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Green Synthesis of Gold Nanoparticles From Various Plant Extracts And Their Biological Applications

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Abstract:

Nanotechnology is a trending area in research field for studying particles at nano scales and it is used over conventional methods and gives size dependent parcels of the functional accoutrements. The present review includes study on green technology for the synthesis of gold nanoparticles from various extracts of different plant parts. The green nanotechnology field that provides sustainability in various implementations. The nanomaterial synthesis using conventional nanotechnology involves the release of poisonous nanomaterials that creates the issue of nanotoxicity but the green nanotechnology helps in derogation of the risk and hazards due to the same. The gold nanoparticles using plants extracts because of their diversity, sustainability and eco-friendly nature. It is concluded that gold nanoparticles synthesized using plants extract such as leaf, root, seed and fruit extracts have antioxidant and antimicrobial activity. Due to their SPR frequency, biocompatibility and tunable property gold nanoparticles has great application in cancer treatment, biosensor, drug delivery and enhancement of plant growth.

Keywords: Green chemistry, green analytical chemistry, clean chemistry, atom economy, sustainable development.

1. Introduction:

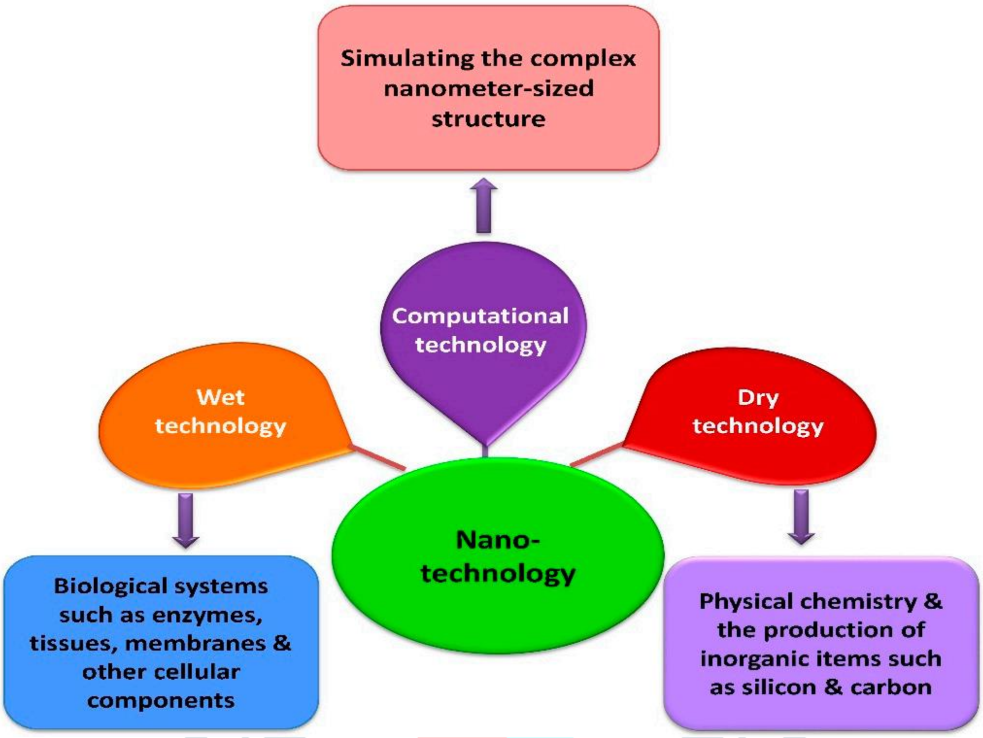
The nanotechnology sector has proven to be one of the most active research fields [1].

Owing to their broad uses in catalysis, sensing, electronics, photonics and medicines, the synthesis of nanoparticles has gained significant attention in recent decades [2]. Scientists have understood the potential of biological organisms to reduce metal precursors since the nineteenth century, but the mechanisms are still not known. Researchers have drawn attention towards biological methods due to the success of nanoparticle synthesis using natural reduction, capping and stabilizing agents, and avoiding harmful chemicals and high energy consumption [3]. A wide variety of products (e.g., Quantum dots (Q-dots) of cadmium sulphide, titanium oxide hybrid-based electrochemical biosensors and oxorubicin-loaded heparinized nanoparticles) can be developed through nanotechnology, and applicable to a broad array of scientific fields, including optoelectronics, biosensors, nano-biotechnology, biomedicine and others [4]. Creation, exploitation and synthesis are nanotechnology concepts that typically consider materials smaller than 1 mm in dimension [5]. Many different methods, such as physical, chemical and green (biological) techniques, have been used to synthesize nanoparticles [6]. The stabilized nanoparticles are formed by reducing ions through reduction (palladium NPs), nucleation (silver NPs) and growth system (silver NPs) [7]. Green chemistry, which uses chemical principles to reduce or eliminate the use of hazardous substances, has led to considerable reductions in toxic residues, which are harmful to man and the environment.

Green chemistry may be defined as chemical-assisted pollution-prevention strategies employed in specific domains such as green analytical chemistry, ecologically friendly analytical chemistry and clean analytical methodologies [8]. Thus, green synthesis is regarded as a viable approach for nanoparticle synthesis since it is biocompatible, inert and environmentally safe [9].

