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Chapter

Biological Synthesis of Metallic Nanoparticles from Different Plant Species

Kalyan Singh Kushwah and Deepak Kumar Verma

Abstract

Green chemistry for the synthesis of different nanoparticles (NPs) from metal has become a new and promising field of research in nanotechnology in recent years. The inspire applications of metal oxide NPs have attracted the interest of researchers around the world. Various physical, chemical and biological methods in material science are being adapted to synthesize different types of NPs. Green synthesis has gained widespread attention as a sustainable, reliable, and eco-friendly protocol for biologically synthesizing a wide range of metallic NPs. Green synthesis has been proposed to reduce the use of hazardous compounds and as a state of a harsh reaction in the production of metallic NPs. Plants extract used for biosynthesis of NPs such as silver (Ag), cerium dioxide (C_2O_2), copper oxide (CuO), Gold (Au), titanium dioxide (TiO_2), and zinc oxide (ZnO). This review article gives an overview of the plant-mediated biosynthesis of NPs that are eco-friendly and have less hazardous chemical effects.

Keywords: biosynthesis, metallic nanoparticles, plant extract

1. Introduction

In the last decade, novel synthesis methods for nanomaterials such as quantum dots (QDs), carbon nanotubes (CNTs), graphene, and their composites have been an interesting area in nanotechnology [1]. Despite the progress of the use of small metallic materials listed as nano, the debate still continues in many aspects associated with this new technological revolution. The conceptual beginnings of green chemistry and nanotechnology are among the great scientific developments that have influenced the design of experiments with the goal of environmental protection. Now the reduction in size of green chemistry and nanotechnology is one of the great scientific developments which are to preserve the environment with experiments [2]. Nanoparticles are the most fundamental component in the making of nanostructures. They are much smaller than the everyday objects around us governed by Newton's laws of motion but larger than an atom or a simple molecule that is the subject of quantum mechanics [3]. Nanoparticles exhibit specific properties that depend on their shape, size, and morphology and enable them to interact with plants, microbes, animals [4]. Nanoparticles are a subclass of ultrafine particles with a length of more than 1 nm and less than 100 nm in two or three dimensions and which cannot exhibit size-related depth properties

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that can vary the NP often their morphological or physical. Their application in controlling microbial growth in green synthesis of NPs and electronics, catalysts, drugs, and biological systems has made them eco-friendly [5]. 'Green Synthesis' is attracting a lot of attention in current research and development on materials science methods and technology. Science will basically make green synthesis of nanomaterials through regulation, control, cleaning and therapeutic process. Some basic principles of its environmental friendliness can thus be explained by several factors such as waste prevention, pollution reduction, and the use of safe non-toxic solvent as well as renewable [6]. Nanoparticles have many applications in several fields, such as microelectronics, hydrogen storage ferrofluids, catalytic systems, and chemical nanosensors as well as nanomedicine, agriculture, food science, and energy [7]. The metallic nanoparticles have unique properties that are different from fine-grained materials which use for many agricultural, industrial, and domestic applications, resulting in increased demand and production of nanoparticles. The list of nano-based commodities silica, iron, titania, alumina, and zinc oxide [8]. These types of NPs are the most white pigment and are being used in many products such as paints, plastics, paper, etc. [9] as well as chromosomal mutations in *Vicia faba* plants [10]. The number of multidrug-resistant bacteria and viral strains has been steadily increasing due to mutation, pollution, and changing environmental conditions are trying to develop drugs for the treatment of this microorganism infection to protect against this disease. Metal Nanoparticles have been found to be effective in inhibiting the growth of much infectious bacterial silver and occupy a prominent place in the category of Ag NPs metals used as antimicrobial agents [11]. Green synthesis methodologies based on biological precursors depend on various reaction parameters such as solvent, temperature, pressure, and pH conditions for the synthesis of various nanoparticles, broadly based on the availability of effective phytochemicals in various plant extracts. The leaves contain ketones, amides, terpenoids, carboxylic acids, aldehydes, flavones, phenols, and ascorbic acids that are capable of reducing the metal salts into metal nanoparticles [12]. *Chrysanthemum carinatum* is herbaceous perennial plant have deeply tapering leaves and large white flowers on the wall and extracts play a very important role in reducing and stabilizing agents that reduce cost production and environmental impact [13, 14].

