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REVIEW ARTICLE

Mono-metallic, Bi-metallic and Tri-metallic Biogenic Nanoparticles Derived from Garlic and Ginger with their Applications

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Abstract: Biogenic metallic nanoparticles (NPs) produced from garlic and ginger have a wide range of applications in the pharmaceuticals, biotechnology and electronics industries. Despite many commercial NPs reported, NPs made from natural extracts are more affordable, straightforward and environmentally friendly than synthetic approaches. Biogenic metallic NPs derived from garlic and ginger have superior biocompatibility, better dispersion, higher stability, and stronger biological activities. This is due to the fact that garlic and ginger possess significant activities against multi-drug resisted pathogens and are in high demand, especially for the prevention of microbial diseases. This review placed a substantial emphasis on comparative investigations of the synthesis of mono-, bi-, and tri-metallic NPs with a variety of sizes and forms, as well as applications using materials like ginger and garlic. The benefits and drawbacks of mono-metallic, bi-metallic, and tri-metallic biogenic NPs produced from garlic and ginger are also comprehensively highlighted. Recent improvements have opened the way to site-specific targeting and drug delivery by these metallic NPs.

Keywords: Biogenic material, chemical reduction, nucleation, metal oxide, nanoparticles, garlic and ginger.

1. INTRODUCTION

Nanoparticles (NPs) have been categorized as organic and inorganic nanoparticles. Liposomes and micelles are examples of organic NPs, whereas silica quantum dots, fullerenes and metallic NPs belong to inorganic NPs. In metallic NPs, numerous metals such as silver, gold, iron, and zinc metals have been reported due to their versatile properties. There are many different varieties of metallic NPs, including metal oxide NPs, bi-metallic NPs, and mono-metallic NPs [1]. There are two approaches for creating metal NPs: top-down and bottom-up methods [2]. Top-down is based upon the grinding or the milling of bulky materials into small nanoparticles [3]. Bottom-up is based upon the designing of nanoparticles from small nanoparticles. Chemical reduction is a key technique in bottom-up strategies, and it is occasionally employed to improve the stability of nanoparticles mixed with the capping agent. The biological method of NP synthesis falls under the bottom-up approach category as well since biomolecules combine metallic materials to produce nanoscale materials [4]. The bottom-up method is efficient, cheaper, and easy for small-scale NPs production as compared to the top-down [5]. The idea of top-down and bottom-up strategies is illustrated in Fig. (**1**). For metallic NPs, a bottom-up method is commonly used and reliable for metallic ions reduction. Initially, metallic atoms are formed that will aggregate into clusters *via* nucleation and growth to form the desired nanostructures [4]. Metallic NPs have been used in numerous applications in biological fields and optoelectronic devices *i.e.*, laser, LED, biosensors, organic solar cells and photodiodes [5 , 6].

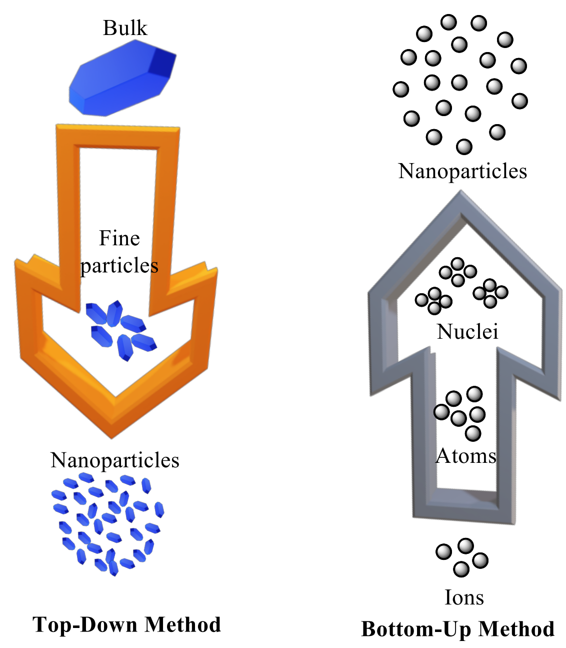

Fig. (1). Nanoparticles synthesis methods. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

Silver nanoparticles (AgNPs) are the most often described type of metallic NPs because of their high surface area, which enhances their biological and catalytic capabilities. Silver is a safe nontoxic and antibacterial metal designated to inhibit different types of pathogenic bacteria [7]. Because of their distinctive optical, electrical, and magnetic capabilities, AgNPs have a wide range of applications in industries including electronics, water treatment, sensor applica-

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