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Review Article

Role of Biogenic Synthesis of Biocompatible Nano Gold Particles and Their Potential Applications - A Review

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ABSTRACT

Nanotechnology is a field that is vast in making an impact in all fields of human life. Nowadays scientists are expanding interest in inorganic nanoparticles i.e. of noble metal nanoparticles (Gold and silver) as they provide superior material properties with functional versatility. Especially, the medical properties of gold have been known for over 2,000 years. Since the nineteenth century, gold-based compounds have been used in many antimicrobial applications. An alternate and feasible method to synthesize gold nanoparticles is to employ biological methods using many biological sources especially plants. This review focuses on the green synthesis of biocompatible gold nanoparticles using various plant sources. Furthermore, this green synthesis approach is a rapid and better alternative to chemical synthesis and also most effective for large scale synthesis of gold nanoparticles.

Keyword: Nanoparticles; gold; green synthesis; plants

INTRODUCTION

New technologies have always been a major driving force in various fields. The convergence between the scientific disciplines of biotechnology and nanotechnology is relatively a recent one. Yet, the combinations of these are highly important in areas of research that has been already resulted in remarkable achievements. The field of nanotechnology is one of the most active areas of research in modern science. It mainly deals with the fabrication of nanoparticles having various shapes, sizes and managing their chemical and physical parameters. Remarkable advances are made in this field to harness the benefit of life sciences, health care and industrial biotechnology.

In recent days nanoparticles attract greater attention due to their various biomedical applications. Nanotechnology was coined by a Japanese scientist and Professor Norio Taniguchi of Tokyo Science University. The development of green processes for the synthesis of nanoparticles is evolving into an important branch of nanotechnology [1].

Most of the chemical methods used for the synthesis of nanoparticles are too expensive and also involve the use of toxic, hazardous chemicals that are responsible for various biological risks. This enhances the growing need to develop environmentally friendly processes through green synthesis. Plant mediated synthesis of metal nanoparticles is gaining more importance owing to its simplicity and rapid rate of synthesis of nano particles and because they contain reducing agents that may play an important role in biosynthesis of metal nano particles [2].

Since ancient times, the synthesis of colloidal gold was crucial to the 4th century Lycurgus Cup, which changes colour depending on the direction of the light. Later it was used as a method of staining glass. Gold is a well-known biocompatible metal and colloidal gold was used as a solution that exerted curative properties for several diseases in ancient times. AuNPs have a great bactericidal effect on a several range of microorganisms; its bactericidal effect depends on the size and shape of the particle. Recently there are a few reports that algae is being used as an important for synthesis of metallic nanoparticles [3].

Noble metal - gold

During the stone age, man discovered and learned to appreciate gold not only for its beauty but also for its resistivity against corrosion, quintessence of beauty and nobility among the metals. The early historical use of gold has also to do with its natural deposits as nuggets, which meant that no chemical processes were needed to be able to use it. In contrast to the history of gold, the development of its chemistry was retarded because of its noble character. Nowadays, the chemistry of gold is rather broad, beginning with classical complex chemistry via novel organo-metallic chemistry up to solid-state chemistry where so-called aurides give evidence of the high electro negativity of this unique metal. Scientifically, the beginning of the chemistry of gold colloids dates from the middle of the nineteenth century, when Michael Faraday performed his famous experiments to generate gold colloids [2]. He reduced tetra chloro aurate using white phosphorus to yield deep-red gold sols. At the beginning of the 20th century it was Wilhelm Ostwald who contributed decisively to the further development of colloid science [2,3].

Nanoparticles can be prepared using a variety of chemicals and physical methods, including chemical reduction, photochemical reduction, electrochemical reduction and heat vaporization. The reagents can be inorganic compounds, such as sodium/potassium borohydrate, hydrazine, and salts of tartrate, or organic compounds, like sodium citrate, ascorbic acid, and amino acids, which are capable of being oxidized. Because noble metal nanoparticles are now widely used in areas of human contact [4], there is a growing need to develop environmentally friendly processes that do not use toxic chemicals in their synthesis. A quest for an environmentally sustainable synthetic process. AuNPs has drawn special attention owing to its immense importance in biomedical and chemical applications [5].

