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Synthesis of Gold Nanoparticles using Plant Extract: An Overview

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Abstract

Nanotechnology is making an impact in every field of life. Researchers are expending their interests towards synthesise of gold nanoparticles as they provide superior properties for different types of applications. Conventionally nanoparticles have been synthesised by various physical and chemical methods, having negative impact on environment. The production of nanoparticles using plant extract is alternative the conventional methods. The photosynthesis is a green and eco-friendly technology used for production of large scale nanoparticles. Plant extracts may act both as reducing agents and stabilizing agents in the synthesis of nanoparticles. The various phytochemicals present in plant extract used for the reducing and stabilisation of nanoparticles. This review article is concentrated on synthesis of gold nanoparticles using plant extract used for various applications.

Keywords: Nanoparticles; Gold; Plant extract; Photosynthesis

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Introduction

During the last few decades, metal nanoparticles have elicit much interest due to their distinct physical, chemical and biological properties and had become most active area of research during past few decades [1,2]. Owing to the interest and importance of nanoparticles many researchers have focused on the synthesis of nanoparticles using various chemical and physical methods. These methods available for the synthesis of gold nanoparticles like ion sputtering, reverse micelle, chemical reduction, hydrothermal, sol gel, etc. [3,4] but unfortunately, are quite expensive and potentially hazardous to the environment which involve use of toxic and perilous chemicals that are responsible for various biological risks. The techniques using naturally occurring reagents such as plant extracts, fungi, sugars, bacteria, biodegradable polymers (chitosan, etc.,), as reductants and stabilising agents could be considered alternative for synthesis of inorganic nanoparticles [3,5,6]. The synthesis of nanoparticles using plant extract provides advancement over other methods as it is simple, one step, cost-effective, environment friendly and relatively reproducible and often results in [7,8].

The nanoparticles are finding their applications in various fields such as biomedical, tissue engineering, health care, environmental, drug delivery, gene delivery, optics, mechanics, non-linear optical devices, food industry, space industry and many more to count on, in fact in every field many more to count on [9]. The remarkable antimicrobial effect of metallic nanoparticles is of interest for researchers due to the growing microbial resistance against the antibiotics and development of resistant strains [3,10]. This mini-review focusses on the role of plants as a biological system for the synthesis of synthesis of gold nanoparticles using plant extract, the worldwide research progressing in this field and their applications.

Synthesis of nanoparticles using plant extracts

Nanoparticles synthesise can be carried out by various chemical and physical methods, but use of such methods are harmful in one or the other way. The photosynthesis of nanoparticles is emerging as the intersection of nanotechnology and biotechnology. Due to a growing need to develop environmentally benign technologies in material synthesis, it has received increased attention [11]. This has motivated the researchers to synthesis the nanoparticles using this route that allow better control of shape and size for various applications.

Synthesis of gold nanoparticles using plant extracts

Synthesis of gold nanoparticles using plant extract is useful not only because of its reduced environmental, but also because it can be used to produce large quantities of nanoparticles. Plant extracts may act both as reducing agents and stabilizing agents in the synthesis of nanoparticles **(Figure 1)**. In view of its simplicity, the use of plant extract for reducing metal salts to nanoparticles has attracted considerable attention within the last few decades [12]. The properties of gold nanoparticles are very different from that of bulk, as the gold nanoparticles are wine red solution while the bulk gold is yellow solid. The gold nanoparticles can be manufactured into a variety of shapes including nanorods, nanospheres, nanocages, nanostars, nanobelts and nanoprisms [13]. The size and shape of gold nanoparticles strongly influence their chemical and other properties. The triangular shaped nanoparticles show attractive optical properties in comparison to spherical one [14]. Due to their wide spread applications in targeted drug delivery, imaging, diagnosis and therapeutics due to their extremely small size, high surface area, stability, non-cytotoxicity and tunable optical, physical and chemical properties, gold nanoparticles have revolutionised the field of medicine [13,15].