1.1. Different Types of Nanotechnologies:

In general, the three types of nanotechnologies are wet, dry and computational. Wet nanotechnology is concerned with the investigation of living organisms and their components such as tissues [9], enzymes and membranes [10] that are predominantly found in water-based systems [11]. Physical chemistry and inorganic compounds such as carbon and silicon are associated with dry nanotechnology. On the other hand, computational nanotechnology is associated with simulations of nanometer-sized components [12]. The three nanotechnologies, viz., wet, dry and computational, are interdependent for optimal functionality (Figure 1).



Fig, 1. Different types of nanotechnologies.

1.2. Biosynthesis of Novel Metal Nanoparticles Using Plant Extracts:

Nanoparticles with sizes ranging from 1 to 100 nm bind larger particles to atomic or molecular structures [13]. They are synthesized via different approaches, mainly divided into physical and chemical processes (Figure 2). The physical process involves laser ablation, condensation, evaporation, etc., whereas the chemical process involves hydrazine, sodium borohydride, green synthesis, etc. Using plant species to produce nanoparticles has been termed a green technique (Figures 2 and 3) and the most reliable environmentally sustainable approach [14]. Nowadays, researchers are attracted towards biological synthesis, including the use of natural reducing, capping and stabilizing agents and without using hazardous, high-cost chemicals and high power consumption [15] (Figures 2). NPs are extensively utilized in human contact areas (medicine and agriculture, [16] and synthesis methods that do not use harmful compounds are increasingly required.

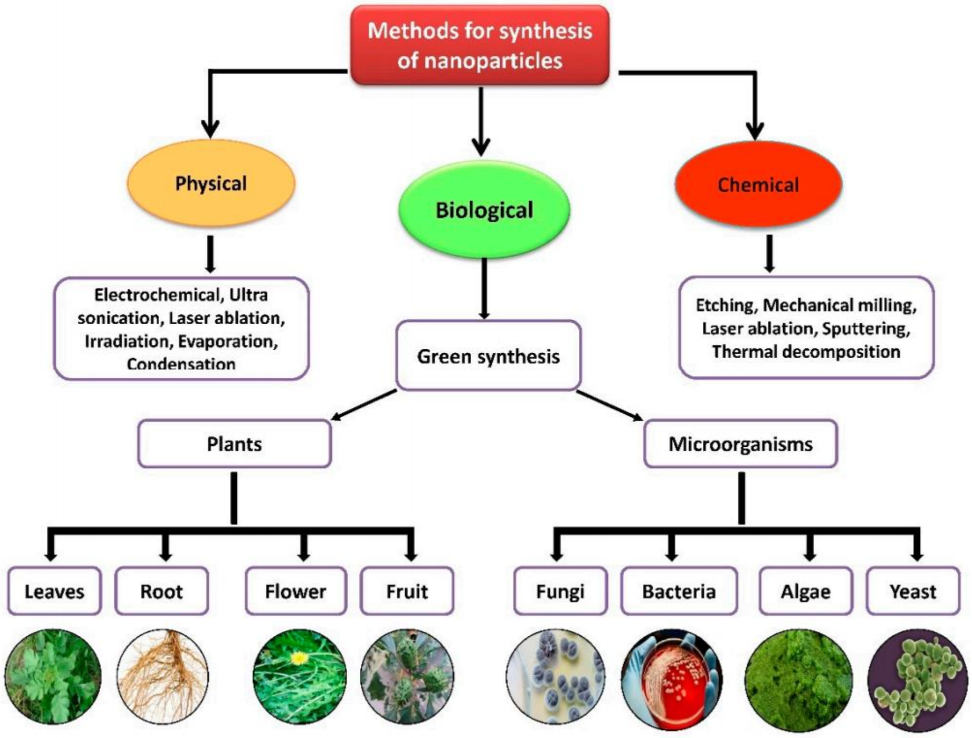


Fig.2 Different methods of nanoparticle synthesis.

1.3. Green Nanotechnology:

Green nanotechnology is related to the field that provides sustainability in various implementations. The main aim of it is the development of non threating methods for the NPs synthesis. The nanomaterial synthesis involve the release of poisonous nanomaterials that creates the issue of nanotoxicity, the green nanotechnology helps in derogation of the risk and hazards due to the same [17].It pursuit to the evaluate the synthetic styles that help to reduce the use of toxic chemicals with intensifying the capability of current synthesis techniques [18]. Green nanotechnology concern with the production of green products. Green products are those whose synthesis start from nontoxic precursor, use of natural source as raw material, involve less energy consumption, use of green solvents and no toxic disposal [19]. The aim of green nanotechnology is to develop environment friendly nanoparticles, develop green methods for large scale nanoparticle production, Discover efficient approaches for using nanoparticles in the development of novel nano-devices [20].

1.4. Why we use Green Nanotechnology:

There is an increasing problem of environmental pollution in today's world due to humanistic activities. Something which is greener and cleaner is more preferable. Green nano-products can be directly applied to check damage from known adulterants and incorporation into environmental technologies can remediate unsafe waste sites, treat pollutants, plant pathogens and related toxins, sense and examiner environmental adulterants, and clean and desalinate weakened water. We prefer green nanotechnology because it provides safe and energy efficient products, reduction in waste and greenhouse gas emissions and involve the use of renewable materials [21].