Methods have long been known to generate beautifully coloured glass by adding gold to generate burgundy, reds, or purple [6]. Faraday attributed this colour to very finely divided colloidal gold, or gold nanoparticles as known today. As the size or shape of the nanoparticle changes, the observed colour also changes. Gold spheres have a characteristic red colour, while silver spheres are yellow. More recent treatments have shown that the colour is due to the collective oscillation of the electrons in the conduction band, known as the surface plasmon oscillation. AuNPs have a great bactericidal effect on a several range of microorganisms; its bactericidal effect depends on the size and shape of the particle [7]. AuNPs have wide range of applications in nano-scale devices and technologies due to its chemical inertness and resistance to surface oxidation (Figure 1) [8].

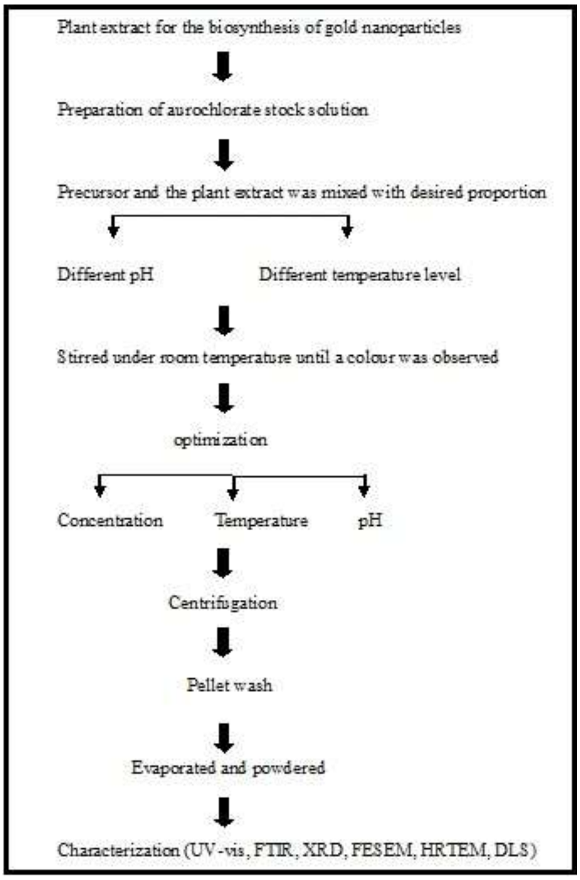

Fig. 1: Generalized procedure for biosynthesis of gold nanoparticles

Physical properties

The surface plasmon resonance is due to the collective oscillations of the electron gas at the surface of nanoparticles (6s electrons of the conduction band for AuNPs) that is correlated with the electromagnetic field of the incoming light, i.e., the excitation of the coherent oscillation of the conduction band. According to Mie theory, the total cross section composed of the SP absorption and scattering is given as a summation over all electric and magnetic oscillations. The resonances denoted as surface Plasmon were described quantitatively by solving Maxwell's equations for spherical particles with the appropriate boundary conditions. Mie theory attributes the plasmon band of spherical particles to the dipole oscillations of the free electrons in the conduction band occupying the energy states immediately above the Fermi energy level.

Biomedical applications

Gold nanoparticles has turned out to play an important role in various fields of nanoscience. Besides their unique colour, gold nanoparticles became of scientific and technological interest because of their stability to air which means that they can be used even in nano sized form for many applications. Noble metals as therapeutic agents, particularly of gold, have distinguished history in medicine. The use of gold in medicine have evolved over thousands of years [9,10]. In China, gold was used in the treatment of ailments such as smallpox, skin ulcers and measles. In Japan, thin gold foils placed in tea, sake and food were seen as beneficial to health. In Bangladesh- Pakistan-India, traditional ayurvedic medicines are still used widely with gold taken as a 'rejuvenator' by millions of people each year.

Over the years, the gold nanoparticles have become more precious than pretty gold. Most important reason, for this has been their wide uses and applications in the fields of diagnostics, surgery and Medicine [11, 12] has had greatest impact in biology & medicine [Table 1]. Some investigators reported the widespread use of gold nanoparticles in four areas of biology, i.e. labelling, delivering, heating and sensing [13, 14].