Biosynthesis of gold nanoparticles using plant extracts is getting more popular due to the strong antibacterial action of nanoparticles and easy reduction of their salts. This simple, single step procedure appears to be suitable for large scale production as it is cost effective, rapid, environmentally benign and is safe for clinical research. Two medicinally important plants *Cucurbita pepo* and *Malva crispa* were also reported for synthesis of gold nanoparticles with potent antibacterial agent against food spoilage pathogens [16]. Gold nanoparticles of size 20-30 nm were rapidly synthesized using aqueous leaves extract of *Acalypha indica* as novel source of bio-reductants [17]. Gold nanoparticles are emerging as promising agents for cancer therapy and nano-sized gold particles have been evaluated against a variety of human cancer cells. The triangular shaped Au core-Ag shell nanoparticles were obtained by the reduction of gold ions by lemongrass extract by electrostatic complexation of Ag^+ ions with negatively charged lemongrass reduced gold nanoparticles followed by reduction of the surface-bound Ag^+ ions by ascorbic acid [18]. The leaf extract of *Cymbopogon citratus*, which acted as a reducing and capping agent also reported for synthesis of gold nanoparticles. The leaf extract and biosynthesized nanoparticles were tested against larvae and pupae of the malaria vector *Anopheles stephensi* and the dengue vector *Aedes aegypti* [19]. Biosynthesis of 10 nm size gold nanoparticles using leaf extract of *Zingiber officinale* was also reported in the literature [20]. *Syzygium cumini* fruit extract was reported to synthesised the silver nanoparticles of 10-15 nm size [21]. The aqueous seed extract of *Abelmoschus esculentus* were used to synthesised gold nanoparticles and its antifungal activities were tested against *Puccinia graminis tritci, Aspergillus flavus, Aspergillus niger* and *Candida albicans*. The synthesised nanoparticles hence, has a great potential in the preparation of drugs used against fungal diseases [22]. The stable gold nanoparticles of variable size were obtained by using extract of leaves of *Pelargonium graveolens* and its endophytic fungus as extracellular synthesis [23]. The synthesis of nanoparticles employing plant extracts is a simple and viable alternative to chemical procedures and physical methods. The triangular and spherical shape nanoparticle with an average size of 50 nm and 100 nm synthesised by using leaf extract of *Nepenthes Khasiana* was also reported confirmed by scanning electron microscopy (SEM) and tunnelling electron microscopy (TEM). At ambient temperature and pressure, the rate of reduction of metal ions using plant agents is found to be much faster [24]. The synthesis of gold nanoparticles of size 15-25 nm has been carried out using *Cassia auriculata* aqueous leaf extract. The reduction of auric chloride takes place within 10 min at room temperature. The surface plasmon resonance (SPR) of the gold nanoparticles formed corresponded to 536 nm and there was an increase in intensity till 10 min as a function of time without any shift in the peak wavelength [25]. The aqueous gold ions when exposed to coriander leaf extract are reduced and resulted in the biosynthesis of gold nanoparticles in the size range from 6.75-57.91 nm [26]. The fruit peel extract of *Punica granutum* was used to synthesis the gold nanoparticles for cancer targeted drug delivery [27]. Hibiscus leaf extract was used to synthesise gold nanoparticles of different size and shape with average particle size of 13 nm [28]. The synthesis of silver nanoparticles employing a shadow-dried *Stevia rebaudiana* leaf extract with particle size ranging from 2 to 50 nm with an average size of 15 nm is was reported [29]. Magnolia and Persimmon leaf broths were used to synthesise gold nanoparticles. On increasing the reaction temperature to 95°C; the reaction rate thus obtained was higher comparable to the rate of gold nanoparticle synthesis by chemical methods. The size of synthesised nanoparticle range from 5 to 300 nm [30]. The mean particle size for the synthesized gold nanoparticles from grape waste ranged from 20 to 25 nm and is a good technique to utilise the waste of grapes. The waste management represents an important challenge in the agri-food based industries and demands an integrated approach in the context of recycling, reuse and recovery [31]. The stable gold nanoparticles of variable size were obtained by using extract of leaves of *Pelargonium graveolens* and its endophytic fungus as extracellular synthesis [23]. The synthesis of gold nanoparticles at room temperature using an aqueous extract of *Hovenia dulcis* fruit with spherical and hexagonal nanoparticles of size 20 nm was also reported. *Hovenia dulcis*, belongs to the family Rhamnaceae and it has long been used in herbal medicine for the treatment of hangover symptoms

