A Review on Recent Trends in Green Synthesis of Gold Nanoparticles for Tuberculosis

Arti Gupta†, Sonia Pandey†, Jitendra Singh Yadav‡

†Uka Tarsadia University, Maliba Pharmacy College, Gopal Vidhya Nagar, Bardoli, Gujarat, India.
‡Shree Naranjibhai Lalbhai Patel College of Pharmacy, Umrakh, Gujarat, India.

Abstract

Tuberculosis (TB) is a contagious disease that has affected mankind. The anti-TB treatment has been used from ancient times to control symptoms of this disease but these medications produced some serious side effects. Herbal products have been successfully used for the treatment of TB. Gold is the most biocompatible metal among all available for biomedical purposes so Gold nanoparticles (GNPs) have sought attention as an attractive biosynthesized drug to be studied in recent years for bioscience research. GNPs are used as better catalysts and due to unique small size, physical resemblance to physiological molecules, biocompatibility and non-cytotoxicity extensively used for various applications including drug and gene delivery. Greendly synthesized GNPs have much more potential in different fields because phytoconstituents used in GNP synthesis itself act as reducing and capping agents and produced more stabilized GNPs. This review is devoted to a discussion on GNPs synthesis with herbs for TB. The main focus is on the role of the natural plant bio-molecules involved in the bioreduction of metal salts during the GNPs synthesis with phytoconstituents used as antitubercular agents.

Introduction

Tuberculosis (TB) is a bacterial infectious disease caused by Mycobacterium tuberculosis, one of the oldest bacterial diseases. TB is still affecting and posing major health, social and economic burdens at the global level. However, low and middle-income countries are mainly affected. If the disease would not be managed efficiently then TB will be resurged due to some other diseases like HIV infection as well as multiple drug-resistant tuberculosis (MDR-TB) by considering these facts in 1993, the World Health Organization (WHO) took an unprecedented step and declared TB a global emergency. Synthetic anti-TB drugs are a two-edged sword while they destroy pathogenic M. tuberculosis they also select for drug-resistant bacteria against which those drugs are then ineffective. TB either kills the infected individual or renders him/her incapable of assuming normal functions. Upon gaining entry into a new host, M. tuberculosis may result in an active infection or remain latent. TB is spread via various sources like infectious aerosols from an infected person. TB infections and their development are represented in Figure 1.

Wide ranges of phytoconstituents having the desired pharmacological effect on the body were responsible for anti-tubercular activity includes alkaloids, glycosides, glycoterpenoids, diterpenoids glycosides, tannins, phenolics and amides, xanthones, quinones, sterol, triterpenoids. Terpenoids are scope for compounds that can be developed as future antimycobacterial drugs. It has been reported that ursolic and oleanolic acids are not so toxic and possess antimicrobial activity against some multi-resistant bacteria.

Various antimycobacterial chemical compounds have also been isolated from plants, including ellagitannin punicalagin, allicin, and these compounds offered various clues for effective management of the disease to lessen the global burden of TB and drug-resistant M. tuberculosis strains.

In this review, the author has emphasized the green synthesis of gold nanoparticles (GNPs) with herbs for TB (Antimicrobial and antibacterial activity). The main focus is on the role of the natural plant bio-molecules involved in the bioreduction of metal salts during the GNPs synthesis with phytoconstituents used as antitubercular agents. The plants having phytoconstituents acting as antitubercular agents discussed in Table 1.

To avoid the adverse effect of recently used synthetic anti-TB drug natural products including plants, animals, and minerals have been the basis of treatment of human diseases. Studies showed that males with above 35 years of age of the patients, female, HIV-infected, older, and Asian-born patients are more prone to the major adverse effect of recent anti-TB drugs.

Owing to the diversity of different natural active
components such as plants, marine algae and types of metal salts and their ability to alter the composition of a reaction mixture through exposure to changes in the temperature, pH, and presence of various additives of biological origin (bio-matrices) which allows to produce nanoparticles of various metals with a defined size and shape. It is well established that biologically synthesized metal nanoparticles had various proved, biomedical applications like targeted delivery of cancer drugs, molecular imaging, wastewater treatment, cosmetics, as antiseptics, bio-sensors, antimicrobials, catalysts, optical fibers, agricultural, bio-labeling and in other areas is

| Table 1. List of plants containing phytoconstituents having anti tubercular activity |
| --- |
| **Botanical/family name** | **Phytoconstituents** | **References** |
| Acalypha indica (Euphorbiaceae) | Kaempferol, acalyphamide and other amides, quinone, sterols, cyanogenic glycoside | 43-47 |
| Allium cepa (Liliaceae) | Antibacterial substances (subterraneean) allicin, ajoene indole alkaloids, steroidal triterpenes | 44-46, 50 |
| Allium sativum (Liliaceae) | Sulphur containing amino acids known as alliin | 51-52, 55 |
| Adhatoda vasica (Acanthaceae) | Vasicine acetate and 2-acetyl benzylamine, bromhexine and ambroxol, semi-synthetic derivatives of vasicine | 54, 57 |
| Aloe vera (Liliaceae) | Anthraquinone glycosides (aloin), | 44, 58 |
| Berberis Hispanica (Berberidaceae) | 59 |
| Byrsonima crassa (Malpighiaceae) | Triterpenes: α-aminin, β-aminin and their acetates, lupeol, oleanolic acid,ursolic acid and α-aminin alkane dotriacontane, triterpenoids as bassic acid | 37, 40 |
| Buddleja saligna (Scrophulariaceae) | Non-cytotoxic triterpenoids oleananolic | 61-63 |
| Burchanis patagonica (Asteraceae) | Oleanolic acid | 33 |
| Clavijap rocera (Theophrastaceae) | Oleane triterpenoid (aegicerin) | 64 |
| Canscora decussate (Gentianaceae) | β-aminin, friedelin, genianine, mangiferin, xanthones | 20, 65 |
| Colebrookea oppositifolia (Lamiaceae) | Oleanonic acid | 31 |
| Callicarpa oppositifolia (Lamiaceae) | Triterpenoids- friedelin, taraxerol and glutinol and a mixture of long chain hydrocarbons Hypotensive, antiarrhythmic | 59 |
| Flacourtia ramontchii (Flacourtiaceae) | Phenolic glucose ester, (−)-flacourtin, ramontoside, β-sitosterol and its β-D-glucopyranoside | 1, 55, 56 |
| Junellia tridens (Verbenaceae) | Oleanonic acid | 51 |
| Kalanchoe integra (Crassulaceae) | Triterpenoids- friedelin, taraxerol and glutinol and a mixture of long chain hydrocarbons Hypotensive, antiamphibic | 59 |
| Leysera gnaphalodes (Asteraceae) | Non-cytotoxic triterpenoids oleananolic | 61-63 |
| Mallotus philippensis (Euphorbiaceae) | Phloroglucinol derivatives; rutinifer, isorutinifer, isosalicinifer | 68, 69 |
| Mimosa pudica, (Mimosaceae) | Mimosine and turgorin | 68, 70 |
| Trichosanthes dioica (Cucurbitaceae) | Amino acids, nicotinic acid, riboflavin, vitamin C, thiamine, 5-hydroxytryptamine | 70 |
| Tinospora cordifolia (Menispermaceae) | Alkaloids, carbohydrates, flavonoids, glycosides, lignin, saponins, terpenes, tannins, steroids | 71-74 |
| Myrtus communis (Myrtaceae) | Phenolic compounds | 77 |
Table 1. Continued

| Botanical/family name | Phytoconstituents                                                                 | References |
|-----------------------|----------------------------------------------------------------------------------|------------|
| Ocimum sanctum (Labiatae) | Essential oil                                                                     | 70-82      |
| Prunus armeniaca (Rosaceae) | Flavonoid glycosides, polyphenols, sterol derivatives, carotenoids, cyanogenic glycosides and volatile compounds | 45, 49-55  |
| Piper species, Piper regnellii (Piperaceae) | Piperine, neolignans, eupomatogenoid-5, Aristolactams, dioxyarachides, lignans, longamide, pluviatil, methyl pluviatil (fargesin), sesamin. | 81-87      |
| Rumex hastatus (Polygonaceae) | Naphthalene acylglucosides, rumexneposides.                                        | 88         |
| Salvia hyspargea (Lamiaceae) | Diterpenoids (Labdane), hyapergenin                                               | 89-92      |
| Senecio chinopholius (Asteraceae) | Sesqui terpenoids (oxoferanoeremophilane)                                          | 93, 94     |
| Vitex trifolia (Verbenaceae) | Diterpenoids (halimane and labdane)                                               | 105        |
| Vitex negundo (Verbenaceae) | Indoid glycosides, isomer flavanones and flavonoids                               | 96-97      |
| Juniperus communis (Cupressaceae) | Isocupressic acid, communc acid and deoxypodophyllotoxin                          | 98-99      |

**Monoterpenoids**

| Botanical/family name | Phytoconstituents                                                                 | References |
|-----------------------|----------------------------------------------------------------------------------|------------|
| Cymbopogon (lemon grass) | Citronellol, nero, dehydro costuslactone                                         | 100        |
| Magnolia grandiflora (Magnoliaceae) | Parthenolide                                                                   | 101        |
| Arbrosia artemisiifolia (Asteraceae) | 11bH-dihydroparthenolide                                                        | 101        |
| Arbrosia confertiflora (Asteraceae) | Santaramine                                                                     | 101        |
| Sanchus hierrensis (Asteraceae) | Santaramine                                                                     | 101        |
| Arbrosia confertiflora (Asteraceae) | Reynosin                                                                        | 101        |
| Artemisia rhose (Compositae) | Santorin                                                                        | 101        |
| Posladium eminens (Asteraceae) | 7-hydroxydehydrocostuslactone                                                   | 102        |
| Zaluzania triloba (Compositae) | Zaluzanin C                                                                     | 101        |

**Sesquiterpenes**

| Botanical/family name | Phytoconstituents                                                                 | References |
|-----------------------|----------------------------------------------------------------------------------|------------|
| Saussurea lappa (Compositae) | Costunolide                                                                     | 101        |
| Magnolia grandiflora (Magnoliaceae) | Parthenolide                                                                   | 101        |
| Arbrosia artemisiifolia (Asteraceae) | 11bH-dihydroparthenolide                                                        | 101        |
| Arbrosia confertiflora (Asteraceae) | Santaramine                                                                     | 101        |
| Sanchus hierrensis (Asteraceae) | Santaramine                                                                     | 101        |
| Arbrosia confertiflora (Asteraceae) | Reynosin                                                                        | 101        |
| Artemisia rhose (Compositae) | Santorin                                                                        | 101        |
| Posladium eminens (Asteraceae) | 7-hydroxydehydrocostuslactone                                                   | 102        |
| Zaluzania triloba (Compositae) | Zaluzanin C                                                                     | 101        |

**Diterpenes**

| Botanical/family name | Phytoconstituents                                                                 | References |
|-----------------------|----------------------------------------------------------------------------------|------------|
| Tetradenia riparia (Lamiaceae) | Sandaracopimara-8(14)-15-diene-7,18-dio                                           | 101        |
| Juniperus excels (Cupressaceae) | Sandracopimaric acid, juniperexcelsic acid                                        | 101        |
| Salvia multicaulis (Lamiaceae) | 12-demethylmulticaline, multicalin, 12-demethylmultithoquinone, multithoquinone, 12-methyl-5-dehydrohorminone, 2-methyl-5-dehydroacetyl/horminone, salvipimarone | 101        |
| Azorella madrepornca (Apiaceae) | 9,12-cyclomulin-13-ol                                                            | 105        |

**Triterpenes**

| Botanical/family name | Phytoconstituents                                                                 | References |
|-----------------------|----------------------------------------------------------------------------------|------------|
| Ajaga remota (Lamiaceae) | Ergosterol-5,8-endoperoxide                                                     | 101        |
| Melia volkensii (Meliaceae) | 6b-hydroxyxulactone, kulonate                                                    | 106        |
| Borrchia frutescens (Asteraceae) | (24R)-24,25-epoxyxyloartan-3-one, (3b,24R)-24,25-epoxyxyloartan-3-ol, (3b,24R)-24,25-epoxycycloartan-3-ol acetate, (21R)-3-oxolamosta-8,24-dien-23-o | 107        |
| Sarmenta scandens (Cesneriaceae) | Zeorin, 7b-acetyl-22-hydroxyxopane, 7b,22-dihydroxyxopane,                         | 11        |
| Baccharis patagonica (Asteraceae) | Oleanonic acid, erythrodio                                                         | 31        |
| Jurcilia tridens (Verbenaceae) | 3-epoleanolic acid, oleanonic acid                                               | 31        |
| Chuquiraga ulicina (Asteraceae) | Lupol acetate, lupenone, 3-hydroxynorlupen-2-one, 3-acetoxynorlupen-2-one         | 31        |
| Acaena pinarinoida (Rosaceae) | Pomeolic acid, pomeolic acid acetate, tormentic acid, 2-epi-tormentic acid, eusaphic acid, nigachidoside F1 glycone | 31        |

proved to be much safer, environment-friendly and cost-effective method of synthesis. Due to the diverse applications of Nanoparticles, several green approaches have been explored for synthesizing nanoparticles using different natural sources such as plants, marine algae, all these having immense tolerance to metal salts and have good ability to secrete extracellular enzymes for reduction of metals to consecutive nanoparticles. Gold is the most biocompatible metal nanoparticles are used in therapeutics and diagnostics in recent days to be studied in the recent field of bioscience. The biosynthesized GNP were found to be better catalysts without using synthetic surfactant or capping agent at a low and definite concentration. GNPs provide non-toxic carriers for drug and gene delivery applications. With these systems, the gold core imparts stability to the assembly, while the monolayer allows tuning of surface properties such as charge and hydrophobicity. An additional attractive feature of GNPs is their interaction with thiols, providing an effective and selective means of controlled intracellular release. By controlling shape like nanospheres, nanorods,
Green synthesis of gold nanoparticles

Green synthesis of gold nanoparticles for tuberculosis

The principle application of GNPs in the biomedical field is sensors, antimicrobials, catalysts, optical fibers, agricultural, bio-labelling development of specific scaffolds, conjugates to biomedical diagnostics and analytics, photothermal and photodynamic therapies, and delivery of target molecules. Different shapes (nanosphere, nanobelt, branched, nanocage, nanoshell, nanocubes, nanorod, nanostar, and nanocluster) of GNPs are represented in Figure 2 and their applications are discussed in Table 2.

