic and ecological importance. They are single or multicellular organisms that live in different habitats, such as freshwater, marine water, or damp rock surfaces. The two different categories of algae are microalgae (microscopic) and macroalgae (macroscopic). They play a vital role in applications such as medicine, pharmacy, forestry, aquaculture, and cosmetics. They are an important source of several commercial products including natural dyes and biofuel [3].

Algae have so been suggested as a model organism for producing bio-nanomaterials. Physical variables like pH, reaction time, exposure time, precursor concentration and temperature affect how nanoparticles form, grow, and stabilize. To alter the size and morphology of the cells and prevent aggregation, these factors can be changed. According to the species and age of the algae, phycocyanin and phycoerythrin contain varying concentrations of carbohydrates, proteins, minerals, vitamins, fatty acids, antioxidants, and pigments. Theoretically, these active substances have been referred to as reducing and stabilizing agents in the creation of nanoparticles [2, 4].

Due to their capacity to reduce metal ions, nanoparticles made from a variety of different algal resources have emerged as one of the most cutting-edge and current areas of biochemical research [5]. Depending on the algae species and method of activity, nanoparticles can be synthesized intracellularly or extracellularly [6].

In comparison to bigger particles, nanoparticles are gaining recognition as complex materials with innovative or cutting-edge properties. Pharmaceutical, industrial, and biotechnological uses all rely heavily

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on nanoparticles. Due to its distinctive qualities in the fields of technology, science, and medical, such as antimicrobial, catheters, food containers, and anticancer, silver nanoparticles have drawn the attention of researchers in recent years [7].

The synthesis of nanoparticles must be done using methods that follow a "green" path because nanoparticles are used in consumer health and industrial products. Several biological approaches, including the utilization of plant extracts, enzymes, bacteria, fungi, and algae, are being studied in order to enable a more environmentally sound synthesis of nanoparticles [8].

This review gives an insight of various updated reports of synthesis of advance nanomaterials using green and simple approach rather than using complicated procedures, hazardous, toxic chemicals for the synthesis of nanomaterials.

2. Biosynthesis of Silver Nanoparticles by Microalgae

In light of the wide applications of AgNPs, their synthesis becomes a very crucial factor. Three different approaches can be used for the synthesis of nanoparticles, namely physical, chemical, and biological or green synthesis.

Recent developments show the critical role of microorganisms and biological systems in production of metal nanoparticles. The use of organisms in this area is rapidly developing due to their growing success and ease of formation of nanoparticles. Moreover, biosynthesis of metal nanoparticles is an environmentally friendly method (green chemistry) without use of harsh, toxic and expensive chemicals. [9].

To cultivate diverse algae species, the researchers employed a variety of techniques, including open culture systems (such as open ponds, tanks, and raceway ponds) and closed cultivation systems (such as photo bioreactors) [10].

In the bulk of the investigations, the following key processes for the production of metal nanoparticles utilizing algae are seen:

- Boiling or heating an algal extract for a predetermined amount of time in water or an organic solution.
- Making molar solutions of ionic metallic compounds.
- Under carefully monitored conditions, both algae and solutions of ionic metallic compounds are incubated for a predetermined amount of time, either with frequent stirring or without [11].

In addition to being widely employed in hard surface products and textiles, silver and silver nanoparticles are also used in a wide range of pharmaceutical, food industrial, and domestic applications.

Usually, an algal species synthesized NP by accumulating and subsequently reducing the cations. They can be synthesized from algal biomass using either the extracellular or intracellular mechanism.

The bio-reduction of a metal ion to its nanoparticle occurs on the surface of the algal cell in the extracellular pathway whereas in the intra-cellular mechanism the bio-reduction through enzymatic activity occurs inside the cell wall and cell membrane [12]. However, most studies related to the synthesis of silver nanoparticles with the algal biomass involve.

Silver nanoparticles were used in *Chlorella vulgaris* conditioned media, which changed colour from bright yellow to dark brown (UV-VIS absorbance at 415 nm) [13, 14].

Chokshi and collaborators, have reported using degreased algal biomass (*Acutodesmus dimorphus*) to create silver nanomaterial [15]. Also, three different genera of microalga live cultures: *Nannochloropsis oculata*, *Dunaliella salina*, and *Chlorella vulgaris*, were subjected to three different doses of aqueous $AgNO_3$ solution (1 mM, 2 mM, and 5 mM). It was observed that just two of the three species of algae, *Nannochloropsis oculata* and *Chlorella vulgaris*, were able to produce nanoparticles, and even then, only at a concentration of 1mM $AgNO_3$ [16, 17].

The synthesis of silver nanoparticles using the freshwater cyanobacterium, *Plectonema boryanum* (UTEX 485) has been already reported [18].

Spirulina in food causes unique therapeutic effects including immunomodulation, anticancer, antioxidant antiviral and antibacterial, metalloprotective [19, 20]. *Arthrospira platensis* is the most available and commonly utilized genus and has been the subject of many studies in the food and pharmaceutical industries [21, 22]. Also, can rapidly produce Ag nanoparticles through extracellular biosynthesis.