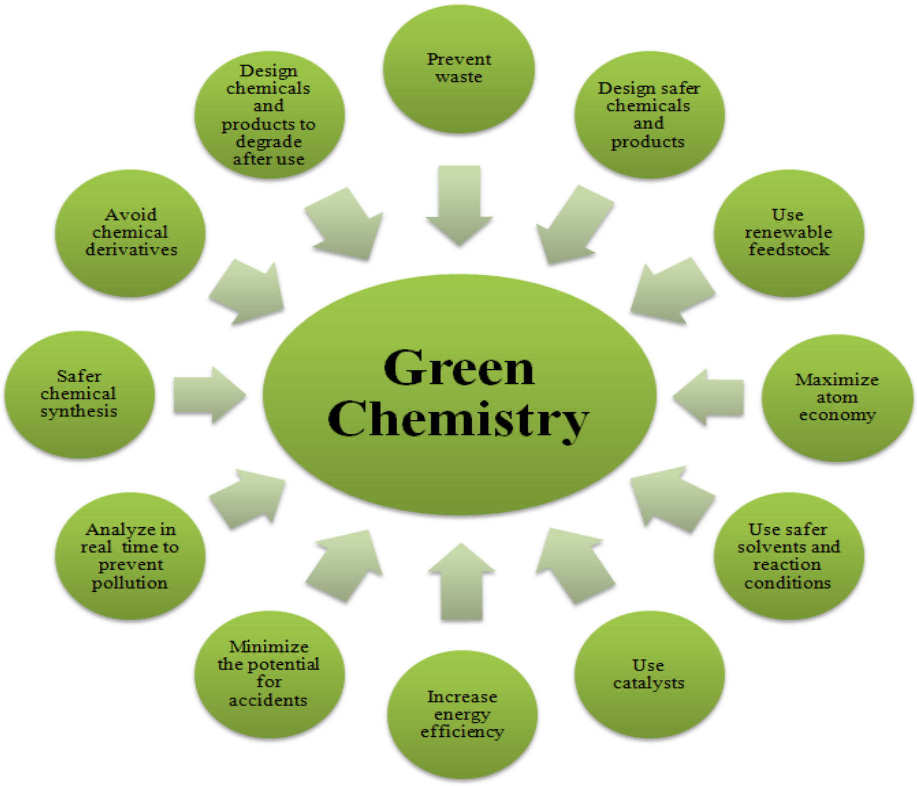


Fig. 3. Principles of Green Chemistry on which Green Nanotechnology Based

Green nanotechnology work on the 12 principles of green chemistry (shown in Figure 1.) such as to design new nanomaterials to achieve economic, social, health, and environmental benefits [22]. The principles of green chemistry impeccably apply to green nanotechnology and nano-manufacturing processes to produce safe, cleaner and more sustainable nanomaterials."

1.5. .Gold Nanoparticles:-

Gold is the quintessential noble element. In its bulk shape, gold's uses in jewelry, coinage, and electronics are widely recognized. Gold nanoparticles (Au NPs) have attracted extensive attention in the last decades due to their unique catalytic, photo physical and electronic properties. Au NPs of various shapes and sizes can be synthesized by adopting different methods (physical, chemical and biological). The Au nanospheres were primary accomplishment in the field of Au NPs, while they were not perfectly spherical. Surfactant, polymers, pharmaceuticals, DNA, RNA, proteins and oligonucleotides are some of the functionalizing agents with which Au NPs can be conjugated [23]. They have broad applications in the fields of environment sensing, electronics, biomedicine and fine chemical synthesis. Because of their multivalency, gold nanoparticles can shield unstable medicines or inadequately soluble imaging contrast agents and facilitate their effective delivery to else inapproachable regions of the body [24]. Optical property of gold nanoparticles helps us to construct optical biosensors such as optical biosensor, electrochemical biosensor and piezoelectric biosensor [25].

The objective of my study is to describe the green synthesis of gold nanoparticles using plants and their biological applications.

2. Techniques For Gold Nanoparticle Synthesis:

There are different methods for Au NPs synthesis as shown in Figure 2.

2.1. Top-Down and Bottom-Up Approach:

Au NPs can be synthesized by two techniques:- top-down approach and bottom-up approach. In top-down approach, a suitable starting molecule is reduced in size, better known as 'modules'. Top-down approach include different physical methods for synthesizing nanoparticles [26]. Different physical methods for nanoparticle synthesis are, molecular beam emphasis, sputter deposition [27], laser desorption, diffusion flame synthesis, milling method, laser ablation [28] and lithographic techniques [29] etc.

In bottom-up approach, the nanoparticles are initially prepared and latterly assembled into final materials by chemicals or biological procedures of synthesis. The bottom-up technique offers the advantage of improving the likelihood of creating nanoparticles with fewer flaws and more uniform chemical compositions.

Bottom-up approach includes chemical and biological methods to synthesize gold nanoparticles. Different chemical methods for synthesizing nanoparticles are electro deposition, sol–gel process [30], chemical vapour deposition soft chemical method, Langmuir Blodgett method [31], co-precipitation method [32] and wet chemical method [33,34].Biological methods involve plants and microorganisms such as algae, virus, bacteria, fungi etc.