Green synthesis of gold nanoparticles

In the late 1990s, the development of non-toxic methods has embraced the principles of green chemistry. Green synthesis of metal nanoparticles has received widespread attention in the past decade due to its ability to meet environmental and economic goals simultaneously without using the chemical and cost-effective too. Green synthesis common approaches for GNPs have been shown in Figure 3. For the green synthesis of GNPs, the antioxidant components of the studied plant extracts are responsible for the reduction of metal salts, leading to the growth and stabilization of the GNPs.

Medicinal herbs having phytochemicals like as alcohols, phenols, proteins, terpenes, alkaloids, saponins, etc which can act as reducing as well as capping agents in the GNPs biosynthesis.

Role of natural constituents for the green synthesis of GNPs

The triterpenes skeletons like cucurbitanes, cycloartanes, dammaranes, euphanes, friedelanes, holostanes, hopanes, isomalabaricanes, lanostanes, lupanes, oleananes, protostanes, tircuallanes, and ursanes are of interest ranging from primarily structural (cholesterol in cell membranes) to functional (carotenoids in photosynthesis, retinal in vision, quinones in electron transfer). Terpenoids play a crucial role in the reduction process of metal ions into nanoparticles, like eugenol the main terpenoid present in many plants.

GNPs of Schinus molle L extract contain phenol, which shows that the differences in transmittance. Purified phenolics like gallic and protocatechuic acid act as reducing and capping agents in GNP synthesis because of the involvement of functional groups present in this phenolic compounds. These findings can help to determine the mechanism of metal nanoparticles by using crude extracts formation and stabilization. Cinnamomum verum extract contains polyols like (flavones and terpenoids) and polysaccharides, both contents act as reducing agent in metal ion synthesis. Flavonoids belong to the group of polyphenolic compounds that comprise

---

**Table 2. Shapes of gold nanoparticles and their applications**

| Shape       | Size     | Applications                                                                 |
|-------------|----------|------------------------------------------------------------------------------|
| Nano rod    | 2-5 nm   | Photothermal Tumor Therapy, gas sensors                                      |
| Nano sphere | 10-200 nm| (i) The development of an ultrasensitive nanoscale optical biosensor based on LSPR wavelength-shift spectroscopy and (ii) The SERS detection of an anthrax biomarker. Nanospheres used as targeted drug delivery on tumor and brain. |
| Nano star   | 46-76 nm | Inkjet printing technology, SERS sensor for Hg²⁺ detection                   |
| Nano clusters| ~1.4 nm | Potential for cancer therapy, biological labelling applications              |
| Nano cube   | 50 nm    | Biomedical Applications                                                      |
| Branched particle | 90 nm | Nanostars have been predicted and demonstrated to shine brighter than any other shapes, thus opening new avenues for highly sensitive detection or biolabelling, among other applications. |
| Nanocage    | 36 nm nanocage | Photothermal cancer treatment, applications in nanobioelectronics, Biomedical Applications. |
| Nanobelt    | Thickness: 80 nm With: 20 nm Length: 0.15 nm | One-dimensional nano-scale sensors, transducers, and resonators. |
| Nanoshell   | ≥100 nm  | Fluorescent diagnostic labels, catalysis, avoiding photo degradation, enhancing photoluminescence, creating photonic crystals, preparation of bio conjugates, chemical and colloidal stability. |

---

**Figure 2. Different shapes of gold nanoparticles.**
several subgroups: anthocyanins, isoflavonoids, flavonols, chalcones, flavones, and flavanones, which can actively participate in the reduction and chelation of metal ions into nanoparticles. Literature established that reactive hydrogen atom release from tautomeric transformations of flavonoids from the enol-form to the keto-form can reduce metal ions to form nanoparticles. For example, flavonoids luteolin and rosmarinic acid present in Ocimum basilicum extracts it is the transform from the enol- to the keto-form.\textsuperscript{111} Apin glycoside obtained from Lawsonia inermis used for the synthesis of anisotropic gold and quasi-spherical silver nanoparticle.\textsuperscript{165} The oxygen atoms belonging to 3-hydroxy and 4-oxo, and the 5-hydroxy and 4-oxo groups, are the preferred potential sites for chelation on quercetin.\textsuperscript{166} Many proteins contain active sites for metal ion accumulation and reduction where GNPs can form and be stabilized. In the process of nanoparticles formation, Protein donates electrons to react with metal ions and their subsequent stabilization that leads to the formation of nanoparticles.\textsuperscript{167} Some low molecular weight protein bands present in the soya bean extract, this may have been used up in biosynthesis of GNPs.\textsuperscript{168} The compounds present in the extracts can act as reducing as well as stabilizing agents and render more biocompatibility to the green synthesis of GNPs.\textsuperscript{169}

The emphasis in this approach is on the synthesis and application of the nanoparticles for a maximum societal benefit, with minimal impact on the ecosystem.\textsuperscript{172} In Table 3 some part of plants which have been exploited by researchers for making AuNPs from the last decades have been summarised.

**Role of microorganisms for the green synthesis of GNPs**

A variety of microorganisms are interacted with inorganic metals like gold, zinc, and silver and are known to use in bioleaching of minerals.\textsuperscript{21} Microbial cells treated with gold nanostructures synthesize by gold salts which are then isolated and purified using various techniques to obtain GNPs. Table 4 reflects a variety of microbes along with their genus which was used to make GNPs of different size ranges.

**Role of biomolecules for the green synthesis of GNPs**

Biomolecules produced by living organisms to catalyze biological functions, such as nucleic acids, amino acids, lipids, and carbohydrates, possess hydroxyl and carbonyl functional groups in their structure which can reduce Au$^{3+}$ ions to Au$^{0}$ neutral atoms. These Au$^{0}$ neutral atoms are then capped to form stabilized GNPs.\textsuperscript{234} This method can use for the biosafety of the reactants in GNPs synthesis. In Table 5 various biomolecules with type and size have been discussed.

**Bioreactors for green synthesis of gold nanoparticles**

Phytomining is the approach through which plants can reduce metal ions both on their surface and in various organs and tissues remote from the ion penetration site. The metals like copper, gold, silver, platinum, iron, and many others accumulated by the plants can be recovered after harvesting methods. For example, Brassica juncea and Medicago sativa, both the plant accumulate 50 nm silver nanoparticles (13.6% of their weight) when grown on silver nitrate as a substrate whereas M. sativa accumulate 4 nm gold icosahedra,\textsuperscript{250} and Iris pseudacorus (yellow iris) accumulate 2 nm semi-spherical copper particles when grown on substrates containing salts of the respective metals. Few approaches have been demonstrated in which different varieties of plant extracts have been used in combination with different varieties of acids and salts of metals.\textsuperscript{170,251}

**Factors affecting the formation of metal nanoparticles in plants**

Various limitations of nanoparticle synthesis by phytoconstituents are observed and it needed to be resolved carefully before industrial manufacture. The prime limitation is the intricacy in the identification of the phytoconstituents present in plants responsible for the NPs synthesis and therapeutic activity. The amount of reducing agent needs to be controlled because it hampers the reduction rate which results in the formation of large aggregated nanoparticles. Simultaneously the process parameter like thermal heating must be under controlled

![Figure 3. Green gold nanoparticles synthesis using plant/plants extract.](image-url)
Table 3. List of synthesized gold nanoparticles using whole, parts or extracts of different plants

| Extract of plants | Part/homeolecule | Size and shape | References |
|-------------------|------------------|----------------|------------|
| Allium cepa L.    | Vitamin C        | ~100 nm        | 173        |
| Anacardium occidentale L. | Polyols and proteins | Hexagonal       | 174        |
| Azadirachta indica | Nimbin, Azadirone, Azadirachtins | 2-100 nm       | 175        |
| Camellia sinesis | Polyphenolic compounds | 25 nm         | 176        |
| Chenopodium album | Oxalic acid      | 12 nm, 10 nm   | 177        |
| Justicia gendarussa | Polyphenol and flavonoid | 27 nm       | 178        |
| Macroleucoma uniflorum (Lami) | Aqueous extract | 14-17 nm      | 179        |
| Mentha piperitl. | Menthol          | 90 nm, 150 nm  | 180        |
| Mirabilis jalapa L. | Polyols | 100 nm        | 181        |
| Swietenia mahogany | Polyhydroxy limonoids | -        | 182        |
| Sapindus mukorossi | Fruit pericarp | 9 nm-19 nm     | 183        |
| Prunus domestica | Fruit extract    | 14 nm-26 nm    | 184        |
| Magnolia kobus | Leaf extract      | 5 nm-300 nm    | 185        |
| Coleus amboinicus bour | Leaf extract | 9.05 nm-31.95 nm | 186        |
| Cassia auriculata | Leaf extract    | 15 nm-25 nm    | 187        |
| Abelmoschus esculentus | Seed, aqueous extract | 45 nm-75 nm  | 188        |
| Zingiber officinale | Rhizome extract | 5 nm-15 nm     | 189        |
| Rosa hybrida Petal | Petal extract  | Petal 10 nm    | 190        |
| Cicer arietinum | Been             | Gold prisms (~25 nm thick) | 191        |
| Sugar beet | Pulp             | Nanowire       | 192        |
| Nyctanthes arboristis | Flower       | 19.8 ± 5.0 nm  | 193        |
| Gnidia glauca | Flower            | 50 nm-150 nm   | 194        |
| Mangifera indica | Peel extract    | 6.03-18 nm; spherical | 195        |
| Gymnocladus assamicus | Pod extract | 4-22 nm; hexagonal, pentagonal and triangular | 196        |
| Cacumen platycladi | ---             | Variable       | 197        |
| Costisandra sativam | Leaf            | 6.75-57.91 nm; spherical | 198        |
| Nerium oleander | Leaf extract    | 2-10 nm; spherical | 199        |
| Butea monosperma | -                | 10-100 nm; spherical, triangular | 200        |
| Pea nut | ---              | 110 to 130 nm; variable | 201        |
| Hibiscus cannabinus | Stem extract | 10-13 nm; spherical | 202        |
| Sesbania grandiflora | Leaf extract | 7-34 nm; spherical | 203        |
| Saltis alba | Leaf extract     | 50-80 nm       | 204        |
| Eucommia ulmoides | Bark            | Spherical      | 205        |
| Galaxaura elongata | Powder or extract | 3.85-77.13 nm; spherical, triangular, and hexagonal | 206        |
| Ocimum sanctum | Leaf extract    | 30 nm; hexagonal | 207        |
| Torreya nucifera | ---              | 10-125 nm; spherical | 208        |
| Olea europaea | Leaf extracts   | 50-100 nm; triangular, hexagonal | 209        |
| Rosa indic | Rose petals      | 3-15 nm; spherical | 210        |
| Pistacia integerrima | Galls extract | 20-200 nm      | 211        |
| Terminalia arjuna | Fruit           | 60 nm, spherical | 212        |
| Euphorbia hirta | Leaf extract    | 6-71 nm, spherical | 213        |
| Morinda citrifolia | Root extract | 12.17-38.26 nm, spherical | 214        |
| Zizyphus mauritiana | Extract | 20-40 nm, spherical | 215        |

because during synthesis it can damage and denature various active molecules like sugars, and proteins resulting in the loss of activity. The reaction rate can be optimized by controlling the reduction reaction by varying the concentration of phytochemicals carefully. All the factors affecting the green synthesis of metal nanoparticles are presented in Figure 4.

