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REVIEW ARTICLE

Synthesis of Nanoparticles by Green Synthesis Method

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HIGHLIGHTS

> Green synthesis of nanoparticles using microorganisms, plants and fungi were made at room temperature.
> Green synthesis provides an environmentally friendly, simple, economical and reproducible approach for faster metal nanoparticle production.
> Nanoparticles obtained by green synthesis method are used in many application fields such as cancer treatment, drug transport, biosensor construction.

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ABSTRACT

As an emphasis on the synergistic interaction of nanotechnology and nanobiotechnology, nanoparticles need to develop environmentally benign technologies in the synthesis of biosynthesis and nanomaterials. Microorganisms, plants and fungi can be used as biodegradable agent material in this field work. Thus, it was possible to develop a simple, fast and green method for the synthesis of nanoparticles. Various strategies are used for the synthesis of nanoparticles. Traditionally, physicochemical techniques have increased environmental concerns due to the reduction of metal ions followed by surface modification, toxic compounds added for stability, and dangerous byproducts formed. At the time of nanoparticle synthesis by adding chemical and physical methods at high temperature and pressure, reducing and stabilizing agents; nanoparticle synthesis by biological methods; room temperature and pressure, reducing and stabilizing agents are needed. Green synthesis method; provides a faster metallic nanoparticle production by offering an environmentally friendly, simple, economical and reproducible approach. Given the wide range of applications of metallic nanoparticles produced, biological methods play a major role in the synthesis of metallic nanoparticles.

Contents

1. Introduction

Nano is a metric measure of one billionth of a meter and covers a width of 10 atoms. In terms of comparison with real objects, an example that hair is 150,000 nanometers may be given. The rapidly developing nanotechnology is the interdisciplinary research and development field of biology, chemistry, physics, food, medicine, electronics, aerospace, medicine, etc., which examines the design, manufacture, assembly, characterization of materials that are smaller than

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100 nanometers in scale, as well as the application of miniature functional systems derived from these materials. It represents the whole of development activities. As fir the nanobiotechnology, on the other hand, it is the result of a combination of biotechnology and nanotechnology branches with a common combined functioning [1].

1.1. Nanoparticles and their properties

The process of removing toxic and waste metals in the environment includes microorganisms, plants and other biological structures; achieved by means of oxidation, reduction or catalysis of metals with metallic nanoparticles.

Metallic nanoparticles produced by biological methods; are used in the biomedical field for purposes such as protection from harmful microorganisms, bio-imaging, drug transport, cancer treatment, medical diagnosis and sensor construction because of their unique properties such as being insulator, optics, antimicrobial, antioxidant, anti-metastasis, biocompatibility, stability and manipulability. Metallic nanoparticles, which can be used in the industrial field due to their catalytic activity, are of great importance nowadays. Figure 1 shows in detail where metallic nanoparticles obtained by biological methods are used [2, 3].

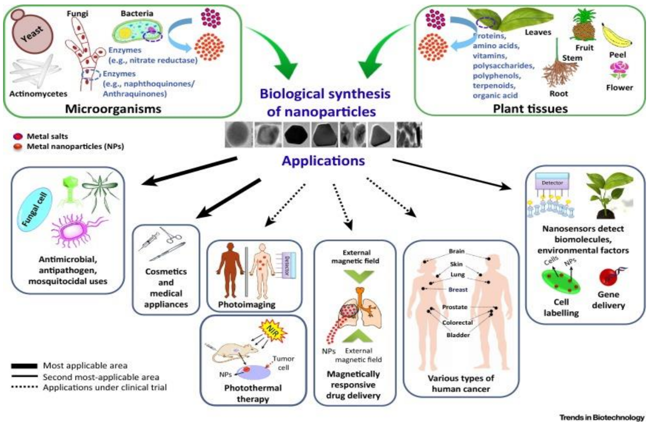

Figure 1 Application areas of metallic nanoparticles synthesized by biological methods [3].

Nanomaterials, which are the mainstay of nanotechnology that serve our lives for many years thanks to the contributions of many sciences, can be classified according to their origins, dimensions and structural configurations. According to their origin; nanomaterials are classified into two main groups: natural nanomaterials that are found in nature such as viruses, proteins, enzymes and minerals, and artificial nanomaterials which are not found in nature and require some processes for their production. According to their dimensions, nanomaterials are examined under four classes:

- nano-sized nanocrystals -also known as zero dimensions- which includes metallic and semiconductor nanoparticles.
- one-dimensional nanomaterials include nanowires, nanobots, and nanotubes.
- two-dimensional nanomaterials such as nanocomposites and nanoplates;
- three-dimensional nanomaterials, bulkers.

According to their structural configurations, nanomaterials are studied under four main groups as metallic nanomaterials, carbon based nanomaterials, dendrimers and composites. Figure 2 shows some types of nanoparticles used in nanotechnology [4–6].