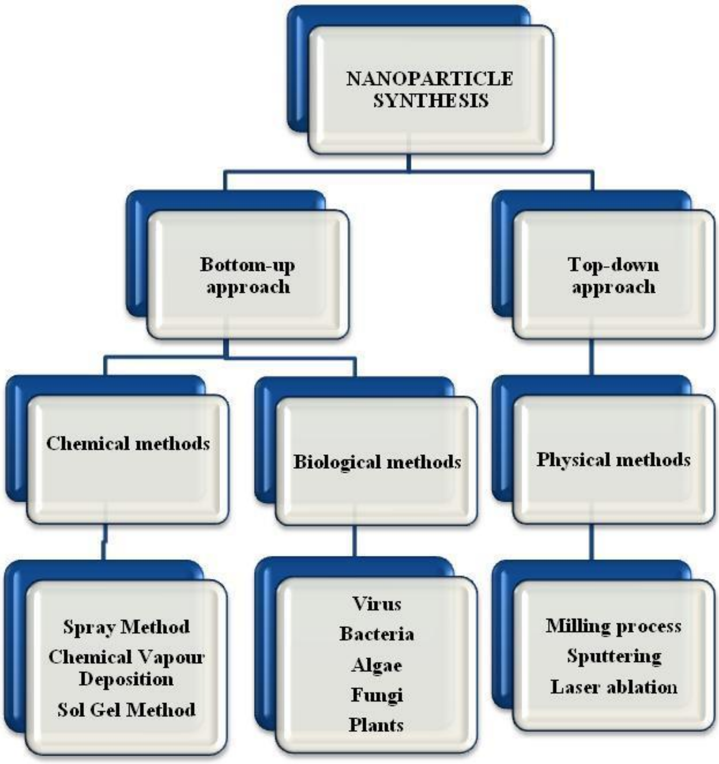


Figure 2. Different Methods of Nanoparticle Synthesis

2.2. Why we Choose Biological Method for Gold NPs Synthesis:

In physical and chemical methods, there is a problem about the control of crystal growth, size and size distribution, stability and aggregation of NPs. Due to different drawbacks of chemical [35]and physical methods [36] , biological approach for synthesizing NPs have been increasing [37,38,39].Biological methods are based on green technology aimed at overcoming negative effects on environment. Biological approach utilize biological materials as reducing bioactive agents, isolated from microorganisms and plants that are eco-friendly, prevent pollution and no production

of waste, effective synthesis and additional energy saving and its economical production of NPs is also very important [40].

In the biological approach bacteria [41], yeasts [42], [43], fungi, algae [44] and plants [45], [46] etc. may be used for producing green NPs at high scale because they contain reducing and capping agent. In biological methods there is use of non-toxic capping agent, less hazardous reducing agent, and environment friendly solvent, no need of high temperature calcination for the production of final product, non-toxic organic solvents are used, methods that used plants can be suitably settled for large scale production of nano-particles [47].

2.3.Why Plants are Best Agents:

From all biological entities plants are the best agent because of their diversity, sustainability, and their waste are also eco-friendly. By using plants it is more easy to maintain cell culture and can also be appropriately settled up for large scale production of nanoparticles [48]. Plants can reduce metal ions faster than fungi or bacteria. The plant mediated nanoparticles are more diverse in size and shape comparatively to those produced by other organisms [49].

Biomolecules of plant extracts can be used in single step synthesis of NPs by reducing metal ions to NPs [50,51]. Plants extracts act both as reducing and capping agents for synthesizing nanoparticle. The biomolecules like vitamins, proteins, alkaloids, polysaccharides, amino acids, and organic acids such as citrates that are present in plant extract help in bioreduction of MNPs [52]. We can faster synthesis rate by using plant extracts of high production capability and increasing the reaction temperature. We can also control particle size and shape by changing the plant type or temperature and composition of the reaction mixture [53].

3. General Mechanism For Green Synthesis of Nanoparticles From Plants:

There are many researches about synthesis of nanoparticles from plants. The general mechanism for synthesis of nanoparticles from plants is presented in Figure 3.

For synthesis of nanoparticles there are three steps: activation, growth and termination.

Activation: Firstly plant parts (fruits, leaves, stems, roots) are washed with distilled water and small pieces are boiled to make the extraction and then mixed with solution of metal ion. Plant extracts comprise bioactive agents such as phenolic acids, sugars, polyphenols, terpenoids, proteins, alkaloids, etc., that firstly reduce the metallic ions and then stabilize them. The metal ions are reduced by biomolecules present in plant extract. The metal salts are converted to metal nanoparticles by oxidation-reduction mechanisms. Therefore, the metals are converted to nanoscale zero-valent metallic particles [54,55].

Growth phase: After the formation of nanoscale metallic particles nucleation takes place. The separated metal atoms congregate to form metal NPs and again biological reduction of metal ions takes place. Along with the process of nucleation, nanoparticles combine to form divergent shapes like rods, cubes, triangles, pentagons, spheres [56,57].

Termination phase: NPs are stabilized and capped by plant metabolites. Reduction ofmetal ion is indicated by change in culture colour [16,58]. In this final step nanoparticles obtain their optimistic and stable morphologies.