To improve the efficacy, size and morphology of nanoparticles synthesized from biological sources by microorganisms several parameters need to be monitored like microorganism type, growth medium, growth stage (phase), synthesis conditions, reaction mixture pH, substrate concentrations, size, shape, incubation temperature and reaction time. The reduction process and stability of the biologically synthesized nanoparticles have a major concern and have to be controlled to improve
Table 4. List of microorganisms which have been used for synthesis of GNPs

| Microorganism                  | Genus                  | Size             | References |
|--------------------------------|------------------------|------------------|------------|
| Pseudomonas fluorescens       | Bacterium              | 50 nm–70 nm      | 214        |
| Shewanella algae              | Bacterium              | 10 nm–20 nm      | 215        |
| Geobacillus stearothermophilus| Bacterium              | -                | 216        |
| Escherichia coli DHHa          | Bacterium              | -                | 217        |
| Marinobacter Pelagius          | Bacterium              | 10 nm            | 218        |
| Serratopthomonas maltophilia  | Bacterium              | 40 nm            | 219        |
| Rhodopseudomonas capsulate    | Bacterium              | 10 nm–20 nm      | 220        |
| Micrococcus luteus            | Bacterium              | -                | 221        |
| Yarrowia lipolytica           | Marine Yeast           | -                | 222        |
| Acanthella elongate           | Sponge                 | 7 nm–20 nm       | 223        |
| Sargassum wightii Greville    | Algae                  | 18.7 nm–93.7 nm  | 224        |
| Streptomyces viridogriseus    | Bacterium              | 8 nm–12 nm       | 225        |
| Candida albicans              | Fungi                  | 18 nm–20 nm      | 226        |
| Aspergillus fischeri          | Fungi                  | 50 nm spherical shaped | 236 |
| Acanthophora specifera        | Algae                  | -                | 228        |
| Chlorella pyrenoida           | Algae                  | -                | 229        |
| Kappaphycus alvarezi          | Algae                  | -                | 230        |
| Galaxaura elongata            | Marine alga            | -                | 231        |
| Tetraselmis kochiensi         | Algae                  | 5–35 nm          | 232        |
| Sargassum myriocystum         | Algae                  | 15 nm            | 233        |
| Sargassum marginaatum         | Algae                  | -                | 234        |
| Laminaria japonica            | Aqueous of extract Brown algae | -        | 235        |

Table 5. List of various biomolecules involved in synthesis of AuNPs

| Biomolecule                  | Type                  | Size (diameter) | References |
|------------------------------|-----------------------|-----------------|------------|
| Linoleic acid                | Fatty acid            | 10 nm           | 235        |
| Tannic acid                  | Fatty acid            | 8 nm–12 nm      | 137        |
| NADPH-dependent enzyme       | Enzyme                | 25 nm           | 236        |
| Aminodextran                 | Polysaccharide        | 18 nm–14 nm     | 237        |
| Chitosan                     | Polysaccharide        | -               | 238        |
| Glucose                      | Carbohydrate          | 22 nm–38 nm     | 239        |
| Sucrose, Raffinose           | Carbohydrate          | 4 nm–16 nm, 30 nm–48 nm | 238 |
| Dextrose-encapsulated        | Carbohydrate          | 25 nm, 60 nm, 120 nm | 230 |
| Starch                       | Polysaccharide        | 11 nm–15 nm     | 231        |
| Bovine serum albumin         | Protein               | -               | 242        |
| Serrapeptase                 | Protein               | 20 nm • 200 nm  | 243        |
| Trypsin                      | Enzyme                | -               | 244        |
| Glycosaminoglycans           | Mucopolysaccharides   | -               | 245        |
| Serratiopeptidase            | Enzyme                | -               | 246        |
| DNA                          | Nucleotide            | 45 nm–80 nm     | 247        |
| Aspartate                    | Amino acid            | 30 nm           | 248        |
| Phospholipid                 | Lipids                | 05 nm           | 249        |

the efficacy of the biologically synthesized nanoparticles. Major limitations in biologically synthesized nanoparticles are, the reduction process is quite slow and stable due to the decomposition of microorganisms over time.111,157,252-254

Nanoparticle aggregation is high at highly acidic pH over the reduction process and nucleation of reduced atoms. This may be related to the fact that a larger number of functional groups that bind and nucleate tetra-chloroauric acid ions become accessible at acidic pH.115,235-236 Efficiency and reaction rate of metal nanoparticle synthesis increases as an increase in the temperature. High temperatures required for crystal particle formation (nucleation rate is higher as increases the temperature). Interaction of phytochemicals with the nanoparticle surface may alter
Green synthesis of gold nanoparticles for tuberculosis

Apart from diversified biomedical applications, GNPs have been reported for antimicrobial activity against food and agriculture pathogens. Inherent property of antibacterial and antimicrobial activity of GNPs along with the entrapped plant extract, facilitate the early recovery from TB. The proposed mechanism for antibacterial activity of GNPs is that it increases gene expression in the redox process which leads to the death of bacteria and fungi. The nano size, surface area and photo thermic nature of GNPs directly influenced the antimicrobial activity. Another excepted mechanism is that intracellularly GNPs attached to the sulfur base present in cells in the form of thiol group in enzymes which leads the disturbance of respiratory chain suddenly by the generation of a large number of free radicals leading to death. On the contrary, the GNPs decrease ATP activities wherein they reduce the t RNA and ribosomal interaction. GNPs also block the transmembrane hydrogen efflux thus lesser concentration of GNPs can inhibit bacterial growth about 250-fold. Due to the smaller size of GNPs then bacterial cells, they stick on the cell wall of pathogens and delay cell process, causing death. Some report shows a different mechanism when compared to other metal nanoparticles. GNPs due to the charge difference on the cell wall and nanoparticle surfaces it attracts bacterial DNA. On the other side, GNPs show the varied activity of gram-positive and gram-negative bacteria, which are classified based on the thick layer called peptidoglycan. Peptidoglycan generally consists of two joined amino sugars, N-acetylglucosamine and N-acetyl muramic acid (NAM), with a pentapeptide coming off the NAM forming an inflexible structure to diffuse the GNPs. Therefore, the peptidoglycan is very strong in gram-positive bacteria that penetrate GNPs across cell wall whereas gram-negative bacteria contain a thin layer which easily undergoes cell death. The anti-microbial activity also assisted by the concentration of capping agents and purification methods apart from the size and peptidoglycan thickness. In green synthesized GNPs the antimicrobial activity may be due to the synergistic effects of GNPS with plant extracts.

The biophysical interactions between bacteria and nanoparticle occur through aggregation biosorption and cellular uptake that can damage the membrane and produce toxicity. The mechanism of antibacterial activity of the GNPs is attributed to the generation of reactive oxygen species that causes an increase of the oxidative stress of microbial cells and the release of intracellular lactate dehydrogenase enzyme into extracellular medium in form of vacuole formation as an indication of potent activity. Such effect was enhanced and exaggerated by photothermal degeneration in a combined approach, GNPs-laser, which causes quick loss of cell membrane integrity.

GNPs have advantages over other metal nanoparticles because they are chemically inert, biocompatible nature and not producing cytotoxicity. Gold is used internally in humans for the last 50 years. Physical properties of the nanoparticle may differ from their corresponding parent materials by decreasing the size of nanoparticles and this relation offered many opportunities for many scientific breakthroughs. GNPs produced good antibacterial activity. It had been shown their best result when particles aggregation is not observed at high levels. GNPs with the same shape and size exhibited different inhibitory effects by changing surface modifications agents. It can also use in targeted molecular imaging in living subjects.

Recently Gupta et al reported that the GNPs of ethanolic and hydroalcoholic exhibited anti-tubercular activity only at MIC 2.5 μg/mL and 20 μg/mL, respectively while ethanolic and hydroalcoholic extracts showed activity at much higher concentrations 50 μg/mL and 75 μg/mL, respectively. GNPs from *Nigella arvensis* (NA-GNPs) leaf extract were evaluated for antibacterial, antioxidant, cytotoxicity and catalytic activities and Chahardodli et al observed that NA-GNPs showed excellent cytotoxicity effects against H1299 and MCF-7 cancer cell lines with an IC50 value of 10 and 25 μg/mL, respectively and catalytic activity of NA-GNPs against methylene blue was 44%. Cheng et al synthesize GNPs using *Chenopodium formosanum* shell extract and concluded that GNPs
possessed potent antibacterial activity against Escherichia coli and Staphylococcus aureus.\textsuperscript{277} Sunderam et al.\textsuperscript{278} reported that green synthesized GNPs of \textit{Anacardium occidentale} leaves extract, data presents good antibacterial effect against \textit{Escherichia coli} and \textit{Bacillus subtilis} and exhibited 74.47\% viability on PBMC and 23.36\% viability on MCF-7 cell lines at a maximum concentration of 100 \(\mu\text{g/mL.}\textsuperscript{278} K atas et al.\textsuperscript{279} reported that the concentration of chitosan needed to synthesize antibacterial chitosan-GNPs with \textit{Lignosus rhinocerotis} (LRE) was lower than those without LRE, suggesting that the addition of LRE as reducing agent resulted in higher antibacterial activity. Thus, chitosan as a stabilizing or capping agent and LRE as a reducing agent for the production of GNPs improved antibacterial activity of their resultant nanoparticles.\textsuperscript{276-279} Veena et al.\textsuperscript{280} developed the green synthesis of \textit{Vitex negundo} GNPs from leaf extracts and results exhibited strong antibacterial activity against gram-negative strains and moderate activity against gram-positive strains.\textsuperscript{280} The overview of the review is presented in Figure 5.

\textbf{Conclusion}

The study of green synthesis of GNPs is a quickly evolving field in nanotechnology for TB. The present review summarises exhaustive literature for plants containing phytoconstituents having antitubercular activity along with the understanding of the synthesis of GNPs not only using plant extracts but biomolecules, microorganism, and various bioreactors. A detailed study is needed to give a lucid mechanism of biosynthesis of GNPs using biomolecules; microorganism present in different plant extracts which will be valuable to improve the properties of GNPs for TB treatment. With green chemical syntheses of these nanomaterials, researchers will able to conduct in-depth studies investigating biomedical applications without further biocompatibility preparations. In the coming years, the green chemistry procedure which utilizes plants their constituents, microorganisms, and biomolecules for nanoparticle preparation for TB has used as an alternative to conventional physicochemical methods since it is facile, rapid, cost-effective, and eco-friendly.

\textbf{Ethical Issues}

Not applicable.

\textbf{Conflict of Interest}

Authors declare no conflict of interest in this study.

\textbf{References}

1. Arya V. A review on anti-tubercular plants. \textit{Int J PharmTech Res} 2011;3(2):872-80.
2. Johnson R. Understanding the Mechanisms of Drug Resistance in Enhancing Rapid Molecular Detection of Drug Resistance in \textit{Mycobacterium tuberculosis} [thesis]. Stellenbosch: University of Stellenbosch; 2007.
3. Tuyiringire N, Tusubira D, Munyampundu JP, Tolo CU, Muvunyi CM, Ogwang PE. Application of metabolomics to drug discovery and understanding the mechanisms of action of medicinal plants with anti-tuberculosis activity. \textit{Clin Transl Med} 2018;7(1):29. doi: 10.1186/s40169-018-0208-3
4. Khan EM, Haque I, Pandey R, Mishra SK, Sharma AK. Tuberculosis of the thyroid gland: a clinicopathological profile of four cases and review of the literature. \textit{Aust N Z J Surg} 1993;63(10):807-10. doi: 10.1111/j.1445-2197.1993.tb0345.x
5. Choi TA, Czerwonka R, Fröhner W, Krahl MP, Reddy KR, Franzblau SG, et al. Synthesis and activity of carboxazole derivatives against \textit{Mycobacterium tuberculosis}. \textit{ChemMedChem} 2006;1(8):812-5. doi: 10.1002/cmdc.200600002
6. Sinha N, Jain S, Tilekar A, Upadhyaya RS, Kishore N, Jana GH, et al. Synthesis of isonicotinic acid N’-arylidene-N’-[2-oxo-2-(4-aryl-piperazin-1-yl)-ethyl]-hydrazides as antituberculosis agents. \textit{Bioorg Med Chem Lett} 2005;15(6):1573-6. doi: 10.1016/j.bmclet.2005.01.073
7. Barnes CC, Smalley MK, Manfredi KP, Kindscher K, Loring H, Sheeley DM. Characterization of an anti-tuberculosis...
resin glycoside from the prairie medicinal plant *Ipomoea leptophylla*. J Nat Prod 2003;66(11):1457-62. doi: 10.1021/np030197

8. Kataev VE, Strobykina I, Andreeva OV, Garifullin BF, Sharipova RR, Mironov VF, et al. [Synthesis and antituberculosis activity of the derivatives of glycoside steviolbioside from the plant *Stevia rebaudiana* and diterpenoid isosteviol containing hydrazide, hydrazide and pyridinyl oximes]. *Bioorg Khim* 2011;37(4):542-51. doi: 10.1134/s0168162110300095