2. Plant-based biosynthesis of metallic NPs

Many researchers have discovered many plant species and components that contain antioxidant compounds such as nitrogenous base amino acids, polyphenols, and sugars [15]. These compounds perform the function of a capping agent for the synthesis of nanoparticles [16]. Generally metal nanoparticles are manufactured in two ways such as bottom-up (fabrication of material from atom to bottom atom) and top to bottom (cutting of bulk material to obtain nano-sized particles). Metal and metal oxide NPs made from plant extract are generally stable even after 1 month and do not undergo any change [17]. Green synthesis of various metallic nanoparticles has reevaluated plants for their natural ability to reduce toxic and hazardous chemicals (**Figure 1**). Nanoparticles of plant-related parts such as leaves, stems, flowers, bark, roots, seeds, and their metabolites have been used for biosynthesis [19]. Generally, there are three aspects that need to be considered for green biosynthesis solvent medium, non-toxic ion reducing agents, and environmentally safe NPs stabilizers [20].

Figure 1.
Work flow of plant-based biosynthesis of metallic nanoparticles [18].

3. Biosynthesis of silver (Ag) nanoparticles

Plants have the ability to store heavy metals in their various parts. As a result, biosynthesis techniques employing plant extracts have produced a simple means to stabilize efficient growth, simple, cost-effective synthesis process, along with traditional preparation methods for the production of NPs [21]. Silver NPs have been synthesized and studied extensively due to their unique chemical, physical and

Biosynthesized NPs	Plant extract used	Size of NPs	Morphology of NPs	Reference
Ag NPs	*Erigeron bonariensis*	13	Spherical	[24]
Ag NPs	*Nigella sativa*	15	Spherical	[25]
Ag Nps	*Morinda tinctoria*	60–95	Spherical	[26]
Ag NPs	*Pedalium murex*	50	Spherical	[27]
Ag NPs	*Adhatoda vasica*	10–50	Spherical	[28]
CeO_2 NPs	*Gloriosa superba*	5	Spherical	[29]
CeO_2 NPs	*Centella asiatica*	19	Spherical	[30]
CeO_2 NPs	*Hibiscus sabdariffa*	4	Spherical	[31]
CeO_2 NPs	*Cymbopogon flexuosus*	10–40	Spherical	[32]
CeO_2 NPs	*Leucas aspera*	4–13	Spherical	[33]
CuO NPs	*Aloe barbadensis*	15–30	Spherical	[34]
CuO NPs	*Ixora coccinea*	80–110	Spherical	[35]

Biosynthesized NPs	Plant extract used	Size of NPs	Morphology of NPs	Reference
CuO NPs	*Syzygium alternifolium*	17	Spherical	[36]
CuO NPs	*Leucaena leucocephala*	10–25	Spherical	[37]
CuO NPs	*Moringa oleifera*	6–61	Spherical	[38]
Au NPs	*Cinnamomum zeylanicum*	25	Spherical	[39]
Au NPs	*Scutellaria barbata*	20–35	Spherical	[40]
Au NPs	*Sesbania drummondii*	6–20	Spherical	[41]
Au NPs	*Avena sativa*	5–20	Rod	[42]
Au NPs	*Medicago sativa*	2–40	Tetrahedral	[43]
TiO_2 NPs	*Psidium guajava*	32	Spherical	[44]
TiO_2 NPs	*Solanum trilobatum*	70	Spherical	[45]
TiO_2 NPs	*Nyctanthes arbortristis*	100–150	Spherical	[46]
TiO_2 NPs	*Catharanthus roseus*	25–110	Irregular	[47]
TiO_2 NPs	*Annona squamosa*	21–25	Spherical	[48]
ZnO NPs	*Sedum alfredii*	53	Hexagonal	[49]
ZnO NPs	*Ruta graveolens*	28	Hexagonal	[50]
ZnO NPs	*Azadirachta indica*	9–25	Spherical	[51]
ZnO NPs	*Eichhornia crassipes*	28–36	Crystalline	[52]
ZnO NPs	*Plectranthus amboinicus*	50–180	Hexagonal	[53]