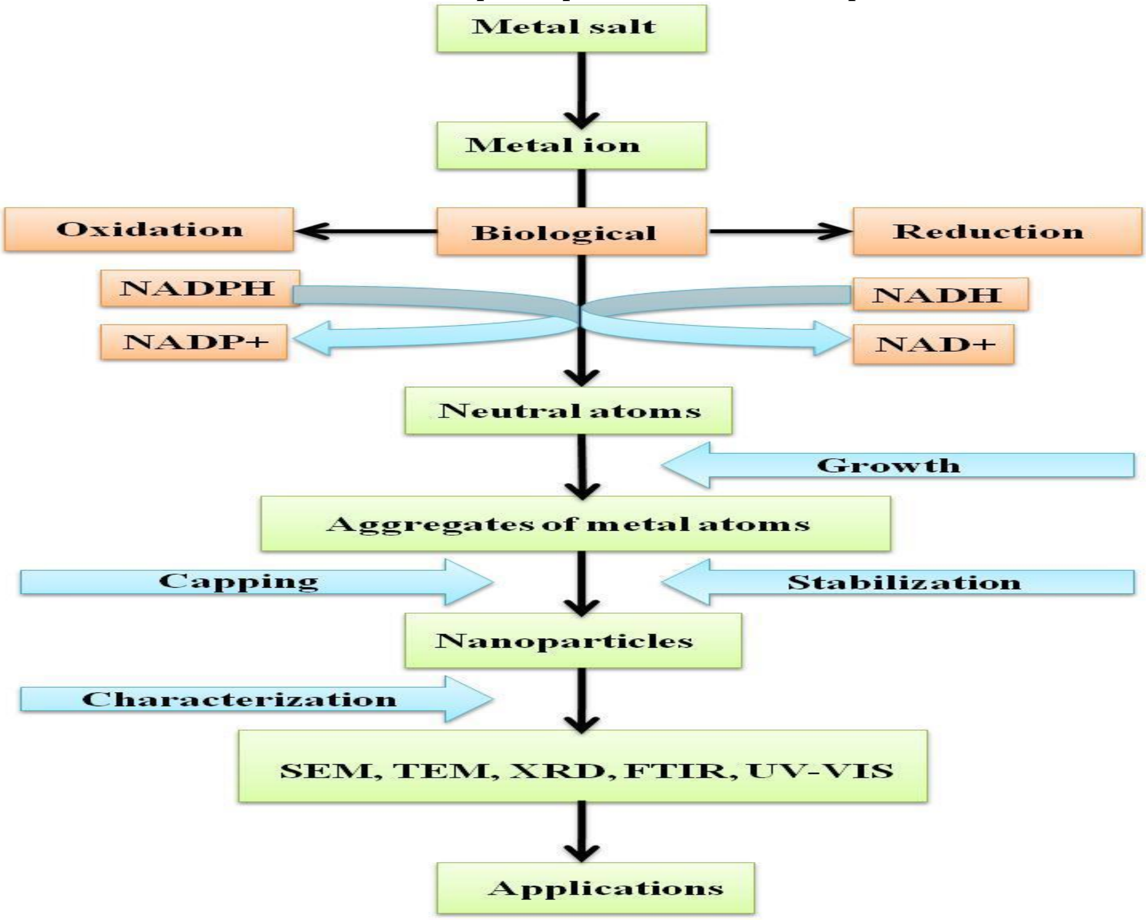


Figure 3. Mechanism for Synthesis of Nanoparticles from Plants

Different plant parts like fruits, leaves, stems, roots and their extracts have been used for different metal nanoparticles synthesis. Many exemplifications are given in Table 2.

Table 2. Synthesis of Different Nanoparticles Using Various Plant Parts and their Activities

Sr. No.	Plans	Plant part used	Nanoparticles	Activity of Nanoparticles	Reference
1	*Acalypha indica*	Leaves	Ag	Antimicrobial activity	[59]
2	*Amaranthus dubius*	Leaves	Fe	Photocatalytic and Antioxidant activity	[60]
3	*Asparagus adscendens*	Root & Leaves	Cu	Antimicrobial activity	[61]
4	*Berberis asiatica*	Roots	Ag	Antimicrobial activity	[62]
5	*Catharanthus roseus*	Leaves	Ag	Antiplasmodial activity	[63]
6	*Celastrus paniculatus*	Leaves	Cu	Photocatalytic and antifungal activity	[64]
7	*Cleome viscosa*	Fruit	Ag	Antibacterial and anticancer Activity	[65]
8	*Coleus aromaticus*	Leaves	Ag	Bactericidal activity	[66]

9	*Cuminum cyminum*	Seed	Cu	Antimicrobial activity	[67]
10	*Desmodium gangeticum*	Root	Cu	Antimicrobial activity	[68]
11	*Diospyros paniculata*	Root	Ag	Antimicrobial activity	[69]
12	*Euphorbia esula*	Leaves	Cu	Catalytic activity	[54]
13	*Glycyrrhiza glabra*	Root	Ag	Anti-ulcer activity	[70]
14	*Lagenaria Siceraria*	Leaves	Fe-oxide	Antimicrobial Activity	[71]
15	*Lantana camara*	Fruit	Ag	Antimicrobial Activity	[72]
16	*Lawsonia inermis*	Leaves	Fe	Antimicrobial Activity	[73]
17	*Magnolia kobus*	Leaves	Cu	Antimicrobial Activity	[74]
18	*Malus domestica*	Fruit	Ag	Antimicrobial Activity	[75]
19	*Moringa oleifera*	Seed	Fe	Antimicrobial Activity	[76]
20	*Persea americana*	Seed	Cu	Antimicrobial Activity	[77]
21	*Piper nigrum*	Seed	SnO_2	Antitumor activity	[78]
22	*Punica granatum*	Seed	Fe_2O_3	Photocatalyticactivity	[79]
23	*Rheum palmatum*	Root	Ag	Antibacterial activity	[80]
24	*Rheum palmatum*	Root	CuO_2	Heterogeneous catalytic activity	[81]
25	*Tradescantia spathacea*	Leaves	SnO_2	Photoantioxidant activity	[82]
26	*Trigonella foenum graecum*	Seed	Ag & Fe-oxide	Antibacterial and Antioxidant Activities	[83]

4. Green Synthesis of Gold Nanoparticles Using Various Extracts of Different Plants:

4.1. By Using Leaf Extract:

Au NPs can be synthesized by the use of leaf extract of different plants. Leaf extract of Buhinia purpurea and HAuCl4 used to prepare gold nanoparticles. Synthesized NPs has excellent anticancer, oxidant, catalytic property. These nanoparticles act as good catalyst for reduction reaction of methylene blue and rhodamine B by $NaBH_4$. Synthesized gold nanoparticles have anticancer activity on lung carcinoma cell line [84].