9. Sharipova RR, Strobykina IY, Mordovskoi GG, Chestnova RV, Mironov VF, Kataev VE. Antituberculosis activity of glycosides from *Stevia rebaudiana* and hybrid compounds of steviolbioside and pyridinecarboxylic acid hydrazides. *Chem Nat Compd* 2011;46(6):902-5. doi: 10.1007/s10060-011-9779-6

10. Garifullin BF, Strobykina IY, Sharipova RR, Kravchenko MA, Andreeva OV, Bazanova OB, et al. Synthesis and antituberculosis activity of the first macrocylic glycerotetrasporins comprising glucosamine and diterpenoid isosteviol. *Carbohydrate Res* 2016;431:15-24. doi: 10.1016/j.carres.2016.05.007

11. Ibrahim MA, Rodenburg DL, Alves K, Fromczek FR, McChesney JD, Wu C, et al. Minor diterpene glycosides from the leaves of *Stevia rebaudiana*. *J Nat Prod* 2014;77(5):1231-5. doi: 10.1021/np4009656

12. Bartozka ED, Lange H, Pocic G, Crestini C. Stimuli-Responsive Tannin-Fe(III) Hybrid Microcrystals Demonstrated by the Active Release of an Anti-Tuberculosis Agent. *ChemSusChem* 2018;11(22):3975-91. doi: 10.1002/cssc.201801546

13. Hussain K, Ismail Z, Sadikun A, Ibrahim P. Antioxidant, anti-TB activities, phenolic and amide contents of standardised extracts of *Piper sarmentosum* Roxb. *Nat Prod Res* 2009;23(3):238-49. doi: 10.1080/14786410801987597

14. Awouafock MD, Kouam SF, Hussain H, Nganga D, Tane P, Schulz B, et al. Antimicrobial prenylated dihydrocalcones from *Eriosema glomerata*. *Planta Med* 2008;74(1):30-4. doi: 10.1055/s-2007-993782

15. Cardoso CAL, Coelho RG, Honda NK, Pott A, Pavan FR, Leite CQ. Phenolic compounds and antioxidant, antimicrobial and antitubercular activities of *Serjania erecta* Radlk. (Sapindaceae). *Braz J Pharm Sci* 2013;49(4):775-82. doi: 10.1590/s1984-82502013000400017

16. Coelho RG, Honda NK, Vieira MDa C, Brum RL, Pavan FR, Leite CQ, et al. Chemical composition and antioxidant and antituberculare activities of *Bromelia balansae* (Bromeliaceae). *J Med Food* 2010;13(5):1277-80. doi: 10.1089/jmfd.2009.0032

17. Trevizan LNF, Nascimento KFD, Santos JA, Kassuya CAL, Cardoso CAL, Vieira MDC, et al. Anti-inflammatory, antioxidant and anti-Mycobacterium tuberculosis activity of viridiflorol: the major constituent of *Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Radlk. *J Ethnopharmacol* 2016;192:510-5. doi: 10.1016/j.jep.2016.08.053

18. Sinsimer D, Huet G, Manca C, Tsenova L, Koo MS, Kurepina N, et al. The phenolic glycolipid of *Spondias mombin* (Sapindaceae). *Phytother. Res* 2006;20(5):576-82. doi: 10.1002/ptr.1664

19. Sykesamran S, Suwannapoch N, Phakhodee W, Thanuhranlert J, Ratananukul P, Chimnoi N, et al. Antimycobacterial activity of prenylated xanthones from the fruits of *Garcinia mangostana*. *Chem Pharm Bull (Tokyo)* 2003;51(7):857-9. doi: 10.1248/cpb.51.857

20. Gholas S, Biswas K, Chaudhuri RK. Chemical constituents of Gentianaceae XXIV: anti-Mycobacterium tuberculosis activity of naturally occurring xanthones and synthetic analogs. *J Pharm Sci* 1978;67(5):721-2. doi: 10.1002/jps.2600670546

21. Chen JI, Peng CF, Huang HY, Chen IS. Benzopyrans, biphénols and xanthones from the root of *Garcinia linii* and their activity against *Mycobacterium tuberculosis*. *Planta Med* 2006;72(5):473-7. doi: 10.1055/s-2005-916253

22. Pickert M, Schaper KJ, Frahm AW. Substituted xanthones as antimycobacterial agents, Part 2: antimycobacterial activity. *Arch Pharm (Weinheim)* 1998;331(5):193-7. doi: 10.1002/(sici)1521-4184(199805)331:5<193::aid-ardp193>3.0.co;2-s

23. Szkardak N, Stachura K, Waszkiewicz AM, Cegla M, Szneler E, Marona H. Synthesis and antimycobacterial assay of some xanthone derivatives. *Acta Pol Pharm* 2008;65(1):21-8.

24. Tran T, Saheba E, Arcerio AV, Chavez V, Li QY, Martinez LE, et al. Quinones as antimycobacterial agents. *Bioorg Med Chem* 2004;12(18):4809-13. doi: 10.1016/j.bmc.2004.07.015

25. Podust LM, Poulos TL, Waterman MR. Crystal structure of cytochrome P450 14alpha-sterol demethylase (CYP51) from *Mycobacterium tuberculosis* in complex with azole inhibitors. *Proc Natl Acad Sci U S A* 2001;98(6):3068-73. doi: 10.1073/pnas.06152898

26. Bocic PJ, Lamprecht JH. Plant sterols and sterolins: a review of their immune-modulating properties. *Altern Med Rev* 1999;4(1):170-7.

27. Bellamine A, Mangla AT, Nes WD, Waterman MR. Characterization and catalytic properties of the sterol 14alpha-demethylase from *Mycobacterium tuberculosis*. *Proc Natl Acad Sci U S A* 1999;96(16):8937-42. doi: 10.1073/pnas.96.16.8937

28. Woldehimel GM, Franzblau SG, Zhang F, Wang Y, Timmermann BN. Inhibitory effect of sterols from *Ruprechtia triflora* and diterpenes from *Calceolaria pinnifolia* on the growth of *Mycobacterium tuberculosis*. *Planta Med* 2003;69(7):628-31. doi: 10.1055/s-2003-41109

29. Jiménez-Arellanes A, Meckes M, Torres J, Luna-Herrera J. Antimycobacterial triterpenoids from *Lantana hispida* (Verbenaceae). *J Ethnopharmacol* 2007;111(2):202-5. doi: 10.1016/j.jep.2006.11.033

30. Akihisa T, Franzblau SG, Ukiya M, Okuda H, Zhang F, Yasukawa K, et al. Antitubercular activity of triterpenoids from *Asteraceae flowers*. *Biol Pharm Bull* 2005;28(1):158-60. doi: 10.1248/bpb.28.158

31. Wächter GA, Valic S, Flagg ML, Franzblau SG, Montenegro G, Suarez E, et al. Antitubercular activity of pentacyclic triterpenoids from plants of Argentina and Chile. *Phytomedicine* 1999;6(5):341-5. doi: 10.1016/s0944-7113(99)8056-7

32. Olugbuyo JRA, Moody JO, Hamann MT. AntiMt activity of triterpenoid-rich fractions from Spondias mombin L. *Afr J Biotechnol* 2009;8(9):1807-9. doi: 10.5897/ajb2009.0009-2528

33. Jiménez A, Meckes M, Alvarez V, Torres J, Parra R. Secondary metabolites from *Chamaedora tepejilote* (Palmae) are active against *Mycobacterium tuberculosis*. *Phytother Res* 2005;19(4):320-2. doi: 10.1002/ptr.1664

34. Ge F, Zeng F, Liu S, Guo N, Ye H, Song Y, et al. In vitro synergistic interactions of oleancolic acid in combination with ioniadiz, rifampicin or ethambutol against *Mycobacterium tuberculosis*. *J Med Microbiol* 2010;59(Pt 5):567-72. doi: 10.1099/jmm.0.014837-0
Gupta et al

35. Weigenand O, Hussein AA, Lall N, Meyer JJ. Antibacterial activity of naphthoquinones and triterpenoids from Euclea natalensis root bark. J Nat Prod 2004;67(11):1936-8. doi: 10.1021/np030465d

36. Truong NB, Pham CV, Doan HT, Nguyen HV, Nguyen CM, Nguyen HT, et al. Antituberculosis cycloartane triterpenoids from Radernachera boniana. J Nat Prod 2011;74(5):1318-22. doi: 10.1021/np200022b

37. Higuchi CT, Pavan FR, Leite CQ, Sanomiya M, Vilegas W, de Andrade Leite SR, et al. Triterpenes and antitubercular activity of Byrsonima crass. Quim Nova 2008;31(7):1719-21. doi: 10.1590/S0100-40422008000700023.

38. Jiménez-Arellanes A, Luna-Herrera J, Cornejo-Garrido J, López-Garcia S, Castro-Musso MTE, Meckes-Fischer M, et al. Ursolic and oleanolic acids as antimicrobial and immunomodulatory compounds for tuberculosis treatment. BMC Complement Altern Med 2013;13:258. doi: 10.1186/1472-6882-13-258

39. Wolska KI, Grudniak AM, Fiecek B, Kraczkiewicz-Dowjat A, Kurek A. Antibacterial activity of oleanolic and ursolic acids and their derivatives. Cent Eur J Biol 2010;5(5):543-53. doi: 10.2478/s11535-010-0045-x

40. Tanachatchairatan T, Brenner JB, Chokhaisiri R, Suksamrarn A. Antimycobacterial activity of cinnamate-based esters of the triterpenes betulinic, oleicolic and ursolic acids. Chem Pharm Bull (Tokyo) 2008;56(2):194-8. doi: 10.1248/cpb.56.194

41. Aparecida Resende F, de Andrade Barcala CA, da Silva Faria MC, Kato FH, Cunha WR, Tavares DC. Antimutagenicity of ursolic acid and oleic acid against doxorubicin-induced clastogenesis in Balb/c mice. Life Sci 2006;79(13):1268-73. doi: 10.1016/j.lfs.2006.03.038

42. Chinsenmbu KC. Tuberculosis and nature’s pharmacy of putative anti-tuberculosis agents. Acta Trop 2016;153:46-56. doi: 10.1016/j.actatropica.2015.10.004

43. Robles-Zepeda RE, Coronado-Aceves EW, Velázquez-Contreras CA, Ruiz-Bustos E, Navarro-Navarro M, Garibay-Escobar A. In vitro anti-mycobacterial activity of nine medicinal plants used by ethnic groups in Sonora, Mexico. BMC Complement Altern Med 2013;13:329. doi: 10.1186/1472-6882-13-329

44. Gupta R, Thakur B, Singh P, Singh HB, Sharma VD, Katoch VM, et al. Anti-tuberculosis activity of selected medicinal plants against multi-drug resistant Mycobacterium tuberculosis isolates. Indian J Med Res 2010;131:809-13.

45. Chidambaram S, Swaminathan R. Determination of anti-tubercular activity of four Indian medicinal plants against Mycobacterium tuberculosis by broth micro dilution method. Int J Pharm Sci Res 2013;4(10):3932-7.

46. Sinha T, Bandyopadhyay A. Ethno-pharmacological importance and valuable phytochemicals of Acalypha indica (L.) a review. Int J Res Pharm Sci 2012;3(3):360-8.

47. Ayyanar M, Ignacimuthu S. Medicinal uses and pharmacological actions of five commonly used Indian medicinal plants: a mini-review. Iran J Pharmocol Ther 2008;7(1):107-14.

48. Kim JH. Anti-bacterial action of onion (Allium cepa L.) extracts against oral pathogenic bacteria. J Nihon Univ Sch Dent 1997;39(3):136-41. doi: 10.2334/jouinsud1959.39.136

49. Gibbons S. Phytochemicals for bacterial resistance--strengths, weaknesses and opportunities. Planta Med 2008;74(6):594-602. doi: 10.1055/s-2008-1074518

50. Mohamad S, Zin NM, Wahab HA, Ibrahim P, Sulaiman SF, Zahariluddin AS, et al. Antituberculosis potential of some ethnobotanically selected Malaysian plants. J Ethnopharmacol 2011;133(3):1021-6. doi: 10.1016/j.jep.2010.11.037

51. Ratnakar P, Murthy PS. Purification and mechanism of action of antitubercular principle from garlic (Allium sativum) active against isoniazid susceptible and resistant Mycobacterium tuberculosis H 37 R v. Indian J Clin Biochem 1995;10(1):34-8. doi: 10.1007/bf02873666

52. Hannan A, Ikram Ullah M, Usman M, Hussain S, Absar M, Javed K. Anti-mycobacterial activity of garlic (Allium sativum) against multi-drug resistant and non-multi-drug resistant Mycobacterium tuberculosis. Pak J Pharm Sci 2011;24(1):81-5.