Table 1.
Different type of metallic NPs biosynthesized from plants extracts.

biological properties [22]. Plants have biomolecules such as proteins, carbohydrates and coenzymes with the ability to reduce metal salts. Other biosynthesis processes of Ag NPs from herbal extracts perform extract-assisted biological synthesis and have yielded many advantages over chemical and physical methods of synthesis of NPs. It is also a fact that these routes are simple, cost-effective, eco-friendly for high production [23]. Synthesis of Ag NPs from *Arbutus unedo* leaf extracts and its organic compounds are responsible for the stabilization and reduction of ions. Various green-synthesized Ag NPs for natural capping agents can be used for drug delivery in pharmaceutical drugs. In most studies, the synthesis of Ag NPs by plant extracts is a simple method (**Table 1**) [54].

4. Biosynthesis of cerium dioxide (CeO_2) nanoparticles

Plants produce biologically active compounds to protect themselves. In plants, it is well organized and unique with various valuable metabolites that use phytochemical biologically active substances. These biocompounds are responsible for the reduction of metal ions during the synthesis of NPs [55]. Cerium dioxide has high catalytic properties due to their broad band gap energy and binding energy, indicating many applications [56]. Depending on the chemistry, the reaction kinetics are affected by the reaction temperature, and this determines the time that most of the temperature difference occurs as a result of changes in the synthesis of NPs [57]. Various compounds such as cerium nitrate, cerium acetate, and cerium chloride have been used as synthesis precursors, and extracts of several plant parts such as leaves, flowers, have been used as reducing agents. The synthesized CeO_2 NPs are spherical shape and crystalline in nature (**Table 1**) [58].

5. Biosynthesis of copper oxide (CuO) nanoparticles

The parameters of plant extracts such as phytochemicals, metal salt concentration, temperature and pH control the rate of formation of nanoparticles as well as their stability and yield [59]. Extracts of plant leaves are considered a good source for metal and metal oxide NPs synthesis. Additionally, plant leaf extracts play a greater role as reducing and stabilizing agents of the biosynthesis process, the phytochemical composition of plant leaf extract is also an important factor in the synthesis of CuO NPs [60]. Green synthesis of Cu NPs can reduce the use of many hazardous chemical substances; many methods use L-ascorbic acid as a reducing agent in synthesis, and the synthesized Cu NPs were highly stable (**Table 1**) [61].

6. Biosynthesis of gold (Au) nanoparticles

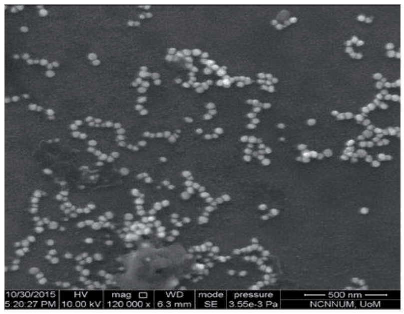
Water is the most accessible and cheapest solvent on earth. Since the advent of nanotechnology, water has been used as a solvent for the synthesis of various NPs [62]. Most research on the biosynthesis of NPs was done from angiosperms using plant extracts, mainly in gold NPs synthesis. Mechanisms of metal depletion and stabilization have also been explored by phytochemicals of plants. They can be helpful in forming NPs [63]. Plant extracts showed the green synthesized NPs to be effective in ions reduction. High variability suggests that this may be one of the reasons that produced large amounts of Au NPs using plant extract (**Table 1**) [64].

7. Biosynthesis of titanium dioxide (TiO_2) nanoparticles

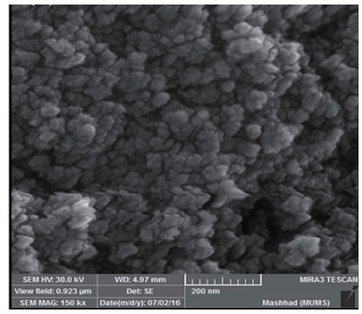
The high prevalence of TiO_2 NPs is due to their many versatile applications resulting from the stability of chemical structure, optical, electrical, and physical properties. These characteristics offer a wide range of TiO_2 is present in three different mineral forms such as anatase, rutile, and brocite. It is generally preferred due to its photocatalytic activity [9]. The synthesis of TiO_2 NPs by plant leaf extracts is mixed with metal precursor solutions in various reactions and temperature conditions [65]. The high production and widespread use of TiO_2 NPs have led to little effort for biogenic production. Several plant species have been investigated for the production of TiO_2 NPs. Several processes have been developed in the last two decades to synthesize biogenic NPs. These methods effectively control the properties of NPs in which most of the potential toxicity materials are used (**Table 1**) [66].

