International Journal of Applied Research 2017; 3(7): 629-631

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2017; 3(7): 629-631
www.allresearchjournal.com
Received: 25-05-2017
Accepted: 30-06-2017

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Nanoparticle synthesis by bio reduction and characterisation

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Abstract
Nanotechnology is a highly interdisciplinary field that encompasses various techniques for the synthesis of diverse nanomaterials. These techniques include physical, mechanical, chemical, biological, and hybrid approaches. Nanoparticles can be synthesized in numerous forms such as colloids, clusters, powders, tubes, rods, wires, and thin films, among others. The choice of technique depends on several factors, including the desired material, the specific type of nanomaterial, as well as the required size and quantity.
The exploitation of nanotechnology holds great promise for the benefit of humanity. However, to fully realize its potential, it is crucial to comprehend the nature of nanomaterials and the methods employed for their synthesis. This paper aims to shed light on synthesis of nanomaterials and indicated the presence of flavones or terpenoids adsorbed on the surface of silver nanoparticles.

Keywords: Microbial cluster, terpenoids, X-Ray diffraction, fourier transform, infrared spectroscopy

Introduction

Nanoparticles can be categorized into various types based on their size, shape, and material characteristics. The classification of nanoparticles depends on their applications or the method of production. These particles exist naturally and can also be produced through human activities. Due to their extremely small size, nanoparticles possess unique material properties. For instance, the dispersion of gold created by Faraday in 1857 remained stable for nearly a century before being destroyed during World War II. Colloidal gold has also been utilized for the treatment of arthritis. Nanoparticles have potential practical applications across various fields.

Initially, the International Organization for Standardization (ISO) defined a nanoparticle as a discrete Nano-object with dimensions smaller than 100 nm in all three Cartesian directions. The ISO standard also provided definitions for two-dimensional and one-dimensional Nano-objects. However, this definition has since been modified. Nanoparticles can also be classified as hard silica particles, fullerenes, or soft Nano droplets. For centuries, the study of biological systems and the engineering of materials such as colloidal dispersions, metallic quantum dots, and catalysts have been conducted in the nanometer regime. For example, the Chinese used Au nanoparticles as an inorganic dye to impart red color to their ceramic porcelains over a thousand years ago. Although the use of colloidal gold dates back centuries, a comprehensive study on its preparation and properties was first published in the mid-19th century.

In general, nanotechnology encompasses the design, fabrication, and application of nanostructures and nanomaterial’s. It also involves a fundamental understanding of the physical properties and phenomena exhibited by nanomaterial and nanostructures. The study of the relationships between physical properties, phenomena, and material dimensions in the nanometer scale is referred to as Nano science. In the United States, nanotechnology is defined as the field concerned with materials and systems that exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes due to their Nano scale size.

Application

Nanoparticles have gained significant attention due to their unique properties and size, leading to their utilization in various applications, including composite materials and as inorganic fillers like carbon black or silica nanoparticles. Nano composites have played a pivotal role in the advancement and creation of innovative materials. For instance, they serve as fundamental components in the development of dielectric insulating and magnetic materials. In the case of polymers, nanoparticles are incorporated to enhance their strength and improve impact resistance.

Moreover, nanoparticles have found increasing use in food packaging to regulate the surrounding atmosphere, thereby preserving freshness and safeguarding against microbial contamination. These composites often employ Nano flakes of clays and clay-like particles, which effectively hinder moisture ingress and minimize gas transport across the packaging film. In addition, antimicrobial nanoparticles have been integrated into paints and coatings, making them particularly valuable in healthcare facilities, including hospitals, as well as food preparation areas.

Composite materials based on carbon nanotubes and layered materials such as graphene have also gained prominence and are observed in numerous applications. Furthermore, nanoparticles and nano fibers play a crucial role in the design and manufacture of novel scaffold structures for tissue and bone repair, among other medical applications. These are just a few examples of the diverse applications of nanoparticles in various fields, showcasing their immense potential for driving advancements and breakthroughs

Bio reduction Method for Nanoparticle Synthesis

Metal nanoparticles have traditionally been synthesized using physical and chemical methods for a significant period of time. However, the exploration of biological synthesis for metal nanoparticles is a relatively recent development. The utilization of plant extracts as biological reducing agents for metal ions has been known since the early 1900s, although the resulting reduction products have not been extensively studied. It has been demonstrated that the synthesis of metal nanoparticles using natural products, along with chemical or physical methods, yields similar outcomes.

The use of plant extracts in the green synthesis of metal nanoparticles has gained considerable importance due to its ability to enhance the chemical, physical, biological, and medicinal properties of the resulting particles. Metal nanoparticles possess significant importance in various fields such as heat transfer fluids, conductors, sensors, electronics, and catalysis, owing to their exceptional morphology, which is dependent on factors such as size and shape.

The biosynthesis of metal nanoparticles is an area of great interest due to the increasing demand for environmentally friendly technologies in material synthesis. Therefore, there is a growing need to develop eco-friendly methods for nanoparticle synthesis that do not rely on harmful chemicals [1, 2]. Several innovative approaches have been explored to achieve environmentally sustainable synthesis of metal nanoparticles. The biosynthesis process involves three fundamental steps: bio reduction of nanoparticles, nanoparticle growth, and nanoparticle stabilization. Various natural sources, such as microorganisms, plant extracts, and natural compounds, have been utilized for the green synthesis of metal nanoparticles, offering advantages such as eco-friendliness, cost-effectiveness, and ease of scalability [3, 4].