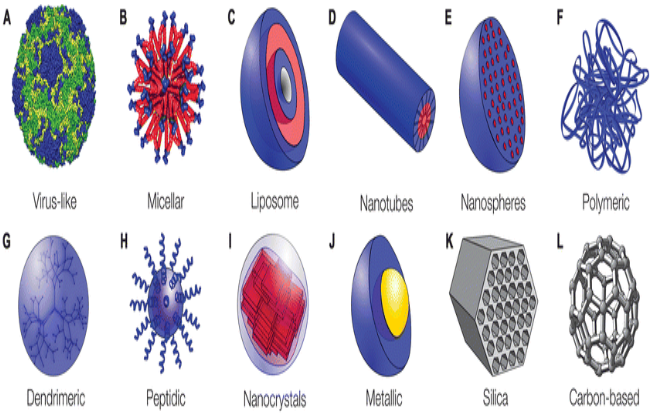

Figure 2 Types of Nanoparticles [5]

The reason for the intense interest of scientists nowadays in nanoparticles is that nanoparticles can exhibit different properties and functions than normal bulk materials. The most important factor that enables production of nanostructures in desired size, shape and properties and provides their usage in various fields is that the effects of classical physics are reduced and the quantum physics becomes active. Other reasons for the different behavior of nanoparticles in physical, chemical, optical, electrical and magnetic behavior include the limitation of load carriers, size dependent electronic structures, increased surface / volume ratio, and other factors incurred by the unique properties of atoms [7].

1.2. Synthesis methods of nanoparticles

In the synthesis of nanoparticles, which can be natural or synthetic origin and exhibit unique properties at the nanoscale, two basic approaches that include various preparation methods and are known from early times are used.

The first approach is the "top-down" method which calls for breaking down of solid materials into small pieces by applying external force. In this approach, many physical, chemical and thermal techniques are used to provide the necessary energy for nanoparticle formation.

The second approach, known as "bottom-up", is based on gathering and combining gas or liquid atoms or molecules. These two approaches have advantages and disadvantages relative to each other.

In the up-down approach, which is costlier to implement, it is impossible to obtain perfect surfaces and edges due to cavities and roughness that can occur in nanoparticles; whereas excellent nanoparticle synthesis results can be obtained by bottom-up approach. In addition, with the bottom up approach, no waste materials that need to be removed are formed, and nanoparticles having smaller size can be obtained thanks to the better control of sizes of the nanoparticles. The classification of synthesis methods of nanoparticles is given in Figure 3 [8–10].

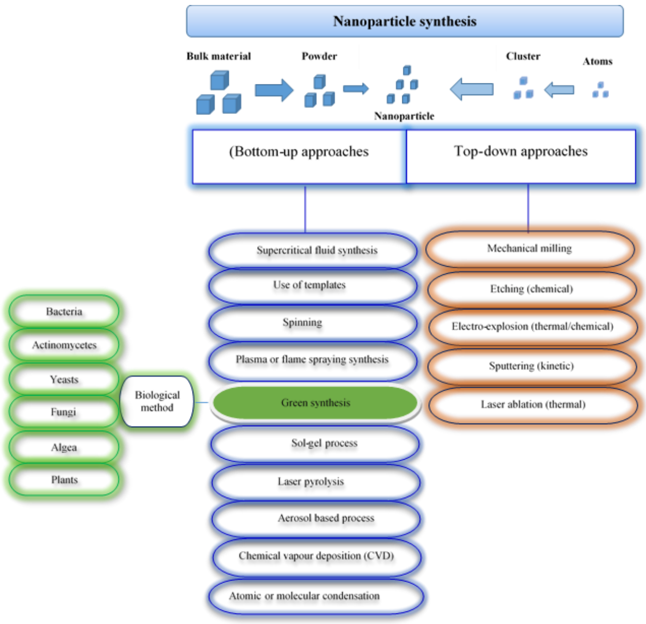

Figure 3 Synthesis methods of nanoparticles [8]

The mechanical abrasion method, which is listed under the top-down approach, uses various ball mills to break down the material into particles and provides the production of nano-sized alloys, composites and semi-crystalline structures. Although this method is inexpensive, efficient and simple, it is susceptible to contamination caused by the balls [11].

2. Green synthesis method

The biological method, which is represented as an alternative to chemical and physical methods, provides an environmentally friendly way of synthesizing nanoparticles. Moreover, this method does not require expensive, harmful and toxic chemicals. Metallic nanoparticles with various shapes, sizes, contents and physicochemical properties can be synthesized thanks to the biological method actively used in recent years.

Synthesis can be done in one step using biological organisms such as bacteria, actinobacteria, yeasts, molds, algae and plants, or their products. Molecules in plants and microorganisms, such as proteins, enzymes, phenolic compounds, amines, alkaloids and pigments perform nanoparticle synthesis by reduction [7, 12–16].