In surgery, resistance to bacterial infection has led to a long tradition of gold being used in microsurgery of the ear and other procedures which require implants that are at risk of infection, including in the eye. In 2001, Boston scientific produced the Niroyal stent, one of the first gold-plated stents, largely in response to the need for stents that could be placed more

Table 1: Biosynthesis of gold nanoparticles using different plant sources its size and shape

Sl.no	Plant name	Plant source	Shape	Size (nm)	Reference
1	*Phyllanthus amarus*	leaf extract	cubic	65-99	19
2	*Momordica charantia*	fruit peel extract	spherical	30-100	2
3	*Amaranthus spinosus*	leaf extract	spherical	10.74	20
4	*Solanum indicum*	fruit extract	circular,hexagonal, triangular and rod	7.4	22
5	*Piper betel*	leaf extract	circular	6	21
6	*Allium cepa*	onion extract	spherical, cubic	~ 100	23
7	*Rosa Berberifolia*	Plant extract	icosahedron structure	8	24
8	*Geranium maculatum*	Plant extract	Nano triangles	20	25
9	*Aloe barbadensis*	Plant extract	Cubic	35	26
10	*Cucurbita digitata*	Plant extract	icosahedron structure	25	27
11	*Nitraria schoberi*	fruit extract	circular	20-30	27
12	*Quercus virginiana*	leaf extract	spherical	10	52
13	*Magnolia grandiflora*	leaf extract	Cubic, spherical	20	52
14	*Pueraria lobata*	leaf extract	icosahedron structure	100	52
15	*Pinus taeda*	leaf extract	Nano triangles	20	52
16	*Sesbania drummondii*	Plant extract	Spherical	6-20	28
17	*Avena sativa*	Plant extract	irregular, and rod	5-20	29
18	*Medicago sativa*	Plant extract	icosahedron structure	2-20	20
19	*Cinnamomun camphora*	Plant extract	Triangular	55–80	30
20	*Camellia sinensis*	leaf extract	Cubic	~ 30	25
21	*Zingiber officinale*	leaf extract	crystalline	10	31
22	*Azadirachta indica*	Plant extract	Cubic	50–100	32

23	*Emblica Officinalis*	Plant extract	Triangular and spherical	15–25	33
24	*Tamarindus indica*	leaf extract	spherical	20–40	34
25	*Cuminum cyminum*	leaf extract	spherical	~ 13	39
26	*Curcuma longa*	leaf extract	spherical	45	39
27	*Ananas comosus*	fruit extract	Cubic	15	25
29	*Tritium aestivum*	Plant extract	Rod shaped	10-30	35
30	*Cice rarietinum*	Plant extract	Nano triangles	22	36
31	*Phyllanthus emblica*	Plant extract	icosahedron structure	7.4	22
32	*Azadira chtaindica*	Leaf extract	Rod shaped	33	26
33	*Ficus religiosa*	Leaf extract	Cubic	23	37
34	*Memecylo numbellatum*	Leaf extract	Circular	13	38
35	*Macrotyloma uniflorum*	Plant extract	spherical	30	39
36	*Citrus limon*	Plant extract	Nano triangles	10	40
37	*Citrus reticulata*	Plant extract	Circular	20-30	40
38	*Citrus sinensis*	Fruit extract	Cubic	10-20	40
39	*Piper pedicellatum*	Plant extract	Nano triangles	30-40	41
40	*Terminalia chebula*	Plant extract	icosahedron structure	4.5	36
41	*Memecylo nedule*	Leaf extract	Circular	20-40	42
42	*Nyctanthes arbotisticus*	Leaf extract	spherical	~10	35
43	*Murayako enigii*	Leaf extract	Nano triangles	~20	43
44	*Mangifera indica*	Leaf extract	Cubic	30-40	44
45	*Musa paradisiaca*	Peel extract	Cubic	30	45
46	*Cinnamomum Zeylanicum*	Plant extract	Circular	20-40	46
47	*Cochlospermum gossypium*	Plant extract	Nano triangles	~6.4	47
48	*Euphorbia hirta*	Plant extract	Rod shaped	10-30	48
49	*Alternanthera sessilis*	Leaf	Cubic	30	49

		extract			
50	*Breyniarhamnoide*	Stem extract	Nano triangles	10	50
51	*Beta vulgaris*	Pulp	Spherical	20	26
52	*Cassia fistula*	Plant extract	Nano triangles	10-30	26
53	*Justicia gendarussa*	Plant extract	Spherical	~ 30	51
54	*Scutellaria barbata*	Plant extract	cubic	5-30	50
55	*Chyrsopogn zizanioides*	Leave Extract	Cubic	130	52
56	*Ginda glauca*	Flower extract	Spherical	10	26
57	*Chedanoium album*	Leave extract	Spherical	10-30	49

accurately. The biological inertness of gold was found to be important in this application and gold plated stents have been found to produce the least number of macroscopic changes in surrounding intravascular tissue [15].