Au NPs of average size 15.3 nm has also been synthesized using leaf extract of *Cacumen platycladi*. Synthesized NPs were of diverse morphology such as sphere, triangles. In this synthesis flavonoids and reducing sugars act both as reducing and protecting agent. Author studied the effect of temperature and pH on size of nanoparticles. Size of NPs decrease with increasing temperature and pH [85].

Hibiscus-rosa-sinensis's leaf extract has also been used to synthesize the gold NPs of different shapes and sizes by varying the ratio of metal salts and extract. From FTIR it was confirmed that amine group was responsible for gold NPs stabilization [86].Au NPs has also been synthesized using Cerasus serrulata leaf extract [87]. The synthesized NPs has size in range from 5 to 25 nm and spherical in shape. C. serrulata contain five main compounds which help in the process of reduction. But the major groups were Butylhydroxytoluene, Hydrocoumarin and coumarin; from these coumarin is best which act as reducing and capping agent for Au NPs synthesis. The synthesized NPs show antibacterial activity against Escherichia coli a gram negative bacterium.

Magnolia kobus has also been used for synthesizing Au NPs [88]. Nanoplates of width 250-300 nm and thickness of 5-7 nm were formed using 5% leaf broth at 25°C and the impact of concentration and temperature on the synthesis rate and size/shape of gold NPs were studied. It was observed that rate of synthesis increase with the temperature and size of NPs decrease with increasing concentration of leaf extract. From FTIR it was confirmed that Au NPs were surrounded by some proteins and metabolites like terpenoids with numerous functional groups such as alcohols, aldehydes, amines, carboxylic acids and ketones.

Murraya koenigii can also be used for the conflation of gold nanoparticle. Varying concentration of leaf extracts of M. koenigii was added to HAuCl4.3H2O to obtain different colloids such as g1, g2, g3, g4 and g5 of different shape and size. Average shape and size of Au NPs prepared was spherical and 20nm respectively. FTIR measurement shows that biomolecules responsible for capping and efficient stabilization in M .koenigii leaf are polyphenols, flavonoids and alkaloids [89].

4.2. By Using Root Extract:

Au NPS of spherical shape and 10-15nm in diameter have been prepared using Glycyrrhiza uralensis root extract. The reduction of methylene blue with *Glycyrrhiza* root extract is catalysed by Au NPs that have been prepared. Catalytic activity was confirmed by the decrease in absorbance value of methylene blue in UV-Vis spectra. The in vitro cytotoxicity of Au NPs was appraised by the colour change from purple to yellow at 517nm. These Au NPs are toxic toward murine macrophage and non-toxic toward breast cancer cell lines [90].

Use of *Lanthana camara* Linn root extract has also been reported for synthesis of Au NPs of average size 11-32nm with spherical morphology. It was reported that N-H and O-H functional groups are responsible for reduction of Au ions to Au NPs and flavonoids for capping and stabilization of Au NPs. The L. camara Au NPs have dose dependent significant inhibitory effect on breast cancer cell line (MDA-MB-231) and normal cell line (Vero) [91].

Au NPs have also been synthesized using root extract of *Morinda citrifolia*. The synthesized Au NPs were 12.17-38-26 nm in size. From FTIR spectrum, it was reported that proteins present in root extract act as reducing and capping agents [92].

Root extract of Trianthema decandra has also been used for the synthesis of Au NPs.

Synthesized NPs were of different shapes such as spherical, triangular, hexagonal and cubic with size ranging from 33.7 to 99.3nm. Triangular nanoparticles show excellent antibacterial activity against Y. enterocolitica, S. faecalis, E. coli, P. vulgaris and S. aureus. Hence these synthesized Au NPs can be used for treatment of human infection due to microorganisms [93].

Au NPs with various shapes such as triangular, spherical and hexagonal with average size 24.7nm have also been prepared using root extract of Arctium lappa. The author reported that synthesized NPs have significant catalytic role for detoxification of common dye Rhodamine B (RhB). Synthesized Au NPs have significant catalytic role for the degradation of 4-Nitrophenol using $NaBH_4$ [94].

4.3. By Using Seed Extract:

Au NPs synthesized from seed extract of Abelmoschus esculentus were of various sizes and the reason was that the nucleation and aggregation occur consecutively. FTIR shows that –OH functional group in the extract act as capping agent in NPs synthesis. The synthesized Au NPs have antifungal activity against P. graminis, A. flavus, A. niger and C. albicans. Hence these NPs have great potential to be used for drug preparation against fungal diseases [95].