Recent studies have successfully demonstrated the biosynthesis of metal nanoparticles using extracts from leaves of diverse plant species, including *Aloe vera* [5], *Acalypha indica* [6], *Garcinia mangostana*, *Capparious zeylanica* leaf broth [7], and Ocimum sanctum leaf broth [8, 9]. These plant species, rich in phytochemicals, present a promising and environmentally benign resource for metallic nanoparticle production. Moreover, this approach simplifies the procedures by eliminating the need for handling microbial cultures, multiple purification steps, and maintaining cell cultures [10]. The utilization of plant extracts in nanoparticle biosynthesis represents a significant aspect of this field.

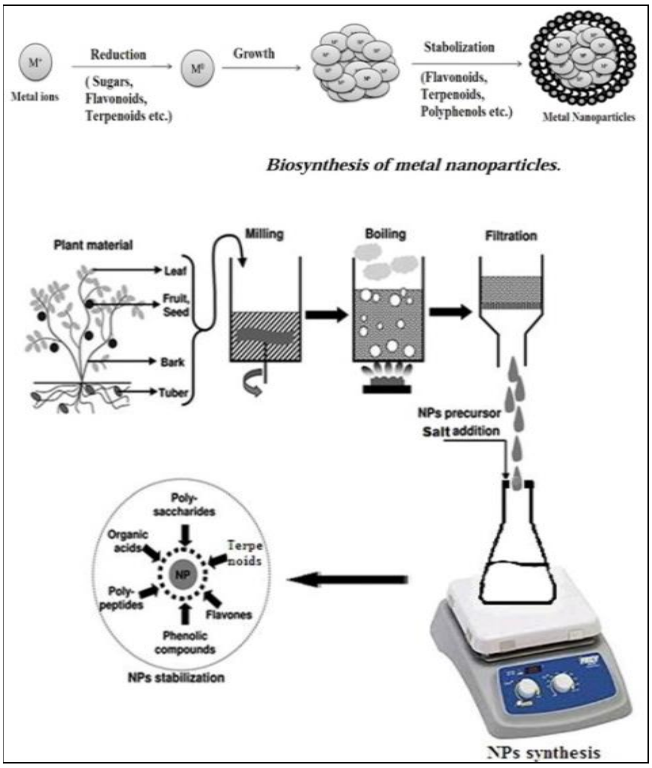

Fig 1: Biosynthesis of Metal Nanoparticles

Characterization

A variety of spectrophotometric techniques, including UV-visible spectroscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy-dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and Zetasizer analysis, were employed to examine the morphology, elemental composition, crystalline structure, functional groups, and stability of the synthesized silver nanoparticles (AgNPs).

Result and Discussion

The process of synthesizing metal nanoparticles through the reduction of metal ions in the aqueous solution using *Azadirachta indica* leaf extract was investigated using UV-visible spectroscopy. The presence of silver nanoparticles in the aqueous medium is characterized by a yellowish-brown color due to surface Plasmon resonance [11]. Upon adding the leaf extract to a silver nitrate solution, the color of the solution transformed from light or faint to a colloidal brown shade, indicating the formastion of silver nanoparticles.

Transmission Electron Microscopy (TEM) analysis revealed that the synthesized silver nanoparticles exhibited a spherical shape, with an average size of 9 nm. The Energy-Dispersive X-ray Spectroscopy (EDS) spectra exhibited strong signals in the silver region at 3 keV, confirming the elemental nature of the nano silver. These signals were attributed to the excitation of surface Plasmon resonance (SPR) in the silver nanoparticles. The size distribution of the nanoparticles was also confirmed through Dynamic Light Scattering (DLS).

The results demonstrated an increase in leaf broth percentage, indicating that an excessive amount of reducing agents led to the aggregation of the synthesized silver particles.

The synthesis process was found to be influenced by the initial concentration of $AgNO_3$. As the concentration of silver nuclei increased, the reaction rate also increased, resulting in smaller particle sizes. Conversely, an excessive concentration of Ag+ ions generated an excess number of nuclei, leading to the agglomeration of nuclei and the growth of particle size. Therefore, the optimal concentration of $AgNO_3$ for the synthesis of monodispersed silver nanoparticles with an average size of 9 nm was determined to be 1.0 x 10-3 M.

Furthermore, it was observed that the synthesis rate of silver nanoparticles increased with higher reaction temperatures. The reduction of Ag+ ions was enhanced as the reaction temperature increased, leading to a higher synthesis rate. However, at very high temperatures, the synthesis rate became uncontrollable, resulting in larger particle sizes.

To identify the potential functional groups responsible for the reduction of silver ions into silver nanoparticles, Fourier Transform Infrared (FTIR) measurements were performed on the leaf broth of *Azadirachta indica* (neem). The results indicated the presence of flavones or terpenoids adsorbed on the surface of silver nanoparticles. These reducing sugars, along with terpenoids, were believed to act as surface-active molecules, stabilizing the nanoparticles and facilitating the reduction of metal ions present in the neem leaf broth

Conclusion

Due to small size of the nanoparticles, as compared to microparticles, these are widely used in all fields of research as well as in medical sciences now a day. The current research work describes, silver nanoparticles (AgNPs) and copper nanoparticles (CuNPs) were synthesized by the leaf broth of *Azadirachta indica* and effect of different reaction parameters such as precursor salt concentration, leaf broth percentage and temperature on the conversion rate and morphology of the AgNPs and CuNPs were analyzed. The results indicated the presence of flavones or terpenoids adsorbed on the surface of silver nanoparticles. These reducing sugars, along with terpenoids, were believed to act as surface-active molecules, stabilizing the nanoparticles and facilitating the reduction of metal ions present in the neem leaf broth.

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