53. Ratnakar P, Suryanarayana Murthy P. Preliminary studies on the antitubercular activity and the mechanism of action of the water extract of garlic (Allium sativum) and its two partially purified proteins (Garlic defensins?). Indian J Clin Biochem 1996;11(1):37-41. doi: 10.1007/bf02868409

54. Dini C, Fabbrì A, Geraci A. The potential role of garlic (Allium sativum) against the multi-drug resistant tuberculosis pandemic: a review. Ann Ist Super Sanita 2011;47(4):465-73. doi: 10.4415/ann_11_04_18

55. Murthy PS, Ratnakar P, Gadre DV, Talwar V, Gupta HC, Gupta RL. Trifluoperazine and CEF-allicin from garlic (Allium sativum) as potential new antitubercular drugs active against drug resistant Mycobacterium tuberculosis. Indian J Clin Biochem 1997;12(Suppl 1):72-5. doi: 10.1007/bf02873066

56. Ignacimuthu S, Shanmugam N. Antimycobacterial activity of two natural alkaloids, vasicine acetate and 2-acetyl benzylamine, isolated from Indian shrub Adhatoda vasica Ness. leaves. J Biosci 2010;35(4):565-70. doi: 10.1007/s12038-010-0065-8

57. Grange JM, Snell NJ. Activity of bromhexine and ambroxol, semi-synthetic derivatives of vasicine from the Indian shrub Adhatoda vasica, against Mycobacterium tuberculosis in vitro. J Ethnopharmacol 1996;50(1):49-53. doi: 10.1016/0378-8741(95)01331-8

58. Grindlay D, Reynolds T. The Aloe vera phenomenon: a review of the properties and modern uses of the leaf parenchyma gel. J Ethnopharmacol 1986;16(2-3):117-51. doi: 10.1016/0378-8741(86)90085-1

59. Hauot AC, Haggoud A, David S, Ibsnouda S, Iraqui M. In vitro evaluation of the antimycobacterial activity and fractionation of Berberis hispanica root bark. J Pure Appl Microbiol 2014;8(2):917-25.

60. Higuchi CT, Sanomiya M, Pavan FR, Leite SR, Sato DN, Franzblau SG, et al. Byrsonima fagifolia Niedenzu apolar compounds with antitubercular activity. Evid Based Complement Alternat Med 2011;2011:128349. doi: 10.1093/ebCAM/nen077

61. Singh A, Venugopala KN, Khedr MA, Pillay M, Nwaeez KU, Coovadia Y, et al. Antimycobacterial, docking and molecular dynamic studies of pentacyclic triterpenes from Buddleja saligna leaves. J Biomol Struct Dyn 2017;35(12):2654-64. doi: 10.1080/07391101.2016.1227725

62. Banuamba K, Gammon DW, Meyers P, Dijoux-Franca MG, Scott G. Anti-mycobacterial activity of five plant species used as traditional medicinal in the Western Cape province (South Africa). J Ethnopharmacol 2008;117(2):385-90. doi: 10.1016/j.jep.2008.02.007

63. Wolska KL, Grudniak AM, Fiecek B, Kraczkiewicz-Dowjat A, Kurek A. Antibacterial activity of oleanolic and ursolic acids and their derivatives. Cent Eur J Biol 2010;5(5):543-53.
Green synthesis of gold nanoparticles for tuberculosis

Joshi C, Magar N. Antibiotic activity of some Indian medicinal plants. J Sci Ind Res 1952;11:261.

Bhatia A, Kumar A, Goel A, Gupta A, Rahal A. Antibacterial activity of hot aqueous extract of Ocimum sanctum leaves against common bacterial pathogens of animals. Pharma Sci Monit 2013;4(3 Suppl 1):279-85.

Kumar A, Rahal A, Chakraborty S, Tiwari R, Ratheef SK, Dharma K. Ocimum sanctum (Tulsi): a miracle herb and boon to medical science-a Review. Int J Agron Plant Prod 2013;4(7):1580-9.

Sehgal J, Siddheswaran P, Senthil Kumar KL, Karthikeyan T. Anti-tubercular activity of fruits of Prunus armeniaca (L.). Int J Pharma Bio Sci 2010;1:12.

Rashid F, Ahmed R, Mahmood A, Ahmad Z, Bibi N, Kazmi SU. Flavonoid glycosides from Prunus armeniaca and the antibacterial activity of a crude extract. Arch Pharm Res 2007;30(8):932-7. doi: 10.1007/bf02993959.

Sharma S, Kalia NP, Suden P, Chauhan PS, Kumar M, Ram AB, et al. Protective efficacy of pipeline against Mycobacterium tuberculosis. Tuberculosis (Edinb) 2014;94(4):389-96. doi: 10.1016/j.tub.2014.04.007.

Scodro RB, Pires CT, Czarra VS, Lemos CO. Cardozo-Filho L, Souza VA, et al. Anti-tuberculosis neolignans from Piper regnellii. Phytomedicine 2013;20(7):600-4. doi: 10.1016/j.phymed.2013.01.005.

Kumar V, Poonam, Prasad AK, Parmar VS. Naturally occurring aristolactams, aristolochic acids and dioxyaporphines and their biological activities. Nat Prod Rep 2003;20(6):565-83. doi: 10.1039/b303648k.

LiangHX, Dai HQ, Fu HA, DongXP, Adelbeyo AH, Zhang LX, et al. Bioactive compounds from Rumex plants. Phytochem Lett 2010;3(4):181-4. doi: 10.1016/j.phytol.2010.05.005.

Toçpu G, Gören AC. Biological activity of diterpenoids isolated from Anatolian Lamiaceae plants. Rec Nat Prod 2007;1(1):1-16.

Ulubelen A, Evren N, Tuzlaci E, Johansson C. Diterpenoids from the roots of Salvia hypargiea. J Nat Prod 1998;51(6):1178-83. doi: 10.1021/np9800421.

Habibi Z, Eftekhar F, Samiee K, Rustaiyan A. Structure and antibacterial activity ofp6 new labdane diterpenoid from Salvia keriaefolia. J Nat Prod 2006;69(2):270-1. doi: 10.1021/np050287h.

Askın T, Hüsnü Can Başer K, Tümen G, Kürkçüoğlu M. Characterization of essential oils of some Salvia species and their antimycobacterial activities. Turk J Biol 2010;34:89-95. doi: 10.3906/biy-0809-2.

Gu JQ, Wang Y, Franzenblau SG, Montenegro G, Timmermann BN. Constituents of Senecio chionophila with potential antibacterial activity. J Nat Prod 2004;67(9):1483-7. doi: 10.1021/np049331z.

Hong Q, Minter DE, Franzenblau SG, Reinecke MG. Anti-tuberculosis compounds from two Bolivian medicinal plants, Senecio mathewesi and Usnea floridis. Nat Prod Commun 2008;3(9):1377-84. doi: 10.1177/1934578X080300901.

Tiwari N, Thakur J, Saikia D, Gupta MM. Antituberucular diterpenoids from Vitex trifolia. Phytomedicine 2013;20(7):605-10. doi: 10.1016/j.phymed.2013.01.003.

Ladda PL, Naikwade NS, Madgum CS. Antimycobacterial and antimicrobial activity of leaf extracts of Vitex negundo Linn. Res J Pharmacogn Phytochem 2010;2(2):166-8.

Tandon VR, Khajuria V, Kapoor B, Kour D, Gupta S. Hepatoprotective activity of Vitex negundo leaf extract against anti-tubercular drugs induced hepatotoxicity. Fitoterapia 2008;79(7-8):533-8. doi: 10.1016/j.fitote.2008.05.005.
Green synthesis of gold nanoparticles using marine algae and evaluation of their catalytic activity. *J Nanoscience Chem* 2016;6(1):1-13. doi: 10.1007/s40097-015-0173-y

115. Ghodake GS, Deshpande NG, Lee YP, Jin ES. Pear fruit extract-assisted room-temperature biosynthesis of gold nanoparticles. *Colloids Surf B Biointerfaces* 2010;75(2):584-9. doi: 10.1016/j.colsurfb.2009.09.040

116. Ghodake G, Eom CY, Kim SW, Jin E. Biogenic nano-synthesis—towards the efficient production of the biocompatible gold nanoparticles. *Bull Korean Chem Soc* 2010;31(10):2771-5. doi: 10.5012/bkcs.2010.31.10.2771

117. Bogireddy NKR, Hoskote Anand KK, Mandal BK. Gold nanoparticles — synthesis by *Sterculia acuminata* extract and its catalytic efficiency in alleviating different organic dyes. *J Mol Liq* 2015;211:688-75. doi: 10.1016/j.molliq.2015.07.027

118. Kumar KM, Mandal BK, Sinha M, Krishnakumar V. *Terminalia chebula* mediated green and rapid synthesis of gold nanoparticles. *Spectrochim Acta A Mol Biomol Spectrosc* 2012;86:490-4. doi: 10.1016/j.saa.2011.11.001

119. Nellore J, Pauline PC, Amarnath K. Biostructures. Biogenic synthesis by *Sphaeranthus amaranthoides*; towards the efficient production of the biocompatible gold nanoparticles. *Digest J Nanomater Biostruct* 2012;7(1):123-33

120. Guo Q, Guo Q, Yuan J, Zeng J. Biosynthesis of gold nanoparticles using a kind of flavonol: dihydromyricetin. *Colloids Surf A Physicochem Eng Asp* 2014;441:127-32. doi: 10.1016/j.colsurfa.2013.08.067

121. Ghosh P, Han G, De M, Kim CK, Rotello VM. Gold nanoparticles in delivery applications. *Adv Drug Deliv Rev* 2008;60(11):1307-15. doi: 10.1016/j.addr.2008.03.016

122. Hu M, Chen J, Li ZY, Au L, Hartland GV, Li X, et al. Gold nanostructures: engineering their plasmonic properties for biomedical applications. *Chem Soc Rev* 2006;35(11):1084-94. doi: 10.1039/b517615h

123. Sugunan A, Thanachayanont G, Dutta J, Hilborn JG. Heavy-metal ion sensors using chitosan-capped gold nanoparticles. *Sci Technol Adv Mater* 2005;6(3-4):335-40. doi: 10.1016/j.stam.2005.03.007

124. Li B, Du Y, Dong S. DNA based gold nanoparticles colorimetric sensors for sensitive and selective detection of Ag(I) ions. *Anal Chim Acta* 2009;644(1-2):78-82. doi: 10.1016/j.aca.2009.04.022

125. Souza GR, Christianson DR, Staquicini FL, Ozawa MG, Snyder EY, Sidman RL, et al. Networks of gold nanoparticles and bacteriophage as biological sensors and cell-targeting agents. *Proc Natl Acad Sci U S A* 2006;103(5):1215-20. doi: 10.1073/pnas.0509739103

126. Li X, Robinson SM, Gupta A, Saha K, Jiang Z, Moyoan DF, et al. Functional gold nanoparticles as potent antimicrobial agents against multi-drug-resistant bacteria. *ACS Nano* 2014;8(10):10682-6. doi: 10.1021/nn5042625

127. Rai A, Prabhune A, Perry CC. Antibiotic mediated synthesis of gold nanoparticles with potent antimicrobial activity and their application in antimicrobial coatings. *J Mater Chem* 2010;20(32):6789-98. doi: 10.1039/c0jm00817f

128. Hernández-Sierra JF; Ruiz F, Pena DC, Martínez-Gutiérrez F, Martínez AE, Guillén Ade J, et al. The antimicrobial sensitivity of *Streptococcus mutans* to nanoparticles of silver, zinc oxide, and gold. *Nanomedicine* 2008;4(3):237-40. doi: 10.1016/j.nano.2008.04.005

129. Corrêa G, Garcia H. Supported gold nanoparticles as catalysts for organic reactions. *Chem Soc Rev* 2008;37(9):2096-126. doi: 10.1039/b707314n

130. Daniel MC, Astruc D. Gold nanoparticles: assembly,
Green synthesis of gold nanoparticles for tuberculosis

supramolecular chemistry, quantum-size-related properties, and applications toward biology, catalysis, and nanotechnology. Chem Rev 2004;104(1):293-346. doi: 10.1021/cr030698+

131. Haruta M. Catalysis of gold nanoparticles deposited on metal oxides. Cattech 2002;6(3):102-15. doi: 10.1023/A:1020081423055

132. Huang D, Liao F, Moles S, Redinger D, Subramanian V. Plastic-compatible low resistance printable gold nanoparticle conductors for flexible electronics. J Electrochem Soc 2003;150(7):G412-G7. doi: 10.1149/1.1582466

133. Lueching NA, Athanassiou EK, Stark WJ. Graphene-stabilized copper nanoparticles as an air-stable substrate for silver and gold in low-cost ink-jet printable electronics. Nanotechnology 2008;19(44):445201. doi: 10.1088/0957-4448/19/44/445201

134. Danckwerts M, Novotny L. Optical frequency mixing at coupled gold nanoparticles. Phys Rev Lett 2007;98(2):026104. doi: 10.1103/PhysRevLett.98.026104

135. Cheng SF, Chau LK. Colloidal gold-modified optical fiber for chemical and biochemical sensing. Anal Chem 2003;75(1):16-21. doi: 10.1021/ac020310v