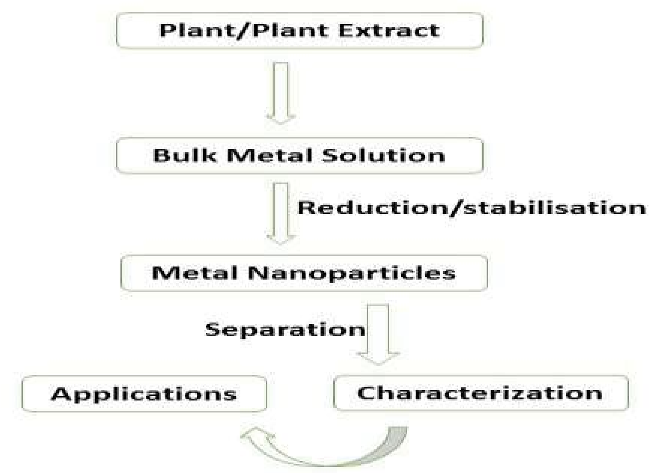

Figure 1 Overview of different steps in plant-extract-mediated nanoparticles synthesis.

[32]. Both gold nanoparticles along with silver nanoparticles were synthesised by using sundried biomass of *Cinnamomum camphora* leaf with aqueous silver or gold precursors at ambient temperature. The triangular as well as spherical shaped gold nanoparticles were found with particle size of 55 to 80 nm [33]. The extracellular synthesis of gold nanoparticles using *Scutellaria barbata* as the reducing agent was reported and the nanoparticles were well-dispersed and particles size ranged in 5-30 nm. The chemical components, mainly including flavonoids, diterpenoids, alkaloids, steroids and polysaccharides were involved in bioreduction of gold nanoparticles [34]. Alfalfa plants were used for synthesis of gold particles with an approximate size of 4 nm with an icosahedron structure with fcc geometry [35]. *Psidium guajava* was also reported to synthesis the gold nanoparticles using phytochemical guavanoic acid as reducing and capping agent and the nanoparticles showed antidiabetic activity by PTP 1B inhibition representing a significant advance in nanomaterial with realistic implications [36]. The treatment of tamarind leaf extract with aqueous chloroauric acid solution, the rapid reduction of chloroaurate ions is observed which lead to formation of gold nanoparticles. The flat and thin single crystalline gold nanoparticles with size of 20-40 nm were formed in this biogenic synthesis [37].