Seed extract of Benincasa hispida has also been used for Au NPs synthesis. Different colloids were prepared using different concentrations of extract to solution of chloroauric acid. The reduction process was fast when 35ml of extract was used against 30ml solution of chloroauric acid. The produced particles were approximately spherical in form, according to TEM image. The polyol present in seed extract help in reducing chloroauric acid and –COOH group present in protein aid in stability of Au NPs [96].

Polydispersed Au NPs can be synthesized using Cuminum cyminum seed extract. The author reported the effect of pH and temperature on morphology the NPs. Increase in temperature and pH result in the production of spherical Au NPs and triangular nano-plates obtained at lower temperature and pH [97].

The Au NPs synthesized from seed extract of Terminalia chebula has significant antimicrobial activity. Antimicrobial properties were studied using E. coli and S. aureus but TC-Au NPs shows antimicrobial activity against S. aureus [98].

Au NPs of spherical shape with average size 15.2 nm has been synthesized using Elettaria cardamomum seed extract. Au NPs (B3) synthesized using 10ml of extract against 30ml solution of $HAuCl_4$ has significant antioxidant activity against DPPH, NO and OH. This radical scavenging activity enhance with increasing concentration of B_3 Au NP. These NPs has effective antibacterial activity against S. aureus. E. coli and P. aeruginosa. Due to antibacterial and antimicrobial activity, Au NPs (B_3) has significant application in pharmaceutical. The synthesized Au NPs has cytotoxicity aid against HeL (Human erythroleukemia) a cell lines, so it can be used for human cancer therapy [99].

4.4. By Using Fruit Extract:

Polydispersed Au NPs with different shapes and average size 20nm has been synthesized using fruit extract of Hovenia dulcis. The synthesized Au NPs have maximum antioxidant activity. These Au NPs have radical scavenging activities for DPPH and hydrogen peroxide. These Au NPs are likewise antimicrobial against E. coli and S. aureus bacteria. [100].

Citrus macroptera's fruit extract has also been used for Au NPs synthesis. It contains citric acid and ascorbic acid that aid in the reduction of Au3+ ions to Au particles, as well as carboxylic, amide and hydroxylic groups, which help to stabilize Au NPs. The synthesized Au NPs have antibiofilm activity. These Au NPs prevent biofilm growth of Pseudomonas aeruginosa by inhibiting the pyocyanin formation that is responsible for biofilm formation. These Au NPs also has cytotoxic effect against three human cancer cell lines, MDA-MB 468 (human breast cancer cell), A549 (adenocarcinogenic human alveolar basal epithial cell) and HepG2 (human liver cancer cell line) [101].

Au NPs synthesized from Terminalia arjuna fruit extract are predominantly spherical in morphology with 25nm average size. Tannin, saponins, terpenoid, glycosides, flavonoids and polyphenolic compounds of the fruit extract of T. arjuna act as reducing and capping agents for Au NPs's synthesis. TA-Au NPs helps to improve seed germination and plant vegetative growth of seedling of Gloriosa superba [102].

Au NPs of sizes 5 to 10nm can be synthesized using Lycopersicon esculentum (Tomato) fruit extract. Tomato juice contains citric acid and ascorbic acid that act as reducing agent. Tomato extract do not act as capping agent, so in this synthesis sodium dodecyl sulfate (SDS) act as capping agent. Methyl parathion can be estimated and detected by using LE-Au NPs in the presence of SDS, hence these Au NPs act as colorimetric sensor [103].Polydisperse and non-spherical Au NPs can be synthesized using Mimusops elengi fruit extract. Antibacterial activity against gram negative bacteria (E. coli) and gram positive bacteria (S. aureus) and antifungal activity against Aspergillus niger and Aspergillus tubingenesis of synthesized Au NPs has also been reported. [104].

5. Biological Apllications of Gold Nanoparticles:

5.1. Cancer Treatment Using Photothermal Therapy:

Cancer is unregulated growth of cells which may spread to other parts of body. Due to unique property of absorption and scattering of electromagnetic radiation, high biocompatiblity and high photothermal efficiency, Au NPs are used for the treatment of cancer using photothermal method [105].

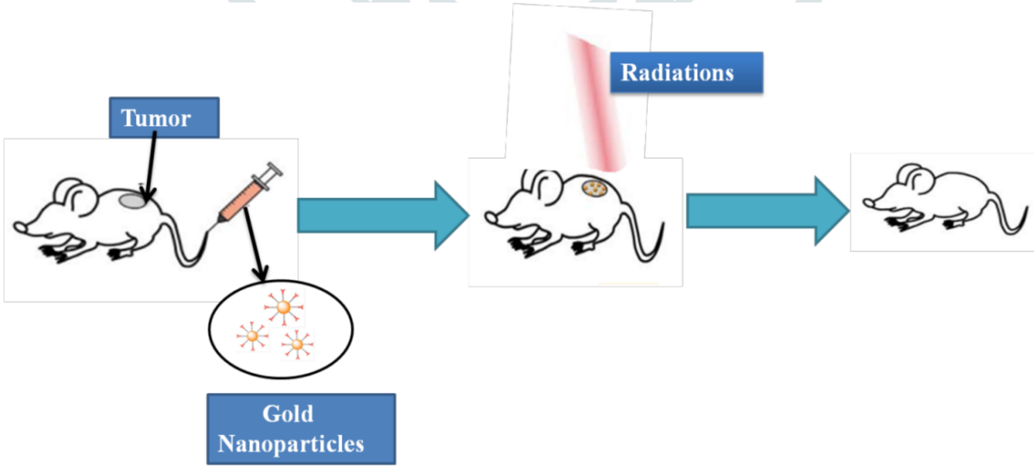


Figure 4. Schematic Diagram Showing Photothermal Therapy Using Au NPs

Biological tissue and water rarely absorb any radiation, so Au NPs with SPR frequency in near-infrared region are best source for bioimaging in locating the tumors. Surface modification of NPs are done to provide protection against aggregation, for specific interactions with cells using tumor specific agents, as well as targeted transport and accumulation in desired organs [106]. Au NPs engulfed in tumor cell absorb radiations and convert them into heat causing hyperthermia of tumor cells leading to cell death [107,108].