In medicine, new technologies have used the ability of tiny gold nanoparticles to collect specifically in a cancerous tumour by passing through the inherently leaky blood vessels attached to a tumour. Thus, when injected into a patient, there is a means by which a potent anticancer compound attached to a gold nanoparticle can be delivered directly and accurately to a tumour while avoiding surrounding healthy tissues [16]. Cancer is also being treated with gold nanoparticles. These gold nanoparticles are able to select cancerous tissue. Once the tissue has been selected by the particles, a laser is used to explode the particles, which cause damage to the cancerous tissue. Use of nanoparticles to treat cancer is to increase the effectiveness of radiation therapy; gold nanoparticles are an effective radio sensitizer, are biocompatible and increase dose deposit. Cancer is commonly treated with X-ray radiation. "The aim of radiotherapy is to deliver a lethal dose to tumour volumes while at the same time avoiding exposure to healthy tissue" Biocompatibility is important because the particles are used within the human body and for them to be beneficial they should not harm healthy tissue. These particles accumulate in tumour cells, which make them useful therapeutic agents for the treatment of cancer [17]. Medicine still has many unsolved problems and nano medicine may hold the key to some of these problems.

Nanoparticles are used in drug delivery because they can be engineered to be sensitive to certain p^H values. These particles will remain in a certain conformation protecting the drug till they reach a certain part of the body with a certain p^H. In response to the pH the nanoparticles change conformation shape and release the drug. Nanoparticles have also been used to inhibit the bacterial reproduction on surfaces, which creates a cleaner environment and prevents disease. Nanoparticles have also been used in orthopaedic implants. They increase the biocompatibility of the implants ultimately leading to a longer life span of the implant and effectiveness of the implant. Overall, nanoparticles can be used to create medical advances because of their unique qualities and applications [18, 53].

Nanoparticles in range of 1 to 500 nm are extremely smaller than human cells which are about 10-20 µm. Nanoparticles have sizes similar to that of the biomolecules encountered at the cellular level. This specific size of nanoparticles promotes development of nano devices and nano sensors that can go into cells to probe proteins or the DNA both inside and outside the cell. As an antimicrobial although silver has a long history of being used as an antimicrobial, in recent year's gold has also become a good rival for silver. For example gold nanoparticles can fight against *'Escherichia coli'* bacteria. In needle-free drug delivery systems gold-based technologies are also provide a unique needle-free delivery system, a technique that used gold nanoparticles and allowed vaccines to be delivered through the skin making use of the fact that small particles can pass through gaps between cells while large ones cannot. One of the most efficient usages of gold nanoparticles in recent years is detecting and fighting against HIV.

Gold nanoparticles and environment

Gold nanoparticle-based technologies provide solution to some of environmentally great issues, such as greener production methods, pollution control and water purification. In the process of mercury control and sensing gold nanoparticles have greater capacity in controlling them, as mercury is considered as one of very toxic material that exists all over. As it has higher probability of causing some diseases such as Alzheimer and autism. Also over 100 tonnes of mercury finds its way into the atmosphere every year. Only gold-based catalysts can provide a considerable promise as mercury oxidation catalysts. One of the most useful applications of gold nanoparticles is increasing water and air quality, Carbon monoxide is a colourless, odourless gas which is very toxic to humans. Gold nanoparticles provide a simple solution by allowing the oxidation of CO to carbon dioxide (CO_2) that transforms an acutely dangerous gas to a far less toxic substance [36].

CONCLUSION

To have a positive effect, the nanoparticles have to be created with a specific purpose. Various plant leaf extracts was found suitable for the synthesis of gold nanoparticle. Reduction of gold ions using the plant extracts resulted in the formation of stable gold nanoparticles. Due to its eco-friendliness, feasibility and economic prospects the methods of biological synthesis has milestones in various aspects. In contrary of its benefits, there are many challenges ahead that need to be solved in order to make the gold nanoparticles based products commercially viable. It is evident that the role of nanoparticles especially gold nanoparticles plays an important role in new age as they have noble abilities in different fields of science.

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