Once the NPs are synthesized, their conformational details about shape, size, dispersity, homogeneity as well as surface morphology are determined by using various techniques, including: energy dispersive X-ray spectroscopy (EDX), scanning electron microscopy (SEM), UV-VIS absorption spectroscopy, transmission electron microscopy (TEM), Fourier transmission infrared (FTIR) spectroscopy and dynamic light scattering (DLS) (Figure 1) [23].

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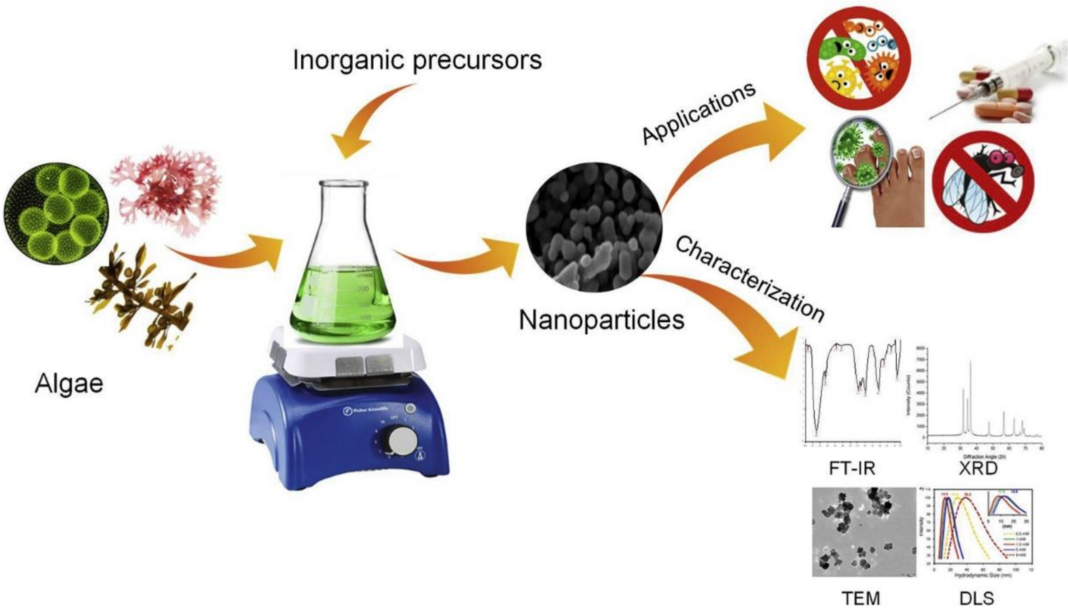

Fig. 1. *Synthesis of silver nanoparticles*

Researchers mostly utilize analytical techniques such as TEM and SEM for morphological analysis of silver nanoparticles. For studies, the sample are sputter-coated on copper grids with a metal nanoparticle solution, dried, and then ready for analysis. Additionally, for improved identification, SEM and TEM are combined with an energy dispersive X-ray analysis (EDX). Is another tool that gives information about symmetry, size and phase identification of metallic nanoparticles [24]. Also, UV-VIS spectra are used to examine the size and shape of metallic nanoparticles in aqueous solution and FTIR spectroscopy is employed to determine the nature of functional groups of active components on the surface of nanoparticles.

Because of their special qualities including catalytic activity and stability, silver NPs are regarded as excellent. Additionally, they have anti-bacterial, anti-viral, and anti-fungal effects. AgNPs are used in antibacterial nanodevices as one of its applications due of their Ag^+ ion action. They have an anti-proliferative impact and can cause cell death, making them effective anti-cancer drugs [25, 26].

AgNPs may be loaded or coated to lessen their toxicity and extend their biological retention period, enabling the targeted killing of malignant cells. AgNPs from *Andrographis echioides* are frequently employed in human breast cancer cell lines and have been proven to impede the development of MCF-2 cells [27, 28]. The viability of tumour cells decreases when the concentration of AgNPs rises. gastrointestinal cancer has responded favourably to *Allium sativum* AgNPs [29, 30].

3. Conclusions

Nanotechnology is improving our everyday lives by enhancing the performance and efficiency of everyday objects. It provides a clean environment by providing safer air and water, and clean renewable energy for a sustainable future. Due to their incredible properties, metallic nanoparticles have been widely used for many applications such as energy, health science, environment, agriculture field etc.

Use of microalgae for the synthesis of nanoparticles could be considered as an eco-friendly approach due to less time consuming, inexpensive, environmental compatibility, scalability, and nanoparticle stabilization compared to the chemical synthesis procedures. However, the use of microalgae for nanoparticle synthesis have not been extensively researched.

In addition, nano-biotechnology that uses algae and microalgae to synthesize nanomaterials is still in its early stages, and further research and development is required.

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