In traditional chemical and physical methods; reducing agents involved in the reduction of metal ions, and stabilizing agents used to prevent undesired agglomeration of the produced nanoparticles carry a risk of toxicity to the environment and to the cell. Besides, the contents of the produced nanoparticles are thought to be toxic in terms of shape, size and surface chemistry. In the green synthesis method in which nanoparticles with biocompatibility are produced, these agents are naturally present in the employed biological organisms. Figure 4 summarizes how nanoparticles are produced by biological methods [17].

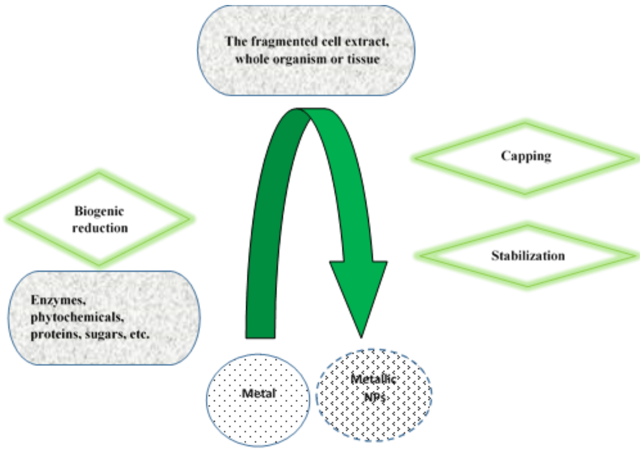

Figure 4 Biological synthesis of nanoparticles [17]

Because of rapid development, affordable culturing costs and easy control and manipulation of growth environment, bacteria are clearly targets in the production of nanoparticles. At the same time, it is known that some species of bacteria have special mechanisms to suppress the toxicity of metals or heavy metals. Bacteria preferred for these properties, can perform nanoparticle synthesis in-situ and ex-situ. Through the use of biochemical pathways and reducing agents such as proteins, enzymes, etc. which present in the bacteria, metal ions can be reduced and precipitated for nanoparticle production [18, 19].

Actinobacteria, which performs the production of secondary metabolites such as antibiotics, are aerobic, immobile, and mostly filamentous gram-positive bacteria. They are resistant to the most toxic heavy metals owing to their detoxification property. Soluble toxic metal ions are detoxified by either being degraded by intracellular or extracellular reduction or precipitation. Thus, nanoparticles being antibacterial, antifungal, anticancer, antioxidant, antibio-contamination and having catalytic activity can be produced [20].

Synthesis of nanoparticles can be done as extra-cellular or intra-cellular with enzymes by employing simply-cultured and fast-breeding eukaryotic yeasts and molds with easy biomass design, as. The incubation conditions and the metallic ion solutions used influence the size of the nanoparticles produced. Being pathogenic for humans limits the use of some molds in nanoparticle production [21].

Algae are eukaryotic aquatic photosites and they break down metallic salts into nanoparticles thanks to the pigments, proteins, carbohydrates, fat, nucleic acid and secondary metabolites they contain. The algae extract that exists in an aqueous medium at a certain temperature is supplemented with metal solutions of the corresponding pH and concentration, and hence the synthesis of nanoparticles is achieved which may have antimicrobial properties without producing any toxic by-products during the synthesis. Size of nanoparticles is determined by certain parameters such as the incubation time of the solution, the ambient temperature, the pH of the mixture used and the metal ion concentration. Algae also provide an advantage to this synthesis method by virtue of their easy availability and usefulness. In addition, effective biomolecules in the reaction medium in the use of bacteria and plant extracts are less extinguished by the nanoparticles formed [22, 23].

Plants, which have great potential for detoxification, reduction and accumulation of metals, are promising, fast and economical in removing metal-borne pollutants. Metallic nanoparticles having various morphological characteristics can be produced intracellularly and extracellularly. Synthesis process; is initiated by addition of extracts obtained from plant parts such as leaves, roots and fruits into the aqueous solution of metal ions. With the materials present in the plant extract, such as sugar, flavonoid, protein, enzyme, polymer and organic acid, acting as a reducing agent, takes charge in bioinduction of metal ions into nanoparticles [8, 10, 13, 22, 24].

3. Conclusion

Recently, a variety of microorganisms and plant extracts have been used to efficiently synthesize metal nanoparticles for green synthesis. Thus, the synthesis of nanoparticles by green synthesis is the most convenient, easy, environmentally friendly way and minimizes the side effects of chemical and physical methods by preventing the use of toxic chemicals and formation of harmful/dangerous by-products.

Nanoparticles have widespread use for their superior properties and are being studied intensively in recent years. The physical and clinical effects of antimicrobial, antioxidative and non-toxic nanoparticles obtained by green synthesis are becoming increasingly important. Future studies will probably focus on obtaining nanoparticles with antimicrobial effects at its maximum level and toxicity at minimum. Because of this reason, synthesizing metallic nanoparticles, -especially by non-toxic green synthesis method-, which are used in many application fields such as cancer treatment, drug transport, biosensor construction is of great importance today.

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