136. Yang N, WeiHong L, Hao L. Biosynthesis of Au nanoparticles using agricultural waste mango peel extract and its in vitro cytotoxic effect on two normal cells. Mater Lett 2014;134:67-70. doi: 10.1016/j.matlet.2014.07.025

137. Khot LR, Sankaran S, Maja JM, Ehsani R, Schuster EW. Applications of nanomaterials in agricultural production and crop protection: a review. Crop Prot 2012;35:64-70. doi: 10.1016/j.cropro.2012.01.007

138. Green M, Harwood H, Barrowman C, Rahman P, Eggeman A, Festy F, et al. A facile route to CdTe nanoparticles and their use in bio-labelling. J Mater Chem 2007;17(19):1989-94. doi: 10.1039/b615871d

139. von Maltzahn G, Park JH, Agrawal A, Bandaru NK, Das SK, Sailor MJ, et al. Computationally guided photothermal tumor therapy using long-circulating gold nanorod antennas. Cancer Res 2009;69(9):3892-900. doi: 10.1158/0008-5472.can-08-4242

140. Cabuzu D, Cirja A, Puiu R, Grumezescu AM. Biomedical applications of gold nanoparticles. Curr Top Med Chem 2015;15(16):1605-13. doi: 10.2174/15680266156661504141 44750

141. Dykman L, Khlebtsov N. Gold nanoparticles in biomedical applications: recent advances and perspectives. Chem Soc Rev 2012;41(6):2256-82. doi: 10.1039/c1cs15166e

142. Tiwari PM, Vig K, Dennis VA, Singh SR. Functionalized gold nanoparticles and their biomedical applications. Nanomaterials (Basel) 2011;1(1):31-63. doi: 10.3390/nano1010031

143. Vayssieres L, Beermann N, Lindquist SE, Hagfeldt A. Controlled aqueous chemical growth of oriented three-dimensional crystalline nanorod arrays: application to iron (III) oxides. Chem Mater 2001;13(2):233-5. doi: 10.1021/cm001202x

144. Zhang X, Yonzon CR, Van Duyne RP. Nanosphere lithography fabricated plasmonic materials and their applications. J Mater Res 2006;21(5):1083-92. doi: 10.1557/jmr.2006.0136

145. Cao CY, Guo W, Cui ZM, Song WG, Cai W. Microwave-assisted gas/liquid interfacial synthesis of flowerlike NiO hollow nanosphere precursors and their application as supercapacitor electrodes. J Mater Chem 2011;21(9):3204-9. doi: 10.1039/c0jm03749d

146. Borzenkov M, Mätätten A, Ihalainen P, Collini M, Cabrini E, Darcago G, et al. Fabrication of inkjet-printed gold nanopatter with photothermal properties on paper substrate. ACS Appl Mater Interfaces 2016;8(15):9909-16. doi: 10.1021/acsami.6b02983

147. Ma W, Sun M, Xu L, Wang L, Kuang H, Xu C. A SERS active gold nanostar dimer for mercury ion detection. Chem Commun (Camb) 2013;49(44):4989-91. doi: 10.1039/c3cc39087

148. Zharov VP, Galitovskaya EN, Johnson C, Kelly T. Synergistic enhancement of selective nanophotothermalysis with gold nanoclusters: potential for cancer therapy. Lasers Surg Med 2005;37(3):219-26. doi: 10.1002/lsm.20223

149. Lin CA, Yang TY, Lee CH, Huang SH, Sperling RA, Zanella M, et al. Synthesis, characterization, and bioconjugation of fluorescent gold nanoclusters toward biological labeling applications. ACS Nano 2009;3(2):395-401. doi: 10.1021/nn800632j

150. Chen J, Wiley B, Li ZY, Campbell D, Saeki F, Cang H, et al. Gold nanocages: engineering their structure for biomedical applications. Adv Mater 2005;17(18):2255-61. doi: 10.1002/adma.200500833

151. Guerrero-Martinez A, Barbosa S, Pastoriza-Santos I, Liz-Marzán LM. Nanostars shine bright for you: colloidal synthesis, properties and applications of branched metallic nanoparticles. Curr Opin Colloid Interface Sci 2011;16(2):118-27. doi: 10.1016/j.cocis.2010.12.007

152. Katz E, Willner I. Biomolecule-functionalized carbon nanotubes: applications in nanobiotechnology. Chemphyschem 2004;5(8):1084-104. doi: 10.1002/chpc.200400193

153. Wang ZL. Functional oxide nanobelts: materials, properties and potential applications in nanosystems and biotechnology. Ann Rev Phys Chem 2004;55:159-96. doi: 10.1146/annurev.physchem.55.091602.094416

154. Kalele S, Gosavi SW, Urban J, Kulkarni SK. Nanoshell particles: synthesis, properties and applications. Curr Sci 2006;91(8):1038-52. doi: 10.2307/2403981

155. Anastas PT, Warner JC. Green Chemistry: Theory and Practice. New York: Oxford University Press; 1998.

156. Ismail EH, Saqer AMA, Assirey E, Naqvi A, Okasha RM. Successful green synthesis of gold nanoparticles using a Corchorus olitorius extract and their antiproliferative effect in cancer cells. Int J Mol Sci 2018;19(9). doi: 10.3390/ijms19091467

157. Ovais M, Khalil AT, Islam NU, Ahmad I, Ayaz M, Saravanan M, et al. Role of plant phytochemicals and microbial enzymes in biosynthesis of metallic nanoparticles. Appl Microbiol Biotechnol 2018;102(16):6799-814. doi: 10.1007/s00253-018-9416-7

158. Koperunchalan M. Bioreduction of chloroauric acid (HAuCl4) for the synthesis of gold nanoparticles (GNPs): a special emphases of pharmacological activity. Int J Phytopharm 2015;5(4):72-80. doi: 10.7439/ipp.v5i4.2503

159. Jesus JA, Lago JH, Laurenti MD, Yamamoto ES, Passero LF. Antimicrobial activity of a new gold-nanoparticle complex: an update. Evid Based Complement Alternat Med 2015;2015:620472. doi: 10.1186/1472-6831-15-24

160. Oldfield E, Lin FY. Terpene biosynthesis: modularity rules. Phytochemistry 2004;65:396-405. doi: 10.1016/j.phyto.2004.01.007

161. Mares-Briones F, Rosas G. Structure and stability of gold
nanoparticles synthesized using Schinus molle L. extract. J Clust Sci 2017;28(4):1995-2003. doi: 10.1007/s10876-017-1197-x

162. Raja S, Ramesh V, Thivaharan V. Antibacterial and anticoagulant activity of silver nanoparticles synthesised from a novel source–pods of Peltophorum pterocarpum. J Ind Eng Chem 2015;29:257-64. doi: 10.1016/j.jiec.2015.03.033

163. Bursal E, Gülcin I. Polyphenol contents and in vitro antioxidant activities of lyophilized aqueous extract of kiwifruit (Actinidia deliciosa). Food Res Int 2011;44(5):1482-9. doi: 10.1016/j.foodres.2011.03.031

164. Sathishkumar M, Sneha K, Won SW, Cho CW, Kim S, Yun YS. Cinnamon zeylanicum bark extract and powder mediated green synthesis of nano-crystalline silver particles and its bactericidal activity. Colloids Surf B Biointerfaces 2009;73(2):332-8. doi: 10.1016/j.colsurfb.2009.06.005

165. Kathuri J, Veerapandian S, Rajendiran N. Biological synthesis of silver and gold nanoparticles using apin as reducing agent. Colloids Surf B Biointerfaces 2009;68(1):55-60. doi: 10.1016/j.colsurfb.2008.09.021

166. Leopoldini M, Russo N, Chiiodo S, Tescano M. Iron chelation by the powerful antioxidant flavonoid quercetin. J Agric Food Chem 2006;54(17):6343-51. doi: 10.1021/jf060986h

167. Li H, Liang R, Turner DH, Rothberg LJ, Duan S. Selective quenching of fluorescence from unbound elogomolecules by gold nanoparticles as a probe of RNA structure. RNA 2007;13(11):2034-41. doi: 10.1261/rna.138807

168. Shukla R, Nune SK, Chanda N, Katti K, Mekapothula S, Kulkarni RR, et al. Soybeans as a phytochemical reservoir for the production and stabilization of biocompatible gold nanoparticles. Small 2008;4(9):1425-36. doi: 10.1002/smll.200800525

169. Dumur F, Guerlin A, Dumas E, Bertin D, Gignmes D, Mayer CR. Controlled spontaneous generation of gold nanoparticles assisted by dual reducing and capping agents. Gold Bull 2011;44(2):119-37. doi: 10.1007/s11001-011-0018-5

170. Edison TJL, Sethuraman MG. Instant green synthesis of silver nanoparticles using Terminalia chebula fruit extract and evaluation of their catalytic activity on reduction of methylene blue. Process Biochem 2012;47(9):1351-7. doi: 10.1016/j.procbio.2012.04.025

171. Ghosh S, Patil S, Ahire M, Kitture R, Gurav DD, Jabgunde AM, et al. Gnidia glauca flower extract mediated synthesis of gold nanoparticles and evaluation of its chemocatalytic potential. J Nanobiotechnology 2012;10:17. doi: 10.1186/1477-3155-10-17

172. Dahl JA, Maddux JL, Hutchison JE. Toward greener nanosynthesis. Chem Rev 2007;107(6):2228-69. doi: 10.1021/cr060943k

173. Parida UK, Bindhani BK, Nayak P. Green synthesis and characterization of gold nanoparticles using onion (Allium cepa) extract. World J Nano Sci Eng 2011;1(4):93-8. doi: 10.4236/wjnee.2011.40015

174. Sheny DS, Mathew J, Philip D. Phytosynthesis of Au, Ag and Au-Ag bimetallic nanoparticles using aqueous extract and dried leaf of Anacardium occidentale. Spectrochim Acta A Mol Biomol Spectrosc 2011;79(1):254-62. doi: 10.1016/j.saa.2011.02.051

175. Thirumurugan A, Jiffin G, Rajagomathi G, Tomy N, Ramachandran S, Jaiganesh R. Biotechnological synthesis of gold nanoparticles of Azadirachta indica leaf extract. Int J Biol Technol 2010;1(1):75-7.

176. Boruah SK, Boruah PK, Sarma P, Medhi C, Medhi OK. Green synthesis of gold nanoparticles using Camellia sinensis and kinetics of the reaction. Adv Mater Lett 2012;3(6):481-6. doi: 10.5185/amlett.2012.12nano.103

177. Dwivedi AD, Gopal K. Plant-mediated biosynthesis of silver and gold nanoparticles. J Biomed Nanotechnol 2011;7(1):163-4. doi: 10.1166/jbn.2011.1250

178. Fazaludeen MF, Manickam C, Ashankkyty IM, Ahmed MQ, Beg Q. Synthesis and characterizations of gold nanoparticles by Justicia gendarussa Burm F leaf extract. J Microbiol Biotechnol Res 2012;2(1):23-34.

179. Aromal SA, Vidhu VK, Philip D. Green synthesis of well-dispersed gold nanoparticles using Macrotyloma uniflorum. Spectrochim Acta A Mol Biomol Spectrosc 2012;85(1):99-104. doi: 10.1016/j.saa.2011.09.035

180. MubarakAli D, Thajuddin N, Jeganathan K, Gunasekaran M. Plant extract mediated synthesis of silver and gold nanoparticles and its antibacterial activity against clinically isolated pathogens. Colloids Surf B Biointerfaces 2011;85(2):360-5. doi: 10.1016/j.colsurfb.2011.03.009

181. Vankar PS, Baijai D. Preparation of gold nanoparticles from Mirabilis jalapa flowers. Indian J Biochem Biophys 2010;47(3):157-60.