8. Biosynthesis of zinc oxide (ZnO) nanoparticles

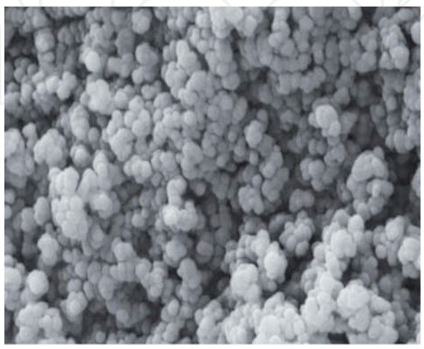
The biosynthesis of ZnO NPs an alternative to physical and chemical methods for the formation of NPs, it is representing an area of significant discovery for a wide range of applications (**Figure 2**) [73]. In recent times, the green method for the synthesis of NPs has become an area of great interest in this direction because the use of conventional chemical methods is very expensive, and as a reducing agent of chemical compounds or organic solvents use is required which produces toxicity [74]. Various studies where the plant-based synthesis of ZnO NPs from various zinc



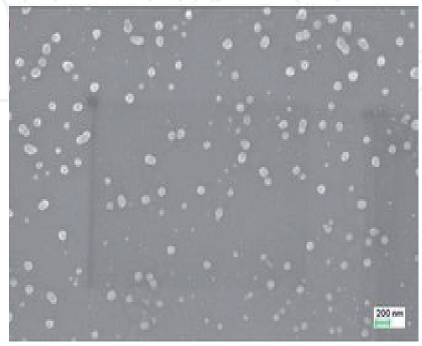
(A) Ag NPs {41}



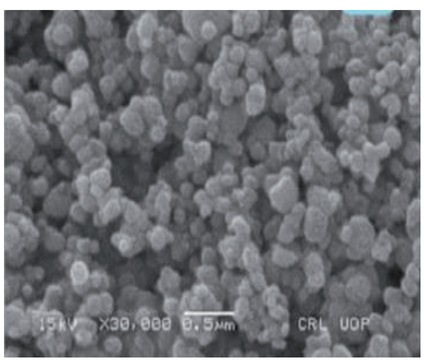
(B) Cerium dioxide {42}



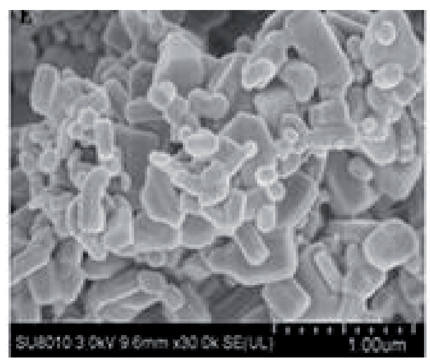
(C) Copper oxide NPs {43}



(D) Gold NPs {44}



(E) Titanium dioxide NPs {45}



(F) Zinc oxide NPs {46}

Figure 2.
Scanning electron microscopic images of biosynthesized NPs: (A) Silver NPs [67], (B) Cerium dioxide NPs [68], (C) Copper oxide NPs [69], (D) Gold NPs [70], (E) Titanium dioxide NPs [71], (F) Zinc oxide NPs [72].

compounds was made using extracts from different parts of the plants are represented in **Table 1** [75].

XPS spectra of AgNPs were measured using a hemispherical analyzer (Physical Electronics 1257 system). For the XPS, a twin anode (Mg and Al) with X-ray source was operated at 400 W of constant power and using Al Kα radiation (1486.6 eV). The samples were placed in a sample stage with an emission angle of 45°. The measurements were carried out by suspending AgNPs on a gold film while gold was served as metallic reference. Au 4f binding energy was 84 eV for samples without any charging effect (**Figure 3**).