Gold nanoparticles of size 5-100 nm were synthesis using buds of *Syzygium aromaticum* and the particles were found to be of crystalline nature. The flavonoids presents in buds were found to be responsible for reduction of gold nanoparticles [38]. The agricultural waste is usually discarded and there use is not investigated so much so far. Banana peels are a classical example of such abundantly available natural material. The peels of banana are usually discarded. Some researchers tried to utilise this waste material for synthesis of nanoparticles. The gold nanoparticles with average particle size of 300 nm were synthesised using banana peel extract and confirmed by different techniques [39]. *Mentha piperita* extract was used to synthesis spherical shaped gold nanoparticles with size around 150 nm and showed antimicrobial activities against *Staphylococcus aureus* and *Escherichia coli* [40]. The extract of *Madhuca longifolia* was used to reduce the gold nanoparticles [41]. The synthesis of crystalline nature gold nanoparticles in a simple, cheap and eco-friendly biological procedure using biomass of *Suaeda monoica* leaves was reported with particle size ranged from 3.89 to 25.83 nm with average particle size of 12.96 nm. The leaves of this plant were used as a medicine for hepatitis and wounds and possess antiviral activity [42]. The leaves extract of *Stevia rebaudiana* for the reduction of gold ions to nanoparticles form have been studied and spherical shaped nanoparticles with size is from 5 to 20 nm have been synthesised [43]. The use of plant extracts for making metallic nanoparticles is inexpensive, easily scaled up and environmentally benign. The biological synthesis of gold nanoparticles by using the leaf extract of *Coleus amboinicus* and size of gold nanoparticles ranged from 4.6 to 55.1 nm. The spherical nanoparticles produced in the beginning of the reaction were stable due to the protection by sufficient biomolecules [44]. The gold nanoparticles with a particle size ranging from 5 to 15 nm were synthesised using *Zingiber officinale* extract which acts both as reducing and stabilizing agent [45]. The extract of *Pistacia integerrima* that act both as reducing and stabilizing agent for synthesis of gold nanoparticles with particle size in range of 20-200 nm [46]. Various other plants have been used for the synthesis of gold nanoparticles as shown in **Table 1**, which are reported in literature.

Future prospective

Gold nanoparticles are one of the most attractive nanomaterials for various applications like antimicrobial, electronic, catalytic, and various biomedical applications. The present review summarise literature for understanding of synthesis of gold nanoparticles using plant extracts. Synthesis of gold nanoparticles using plant extract is useful not only because of its reduced environmental, but also because it can be used to produce large quantities of nanoparticles. Plant extracts may act both as reducing agents and stabilizing agents in the synthesis of nanoparticles. Synthesis of gold nanoparticles using plant extract have advantage over the other physical methods as it is safe, eco-friendly and simple to use. Plants have huge potential for the production of gold nanoparticles of wide potential of applications with desired shape and size. A detailed study is needed to give a lucid mechanism of biosynthesis of gold nanoparticles using biomolecules present in different plant extracts which will be valuable to improve the properties of gold nanoparticles.

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Table 1 Synthesis of gold nanoparticles using extracts of different plants.

S. No.	Extract of plants	Size and shape of nanoparticles	References
1.	Mango	6.03-18 nm,; spherical	**[47]**
2.	*Gymnocladus assamicus*	4-22 nm; hexagonal, pentagonal and triangular	**[48]**
3.	*Cacumen Platycladi*	variable	**[49]**
4.	*Pogestemon benghalensis*	13.07 nm; cubic	**[50]**
5.	Coriander	6.75-57.91 nm; spherical	**[51]**
6.	*Nerium oleander*	2-10 nm; spherical	**[52]**
7.	*Butea monosperma*	10-100 nm; spherical, triangular	**[53]**
8.	Pea nut	110 to 130 nm; variable	**[54]**
9.	*Solanum nigrum*	50 nm; spherical	**[55]**
10.	*Hibiscus cannabinus*	10-13 nm; spherical	**[56]**
11.	*Sesbania grandiflora*	7-34 nm; spherical	**[57]**
12.	*Salix alba*	50-80 nm; ---	**[58]**
13.	*Eucommia ulmoides*	----; spherical	**[59]**
15.	*Galaxaura elongata*	3.85–77.13 nm; spherical	**[60]**
16.	*Ocimum sanctum*	30 nm; hexagonal	**[61]**
17.	*Torreya nucifera*	10-125 nm; spherical	**[62]**
18.	olive	50-100 nm; triangular, hexagonal and spherical	**[63]**
19.	*Rosa indica*	23.52-60.83 nm; spherical	**[64]**
20.	*Pistacia integerrima*	20-200 nm; ----	**[65]**
21.	*Terminalia arjuna*	60 nm, spherical	**[66]**
22.	*Euphorbia hirta*	6-71 nm, spherical	**[67]**
23.	*Morinda citrifolia*	12.17-38.26 nm, spherical	**[68]**
24.	*Zizyphus mauritiana*	20-40 nm, spherical	**[69]**

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