182. Mondal S, Roy N, Laskar RA, Sk I, Basu S, Mandal D, et al. Biogenic synthesis of Ag, Au and bimetallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (Swietenia mahogani JACQ.) leaves. Colloids Surf B Biointerfaces 2011;82(2):497-504. doi: 10.1016/j.colsurfb.2010.10.007

183. Reddy V, Torati RS, Oh S, Kim C. Biosynthesis of gold nanoparticles assisted by Sapium sebiferum Gaertn. Fruit pericarp and their catalytic application for the reduction of p-nitroaniline. Ind Eng Chem Res 2013;52(2):556-64. doi: 10.1021/ie302037c

184. Dauthal P, Mukhopadhyay M. Prunus domestica fruit extract-mediated synthesis of gold nanoparticles and its catalytic activity for 4-nitrophenol reduction. Ind Eng Chem Res 2012;51(40):13014-20. doi: 10.1021/ie300369g

185. Song JY, Jang H-K, Kim BS. Biological synthesis of gold nanoparticles using Magnolia kobus and Dioppyros kaki leaf extracts. Process Biochem 2009;44(10):1133-8. doi: 10.1016/j.procbio.2009.06.005

186. Narayanan KB, Sakhthivel N. Phytosynthesis of gold nanoparticles using leaf extract of Coleus amboinicus Lour. Mater Charact 2010;61(11):1232-8. doi: 10.1016/j.matchar.2010.08.003

187. Kumar VG, Gokavarapu SD, Rajeswari A, Dhas TS, Karthick V, Kapadia Z, et al. Facile green synthesis of gold nanoparticles using leaf extract of antidiabetic potent Cassia auriculata. Colloids Surf B Biointerfaces 2011;87(1):159-63. doi: 10.1016/j.colsurfb.2011.05.016

188. Jayaseelan C, Ramkumar R, Rahuman AA, Perumal P. Green synthesis of gold nanoparticles using seed aqueous extract of Abelmoschus esculentus and its antifungal activity. Ind Crops Prod 2013;45:423-9. doi: 10.1016/j.indcrops.2012.12.019

189. Kumar KP, Paul W, Sharma CP. Green synthesis of silver nanoparticles with Zingiber officinale extract and study of its blood compatibility. BioNanoScience 2012;2(3):144-52. doi: 10.1007/s12668-012-0044-7

190. Noruzi M, Zare D, Khoshnevisan K, Davoodi D. Rapid green synthesis of gold nanoparticles using Rosa hybrida petal extract at room temperature. Spectrochim Acta A Mol Biomol Spectrosc 2011;79(5):1461-5. doi: 10.1016/j.saa.2011.05.001
Green synthesis of gold nanoparticles for tuberculosis

191. Ghule K, Ghule AV, Liu JY, Ling YC. Microscale size triangular gold prisms synthesized using Bengal gram beans (Cicer aritinum L.) extract and HauCl4x3H2O: a green biogenic approach. J Nanosci Nanotechnol 2006;6(12):3746-51. doi: 10.1166/jnn.2006.608

192. Castro L, Blázquez ML, Muñoz JA, González F, García-Balboa C, Ballester A. Biosynthesis of gold nanowires using sugar beet pulp. Process Biochem 2011;46(5):1076-82. doi: 10.1016/j.procbio.2011.01.025

193. Das RK, Gogoi N, Bora U. Green synthesis of gold nanoparticles using Nytcanthes arbortristis flower extract. Bioprocess Biosyst Eng 2011;34(5):615-9. doi: 10.1007/s00449-010-0510-y

194. Tamuly C, Hazarika M, Bordoloi M. Biosynthesis of Au nanoparticles by Gymnocalcias asamincas and its catalytic activity. Mater Lett 2013;108:276-9. doi: 10.1016/j.matlet.2013.07.020

195. Zhan G, Huang J, Lin L, Lin W, Emmanuel K, Li Q. Synthesis of gold nanoparticles by Cucumens Platycladi leaf extract and its simulated solution: toward the plant-mediated biosynthetic mechanism. J Nanopart Res 2011;13(10):4957. doi: 10.1007/s11051-011-0476-y

196. Narayan BN, Shakhitveel N. Coriander leaf mediated biosynthesis of gold nanoparticles. Mater Lett 2008;62(30):4588-90. doi: 10.1016/j.matlet.2008.08.044

197. Tahir K, Nazir S, Li B, Khan AU, Khan ZUH, Gong PY, et al. Nerium oleander leaves extract mediated synthesis of gold nanoparticles and its antioxidant activity. Mater Lett 2015;156:198-201. doi: 10.1016/j.matlet.2015.05.062

198. Patra S, Mukherjee S, Barui AK, Ganguly A, Sreeradha B, Patra CR. Green synthesis, characterization of gold and silver nanoparticles and their potential application for cancer therapeutics. Mater Sci Eng C Mater Biol Appl 2015;53:298-309. doi: 10.1016/j.msec.2015.04.048

199. Raju D, Vishwakarma RK, Khan BM, Mehta UJ, Ahmad A. Biological synthesis of cationic gold nanoparticles and binding of plasmid DNA. Mater Lett 2014;129:59-61. doi: 10.1016/j.matlet.2014.05.021

200. Bindhu MR, Vijaya Rekha P, Umamaheswari T, Umadevi M. Antibacterial activities of Hibiscus cannabinus stem-assisted silver and gold nanoparticles. Mater Lett 2014;131:194-7. doi: 10.1016/j.matlet.2014.05.172

201. Das J, Paul Das M, Velusamy P. Sesbania grandiflora leaf extract mediated green synthesis of antibacterial silver nanoparticles against selected human pathogens. Spectrochim Acta A Mol Biomol Spectrosc 2013;104:265-70. doi: 10.1016/j.saa.2012.11.075

202. Islam NU, Jalil K, Shahid M, Rauf A, Muhammad N, Khan A, et al. Green synthesis and biological activities of gold nanoparticles functionalized with Salix alba. Arab J Chem 2019;12(8):2914-25. doi: 10.1016/j.arabjc.2015.06.025

203. Guo M, Li W, Yang F, Liu H. Controllable biosynthesis of gold nanoparticles from a Eucommia ulmoides bark aqueous extract. Spectrochim Acta A Mol Biomol Spectrosc 2015;142:73-9. doi: 10.1016/j.saa.2015.01.109

204. Abdel-Raouf N, Al-Enazi NM, Ibraheem IB. Green biosynthesis of gold nanoparticles using Galaxaura elongata and characterization of their antibacterial activity. Arab J Chem 2017;10:S3029-S39. doi: 10.1016/j.arabjc.2013.11.044

205. Philip D, Unni C. Extracellular biosynthesis of gold and silver nanoparticles using Krishna tuli (Ocimum sanctum) leaf. Physica E Low Dimens Syst Nanostruct 2011;43(7):1318-22. doi: 10.1016/j.physe.2010.10.006

206. Kalpana D, Pichiaa PBT, Sankarganesha A, Park WS, Lee SM, Wahab R, et al. Biogenesis of gold nanoparticles using plant powders and assessment of in vitro cytotoxicity in 3T3-L1 cell line. J Pharm Innov 2013;8(4):265-75. doi: 10.1007/s12247-013-9166-x

207. Khalil MMH, Ismail EH, El-Magdoub F. Biosynthesis of Au nanoparticles using olive leaf extract: 1st nano updates. Arab J Chem 2012;5(4):431-7. doi: 10.1016/j.arabjc.2010.11.011

208. Jha AK, Prasad K. Rose (Rosa sp.) petals assisted green synthesis of gold nanoparticles. J Bionanoscience 2013;7(3):245-50. doi: 10.1016/j.jbns.2013.1139

209. Islam NU, Jalil K, Shahid M, Muhammad N, Rauf A. Pistaica integerrima gall extract mediated green synthesis of gold nanoparticles and their biological activities. Arab J Chem 2019;12(8):2310-9. doi: 10.1016/j.arabjc.2015.02.014

210. Annamalai A, Christina VLP, Sudha D, Kalpana M, Lakshmi PTV. Green synthesis, characterization and antimicrobial activity of Au NPs using Euphorbia hirta L. leaf extract. Colloids Surf B Biointerfaces 2013;108:60-5. doi: 10.1016/j.colsurfb.2013.02.012

211. Suman TY, Rajasree SR, Ramkumar R, Rajthilak C, Perumal P. The green synthesis of gold nanoparticles using an aqueous root extract of Morinda citrifolia L. Spectrochim Acta A Mol Biomol Spectrosc 2014;118:11-6. doi: 10.1016/j.saa.2013.08.066

212. Sadeghi B, Ziyypsus mauritiana extract-mediated green and rapid synthesis of gold nanoparticles and its antibacterial activity. J Nanostruct Chem 2015;5(3):265-73. doi: 10.1007/s40097-015-0157-y

213. Bosecker K. Bioreaching: metal solubilization by microorganisms. FEMS Microbiol Rev 1997;20(3-4):591-604. doi: 10.1016/s0168-6445(97)00036-3

214. Rajasree SRR, Suman TY. Extracellular biosynthesis of gold nanoparticles using a gram negative bacterium Pseudomonas fluorescens. Asian Pac J Trop Dis 2012;2:S796-S9. doi: 10.1016/S2222-1808(12)00267-9

215. Konishi Y, Tsukiyama T, Tachimi T, Saitoh N, Nomura T, Nagamine S. Microbial deposition of gold nanoparticles by the metal-reducing bacterium Shewanella algae. Electrochim Acta 2007;53(1):186-92. doi: 10.1016/j.electacta.2007.02.073

216. Mohammed Fayaz A, Girilal M, Rahman M, Venkatesan R, Kalaichelvan PT. Biosynthesis of silver and gold nanoparticles using thermophilic bacterium Geobacillus steaothermophilus. Process Biochem 2011;46(10):1958-62. doi: 10.1016/j.procbio.2011.07.003

217. Du L, Jiang H, Liu X, Wang E. Biosynthesis of gold nanoparticles assisted by Escherichia coli DH5α and its application on direct electrochemistry of hemoglobin. Electrochim commun 2007;9(5):1165-70. doi: 10.1016/j.elecom.2007.01.007

218. Sharma N, Pinnaka AK, Raje M, Fnu A, Bhattacharyya MS. Choudhury AR. Exploitation of marine bacteria for production of gold nanoparticles. Microb Cell Fact 2012;11:86. doi: 10.1186/1475-2859-11-86

219. Nangia Y, Wangoo N, Goyal N, Shekhawat G, Suri CR. A novel bacterial isolate Stenotrophomonas maltophilia as living factory for synthesis of gold nanoparticles. Microb Cell Fact 2009;8:39. doi: 10.1186/1475-2859-8-39

220. He S, Guo Z, Zhang Y, Zhang S, Wang J, Gu N. Biosynthesis of gold nanoparticles using the bacteria Rhodopseudomonas capsulata. Mater Lett 2007;61(18):3984-7. doi: 10.1016/j.matlet.2007.01.018

221. Arunkumar P, Thanalakshmi M, Kumar P, Premkumar K. Micrococcus luteus mediated dual mode synthesis of gold nanoparticles: involvement of extracellular α-amylase and...
cell wall teichuronic acid. Colloids Surf B Biointerfaces 2013;103:517-22. doi: 10.1016/j.colsurfb.2012.10.051

222. Agnihotri M, Joshi S, Kumar AR, Zinjade S, Kulkarni S. Biosynthesis of gold nanoparticles by the tropical marine yeast Yarrowia lipolytica NCIM 3589. Mater Lett 2009;63(15):1231-4. doi: 10.1016/j.matlet.2009.02.042

223. Inbakandan D, Venkatesan R, Ajmal Khan S. Biosynthesis of gold nanoparticles utilizing marine sponge Acanthella elongata (Dendy, 1905). Colloids Surf B Biointerfaces 2010;81(2):634-9. doi: 10.1016/j.colsurfb.2010.08.016

224. Arockiya Aarthi Rajathi F, Parthiban C, Ganesh Kumar V, Anantharaman P. Biosynthesis of antibacterial gold nanoparticles using brown alga, Stoechospermum marginatum (kützing). Spectrochim Acta A Mol Biomol Spectrosc 2012;99:166-73. doi: 10.1016/j.saa.2012.08.081

225. Singaravelu G, Arockiamary JS, Kumar VG, Govindaraju K. A novel extracellular synthesis of monodisperse gold nanoparticles using marine alga, Sargassum wightii Greville. Colloids Surf B Biointerfaces 2007;57(1):97-101. doi: 10.1016/j.colsurfb.2007.01.010

226. Balagurunathan R, Radhakrishnan M, Rajendran RB, Velmurugan D. Biosynthesis of gold nanoparticles by actinomycete Streptomyces viridogenus strain HM10. Indian J Biochem Biophys 2011;48(5):331-5.

227. Chauhan A, Zubair S, Tufail S, Sherwani A, Sajid M, Raman SC, et al. Fungus-mediated biological synthesis of gold nanoparticles: potential in detection of liver cancer. Int J Nanomedicine 2011;6:2305-19. doi: 10.2147/ijn.s23195

228. Swaminathan S, Murugesan S, DamodarKumar S, Dhamotharan R, Bhuvaneshwari SJ. Synthesis and characterization of gold nanoparticles from alga Acanthophora specifera (VAHL) boergesen. Int J Nanosci Nanotechnol 2011:2:85-94.

229. Oza G, Pandey S, Mewada A, Kalita G, Sharon M. Facile biosynthesis of gold nanoparticles exploiting optimum pH and temperature of fresh water algae Chlorella pyrenoidusa. Adv Appl Sci Res 2012(3):1405-12.