5.2. Drug Delivery:

Au NPs can also be used as vehicle for drug delivery in treatment of diseases. For drug delivery Au NPs's surfaces are modified with cationic polymers or reactive functional groups (e.g. thiol, carboxyl and amine) [109]. Drugs are adsorbed on the surface of Au NP either covalently or noncovalently. Au NP with drug entered into cell either by gene gun or by natural untaken by cell. Inside the cell Au NP release the drug, this release may be due to natural cell functioning or induced by different methods (e.g. photothermal) [110]. There are various experiments that have proven the functioning of Au NPs in drug delivery [111,112].

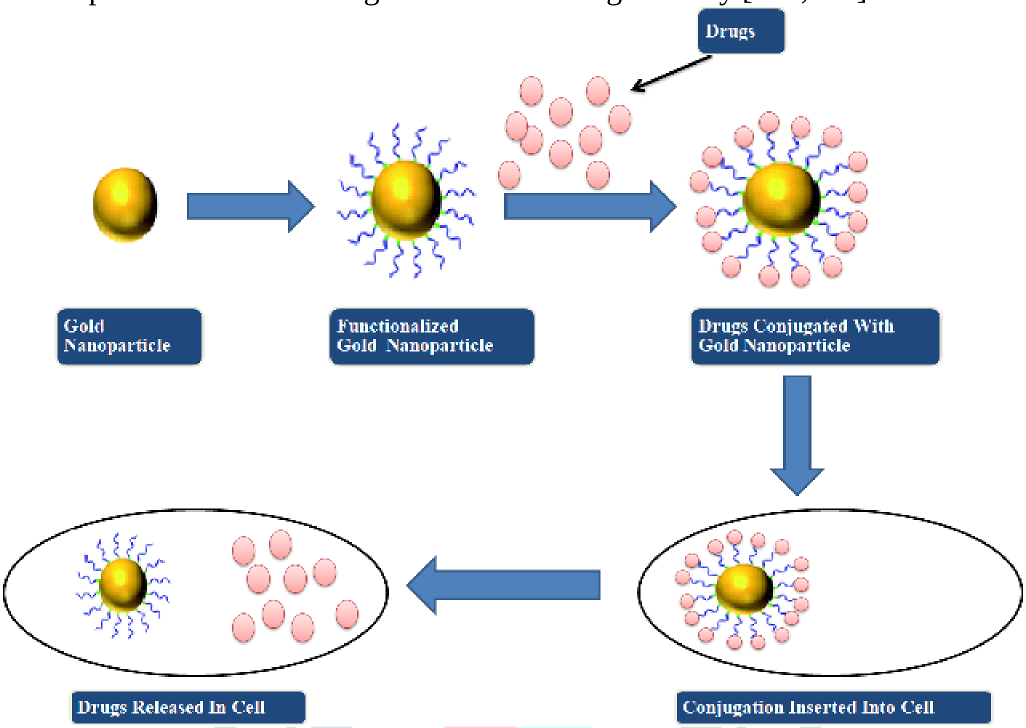


Figure 5. Schematic Diagram for Drug Delivery Using Gold Nanoparticle

5.3. Biosensors:

Generally sensors are used to specify the presence of analytes and read outs are used for analyte concentration determination. There is change in optical property of gold nanoparticle if optical read out is used. Cysteine-linked core-satellite Au NPs has been used for detection of $Co2+$spiked in diluted human serum [113]. Au NP's biosensor has been developed for the detection of E. coli O157: H7. The bacteria were detected by measuring the electrochemical signal of Au NPs [114].

5.4. Enhancement in Plant Growth:

Au NPs helps in enhancing plant growth and seed yield. In Brassica juncea Au NPs increased permeability of seed capsule, more light absorbance by chlorophyll thus fastening the photochemical reaction and increase in number of leaves [115]. Seed yield and growth of Arabidopsis thaliana also enhanced by Au NPs [116]. Au NPs synthesized using fruit extract of Terminalia arjuna, have significant effect on inducing seed germination and growth of Gloriosa superba plant [102].

6. Conclusions:

The review article concluded that, nanotechnology deals with study of particle at nanoscale and great application in real world. Due to small size nanoparticles have improved chemical, physical, and biological properties. Green nanotechnology that works on principles of green chemistry provides green, safe and sustainable method for nanosynthesis. There are different green methods to prepare gold nanoparticles; the present study involves synthesizes gold nanoparticles using plants extracts because of their diversity, sustainability and eco-friendly nature. It is concluded that gold nanoparticles synthesized using plants extract such as leaf, root, seed and fruit extracts have antioxidant and antimicrobial activity. Due to their SPR frequency, biocompatibility and tunable property gold nanoparticles has great application in cancer treatment, biosensor, drug delivery and enhancement of plant growth.

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