Raman spectra were measured using a Bruker Raman spectrometer; model Senterra with laser excitation at 633 nm, and laser power at 10 mW. Spectral data were collected using a 50× microscope objective (NA = 0.51) with 30 s integration time. The surface-enhanced Raman scattering (SERS) samples were prepared by mixing 360 μL of colloidal solution with 40 μL of aqueous solutions of the probe molecule, resulting in a final R6G concentration of 1.0×10^{-5} mol L^{-1} (**Figure 4**).

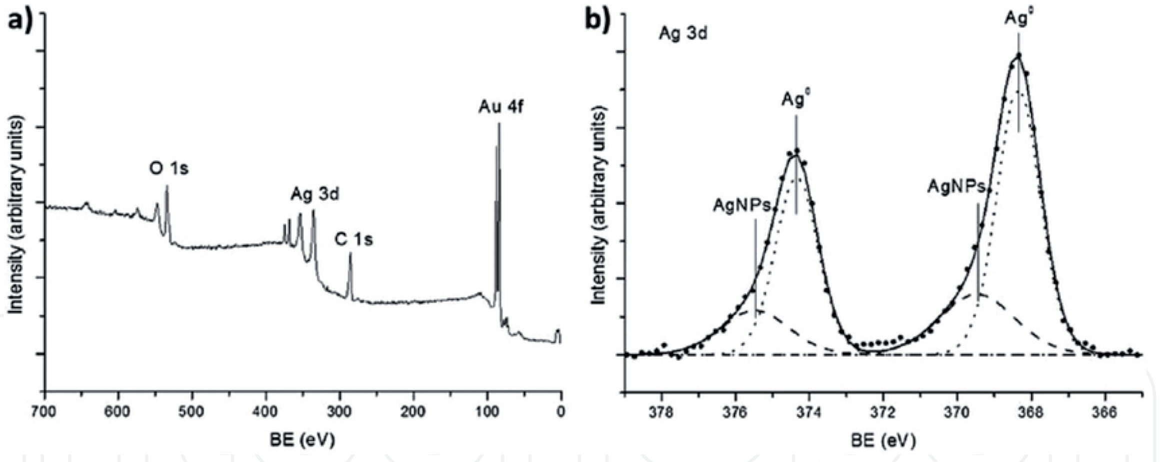


Figure 3.
X-ray photoelectron Spectroscopy of AgNPs [76].

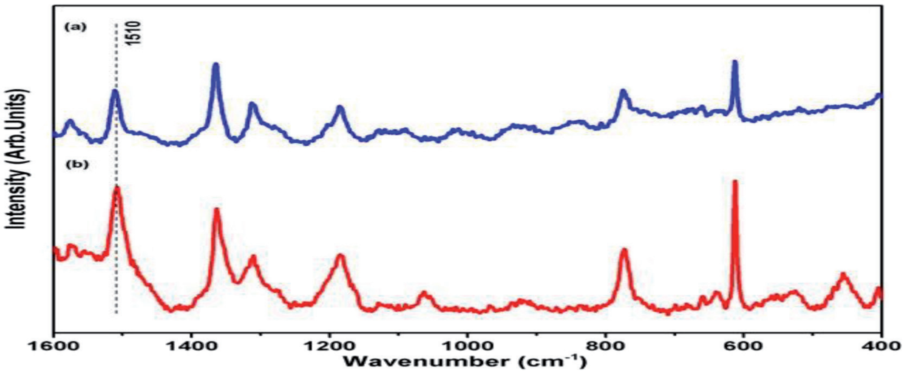


Figure 4.
Surface-enhanced Raman scattering spectrum of AgNPs [77].

9. Conclusion

Today, nanotechnology is considered to be very essential to help promote ultra-modern farming systems with very little environmental damage. Since the beginning, methods of synthesis of plant-based NPs using bioprocess have been considered eco-friendly and cost-effective for the last decades. Many types of natural extracts such as plant leaves have been employed as efficient resources for the synthesis of NPs. A large number of NPs are being explored in many areas of agriculture and biotechnology.

Conflict of interest

Authors declare that there is no conflict of interest for publication of this article.

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