230. Rajasulochana P, Dhamotharan R, Murugakothon P, Murugesan S, Krishnamoorthy P. Biosynthesis and characterization of gold nanoparticles using the alga Kappaphycus alvarezii. Int J Nanosci 2010:9(05):511-6. doi: 10.1142/s0219581x10007149

231. Senapati S, Syed A, Moez S, Kumar A, Ahmad A. Intracellular synthesis of gold nanoparticles using algae Tetraselmis cohnensis. Mater Lett 2012;79:116-8. doi: 10.1016/j.matlet.2012.04.009

232. Stalin Dhas T, Ganesh Kumar V, Stanley Abraham L, Karthick V, Govindaraju K. Sargassum myriocystum mediated biosynthesis of gold nanoparticles. Spectrochim Acta A Mol Biomol Spectrosc 2012;99:97-101. doi: 10.1016/j.saa.2012.09.024

233. Ghodake G, Lee DS. Optoelectronics. Biological synthesis of gold nanoparticles using the aqueous extract of the brown algae Laminaria japonica. J NanoElectron Optoelectron 2011;6(3):268-71. doi: 10.1166/jno.2011.1166

234. Shah M, Badwaik V, Kherde Y, Waghwani HK, Modi T, Aguilar ZP, et al. Gold nanoparticles: various methods of synthesis and antibacterial applications. Front Biosci (Landmark Ed) 2014;19:1320-44. doi: 10.2741/4284

235. Das R, Nath SS, Bhattacharjee R. Preparation of linoleic acid capped gold nanoparticles and their spectra. Physica E Low Dimens Syst Nanostruct 2010:43(1):224-7. doi: 10.1016/j.physe.2010.07.008

236. Narayanan KB, Salkhivell N. Facile green synthesis of gold nanostructures by NADPH-dependent enzyme from the extract of Sclerotium rorbusii. Colloids Surf A Physicochem Eng Asp 2011;380(1-3):156-61. doi: 10.1016/j.colsurfa.2011.02.042

237. Morrow BJ, Matijević E, Goia DV. Preparation and stabilization of monodisperse colloidal gold by reduction with aminodextran. J Colloid Interface Sci 2009;335(1):62-9. doi: 10.1016/j.jcis.2009.02.053

238. Du Y, Luo XL, Xu JJ, Chen HY. A simple method to fabricate a chitosan-gold nanoparticles film and its application in glucose biosensor. Bioelectrochemistry 2007;70(2):342-7. doi: 10.1016/j.bioelechem.2006.05.002

239. Katti KK, Kattumuri V, Bhaskaran S, Katti KV, Kannan R. Facile and general method for synthesis of sugar coated gold nanoparticles. Int J Green Nanotechnol Biomed 2009;1(1):B53-b9. doi: 10.1080/19430850902983848

240. Badwaik VD, Vangala LM, Pender DS, Willis CB, Aguilar ZP, Gonzalez MS, et al. Size-dependent antimicrobial properties of sugar-encapsulated gold nanoparticles synthesized by a green method. Nanasce Res Lett 2012;7(1):623. doi: 10.1186/1556-276x-7-623

241. Engelbrekt C, Sorensen KH, Zhang J, Welinder AC, Jensen JS, Ulstrup J. Green synthesis of gold nanoparticles with starch–glucose and application in bioelectrochemistry. J Mater Chem 2009;19(42):7839-47. doi: 10.1039/b911111e

242. Basu N, Bhattacharya R, Mukherjee P. Protein-mediated autocatalysis of gol salts to gold nanoparticles. Biomed Mater 2008;3(3):034105. doi: 10.1088/1748-6041/3/3/034105

243. Ravindra P. Protein-mediated synthesis of gold nanoparticles. Mater Sci Eng B 2009;163(2):93-8. doi: 10.1016/j.mseb.2009.05.013

244. Yuan H, Khoury CG, Hwang H, Wilson CM, Grant GA, Vo-Dinh T. Gold nanostars: surfactant-free synthesis, 3D modelling, and two-photon photoluminescence imaging. Nanotechnology 2012;23(7):075102. doi: 10.1088/0957-4484/23/7/075102

245. Kemp MM, Kumar A, Mousa S, Park TJ, Ajayan P, Kuboteca N, et al. Synthesis of gold and silver nanoparticles stabilized with glycosaminoglycans having distinctive biological activities. Biomacromolecules 2009;10(3):589-95. doi: 10.1021/bm801266t

246. Venkatpurwar VP, Pokharkar VB. Biosynthesis of gold nanoparticles using therapeutic enzyme: in-vitro and in-vivo efficacy study. J Biomed Nanotechnol 2010(6)(6):667-74. doi: 10.1166/jbn.2010.1163

247. Sohn JS, Kwon YW, Jin JJ, Jo BW. DNA-templated preparation of gold nanoparticles. Molecules 2011;16(10):8143-51. doi: 10.3390/molecules16108143

248. Shao Y, Jin Y, Dong S. Synthesis of gold nanoplates by aspartate reduction of gold chloride. Chem Commun (Camb) 2004(9):1104-5. doi: 10.1039/b315732f

249. He P, Urban MW. Phospholipid-stabilized Au-nanoparticles. Biomacromolecules 2005;6(3):1224-5. doi: 10.1021/bm0501961

250. Armendariz V, Herrera I, Peralta-Videa JR, Jose-Yacaman M, Troiani H, Santiago P, et al. Size controlled gold nanoparticles. J Mater Chem 2004(9):1104-5. doi: 10.1039/b315732f

251. Khan M, Khan M, Adil SF, Tahir MN, Tremel W, Alkhathlan HZ, et al. Green synthesis of silver nanoparticles mediated by Pulsicaria glutinosa extract. Int J Nanomedicine 2013;8:1507-16. doi: 10.2147/ijn.s43309
Green synthesis of gold nanoparticles for tuberculosis

252. Raveendran P, Fu J, Wallen SL. Completely “green” synthesis and stabilization of metal nanoparticles. J Am Chem Soc 2003;125(46):13940-1. doi: 10.1021/ja0329267

253. Selvakannan P, Mandal S, Phadtare S, Gole A, Pasricha R, Adyanthaya SD, et al. Water-dispersible tropylium-protected gold nanoparticles prepared by the spontaneous reduction of aqueous chloroaurate ions by the amino acid. J Colloid Interface Sci 2004;269(1):97-102. doi: 10.1016/j.jcis.2004.06.016

254. Willett RL, Baldwin KW, West KW, Pfeiffer LN. Differential adhesion of amino acids to inorganic surfaces. Proc Natl Acad Sci U S A 2005;102(22):7817-22. doi: 10.1073/pnas.0504856102

255. Gan PP, Li SFP. Potential of plant as a biological factory to synthesize gold and silver nanoparticles and their applications. Reviews in Environmental Science and Biotechnology 2012;11(2):169-206. doi: 10.1007/s11157-012-9278-7

256. Asgari F, Majd A, Jonoubi P, Najafi F. Effects of silicon nanoparticles on molecular, chemical, structural and ultrastructural characteristics of oat (Avena sativa L.). Plant Physiol Biochem 2018;127:152-60. doi: 10.1016/j.phyto.2018.03.021

257. Sathishkumar M, Sneh K, Won SW, Cho CW, Kim S, Yun YS. Cinnamon zeylanicum bark extract and powder mediated green synthesis of nano-crystalline silver particles and its bactericidal activity. Colloids Surf B Biointerfaces 2009;73(2):332-8. doi: 10.1016/j.colsurfb.2009.06.005

258. Bankar A, Joshi B, Kumar AR, Zinarde S. Banana peel extract mediated synthesis of gold nanoparticles. Colloids Surf B Biointerfaces 2010;80(1):45-50. doi: 10.1016/j.colsurfb.2010.05.029

259. Patra JK, Baek KH. Green nanobiotechnology: factors affecting synthesis and characterization techniques. J Nanomater 2014;2014:417305. doi:10.1155/2014/417305

260. Vijayaraghavan K, Ashokkumar T. Plant-mediated biosynthesis of metallic nanoparticles: a review of literature, factors affecting synthesis, characterization techniques and applications. J Environ Chem Eng 2017;5(5):4866-83. doi: 10.1016/j.jece.2017.09.026

261. Lukman AI, Gong B, Marjo CE, Roessner U, Harris AT. Facile synthesis, stabilization, and anti-bacterial performance of discrete Ag nanoparticles using Medicago sativa seed exudates. J Colloid Interface Sci 2011;353(2):433-44. doi: 10.1016/j.jcis.2010.09.088

262. Guo JZ, Cui H, Zhou W, Wang W. Ag nanoparticle-catalyzed chemiluminescent reaction between luminol and hydrogen peroxide. J Photochem Photobiol A Chem 2008;193(2-3):89-96. doi: 10.1016/j.jphotochem.2007.04.034

263. Wu W, Huang J, Wu L, Sun D, Lin L, Zhou Y, et al. Two-step size- and shape-separation of biosynthesized gold nanoparticles. Sep Purif Technol 2013;106:117-22. doi: 10.1016/j.seppur.2013.01.005

264. Haverkamp RG, Marshall AT. The mechanism of metal nanoparticle formation in plants: limits on accumulation. J Nanopart Res 2009;11(6):1453-63. doi: 10.1007/s11051-008-9533-6

265. Zhang Y, Shareena Dasari TP, Deng H, Yu H. Antimicrobial activity of gold nanoparticles and ionic gold. J Environ Sci Health C Envir Carcinog Ecotoxicol Rev 2015;33(3):286-327. doi: 10.1080/10590501.2015.1055161

266. Xu JW, Yao K, Xu ZK. Nanomaterials with a photothermal effect for antibacterial activities: an overview. Nanoscale 2019;11(18):8680-91. doi: 10.1039/c9nr01833f

267. Shamaila S, Zafar N, Riaz S, Sharif R, Nazir J, Naseem S. Gold nanoparticles: an efficient antimicrobial agent against enteric bacterial human pathogen. Nanomaterials (Basel) 2016;6(4). doi: 10.3390/nano6040071

268. Zhou Y, Kong Y, Kundu S, Cirillo JD, Liang H. Antibacterial activities of gold and silver nanoparticles against Escherichia coli and bacillus Calmette-Guérin. J Nanobiotechnology 2012;10:19. doi: 10.1186/1477-3155-10-19

269. Brewster M, Zhang T, Dong W, Rutherford M, Tian ZR. Future approaches of nanomedicine in clinical science. Med Clin North Am 2007;91(5):963-1016. doi: 10.1016/j.mcna.2007.05.006

270. Mishra A, Mehdi SJ, Irshad M, Ali A, Sardar M, Moshahid M, et al. Effect of biologically synthesized silver nanoparticles on human cancer cells. Sci Adv Mater 2012;4(12):1200-6. doi: 10.1166/sam.2012.1414

271. Zhang JW, Monteiro-Riviere NA. Use of confocal microscopy for nanoparticle drug delivery through skin. J Biomed Opt 2013;18(6):061214. doi: 10.1117/1.4818124

272. Umamaheswari K, Baskar R, Chandra K, Rajendiran N, Chandrasekar S. Antibacterial activity of gold nanoparticles and their toxicity assessment. BMC Infect Dis 2014;14(Suppl 3):P64. doi: 10.1186/1471-2334-14-S3-P64

273. Tomar A, Garg G. Short review on application of gold nanoparticles. Glob J Pharmaco 2013;7(1):34-8. doi: 10.5829/idosi.gjp.2013.7.1.66173

274. Cai W, Gao T, Hong H, Sun J. Applications of gold nanoparticles in cancer nanotechnology. Nanotechnol Sci Appl 2008;1:17-32. doi: 10.2147/nsa.s3788

275. Gupta A, Pandey S, Vargiya B, Shah S, Yadav JS. Green synthesis of gold nanoparticles using different leaf extracts of Ocimum gratissimium Linn for anti-tubercular activity. Current Nanomedicine 2019;9(2):146-57. doi: 10.2174/2468

276. Chahardoli A, Karimi N, Sadeghi F, Fatollahi A. Green approach for synthesis of gold nanoparticles from Nigella arvensis leaf extract and evaluation of their antibacterial, antioxidant, cytotoxicity and catalytic activities. Artif Cells Nanomed Biotechnol 2018;46(3):579–88. doi: 10.1080/21691401.2017.1332634

277. Chen MN, Chan CF, Huang SL, Lin YS. Green biosynthesis of gold nanoparticles using Chenopodium formosanum shell extract and analysis of the particles' antibacterial properties. J Sci Food Agric 2019;99(7):3693-702. doi: 10.1002/jsfa.9600

278. Sunderam V, Thiyagarajan D, Lawrence AV, Mohammed SSS, Selvaraj A. In-vitro antimicrobial and anticancer properties of green synthesized gold nanoparticles using Anacardium occidentale leaves extract. Saudi J Biol Sci 2019;26(3):455-9. doi: 10.1016/j.sjbs.2018.12.001

279. Katas H, Lim CS, Nor Azlan AYH, Buang F, Moh Busra MF. Antibacterial activity of biosynthesized gold nanoparticles using biomolecules from Lignosus rhinocerotis and chitosan. Saudi Pharm J 2019;27(2):283-92. doi: 10.1016/j.jsps.2018.11.010

280. Veena S, Devasena T, Sathak SSM, Yasasve M, Vishal LA. Green synthesis of gold nanoparticles from Vitex negundo leaf extract: characterization and in vitro evaluation of antioxidant–antibacterial activity. J Clust Sci 2019;30(6):1591-7. doi: 10.1007/s10876-019-01601