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A Synoptic Review on Gold Nanoparticles: Green Synthesis and Antibacterial Application

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ABSTRACT: The synthesis of nanoscale materials, especially metallic nanoparticles, has accrued utmost interest over the past decade owing to their unique properties that make the mapplicable in different fields of science and technology. The limitation to the use of these nanoparticles is the paucity of an effective method of synthesis that will produce homogeneous size and shape nanoparticles as well as particles with limited or no toxicity to the human health and the environment. The biological method of nanoparticle synthesis is a relatively simple, cheap and environmentally friendly method than the conventional chemical method of synthesis and thus gains an upper hand. Functionalized metal nanoparticles are of great interest in terms of their potential applications in biomedical applications. Although many reports have been published about the biogenesis of gold nanoparticles using several plant extracts, the capacity of a large number of such extracts to form gold nanoparticles has yet to be elucidated.

Key words: Nanoscale materials, biological method of nanoparticle, plant extracts,

I. INTRODUCTION

Nanotechnology is the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new or vastly different properties. The definition of nanotechnology is based on the prefix “nano” which is from the Greek word meaning “dwarf”. In more technical terms, the word “nano” means 10-9, or one billionth of something. The word nanotechnology is generally used when referring to materials with the size of 0.1 to 100 nanometers; however it is also inherent that these materials should display different properties from bulk materials as a result of their size. These differences include physical strength, chemical reactivity, electrical conductance, magnetism, and optical effects.

Bio-Nanotechnology is a branch of nanotechnology, which correlates the biological principles along-with physical and chemical approaches for production of nanoparticles. Novel Metal nanoparticles having a high definite surface area and a high fraction of surface atom; have been studied extensively because of their exceptional physicochemical characteristics including catalytic, optical properties, electron properties etc. Silver, Aluminum, Gold, Zinc, Carbon, Titanium, Palladium, Iron, Copper etc have been usually used for the synthesis of their nanoparticles [1].

Nanoscience will be leave no field untouched and its ground breaking technical innovations; the agricultural sector is no exception. Metallic nanoparticles show sharp prejudice from their bulk in many respects which becomes bonus for developing diagnostic tools and antimicrobials. There are Certain nanocrystals which are attractive probes of biological markers because of small size (1-100nm), large surface to volume ratio, chemically alterable physical properties, change in the chemical and physical properties with respect to size and shape, strong affinity to target particularly proteins, structural sturdiness in spite of atomic granularity, enhanced or delayed particles aggregation depending on the type of the surface modification, enhanced photoemission, high electrical and heat conductivity and improved surface catalytic activity [2,3,4,5].

By the above said applications of nanoparticles it is important to emphasis on their synthesis. Synthesis of metallic nanoparticles can be achieved by different methods i.e. physical, chemical and biological. Biological method of synthesis can be divided into intracellular and extracellular with three main steps, which must be evaluated based on green chemistry perspectives, including selection of solvent medium, selection of environmentally benign reducing agent, and selection of nontoxic substance for the NPs stability [6].

II. SYNTHESIS OF GOLD NANOPARTICLES

The production of nanoparticles majorly involves physical and chemical processes. Metallic nanomaterials can be obtained by both the so-called 'top-down' (reducing the size of the smallest structures to the nanoscale) and 'bottom-up' (manipulating individual atoms and molecules into nanostructures and more closely resembles chemistry or biology). The top-down method involves the mechanical grinding of bulk metals and subsequent stabilization of the resulting nanosized metal particles by the addition of colloidal protecting agents [7, 8]. The bottom-up methods, on the other hand, include reduction of metals, electrochemical methods, and sono-decomposition. The simplest method involves the chemical method of reduction of the metal salt $HAuCl_4$ in water [9].

III. PLANTS EXTRACTS MEDIATED GREEN SYNTHESIS OF GOLD NANOPARTICLES

The problem with most of the chemical and physical methods of gold nanoparticles production is that they are extremely expensive and also involve the use of toxic, hazardous chemicals, which may pose potential environmental and biological risks and also absorbed on the surface and can hinder their usage in medical applications [10, 11]. It is an unavoidable fact that the gold nanoparticles synthesized in these ways have to be handled by humans and must be available at cheaper rates for their medical purposes; thus, there is a need for an environmentally and economically feasible way to synthesize these nanoparticles. The need for such a method has led to the need for biomimetic production of gold nanoparticles whereby biological methods are used to synthesize these nanoparticles. The growing need to develop environmentally friendly and economically feasible technologies for material synthesis led to the search for biological methods of synthesis. There are three major sources of synthesizing gold nanoparticles: bacteria, fungi, and plant extracts. Biosynthesis of gold nanoparticles is a bottom-up approach that mostly involves reduction/oxidation reactions.

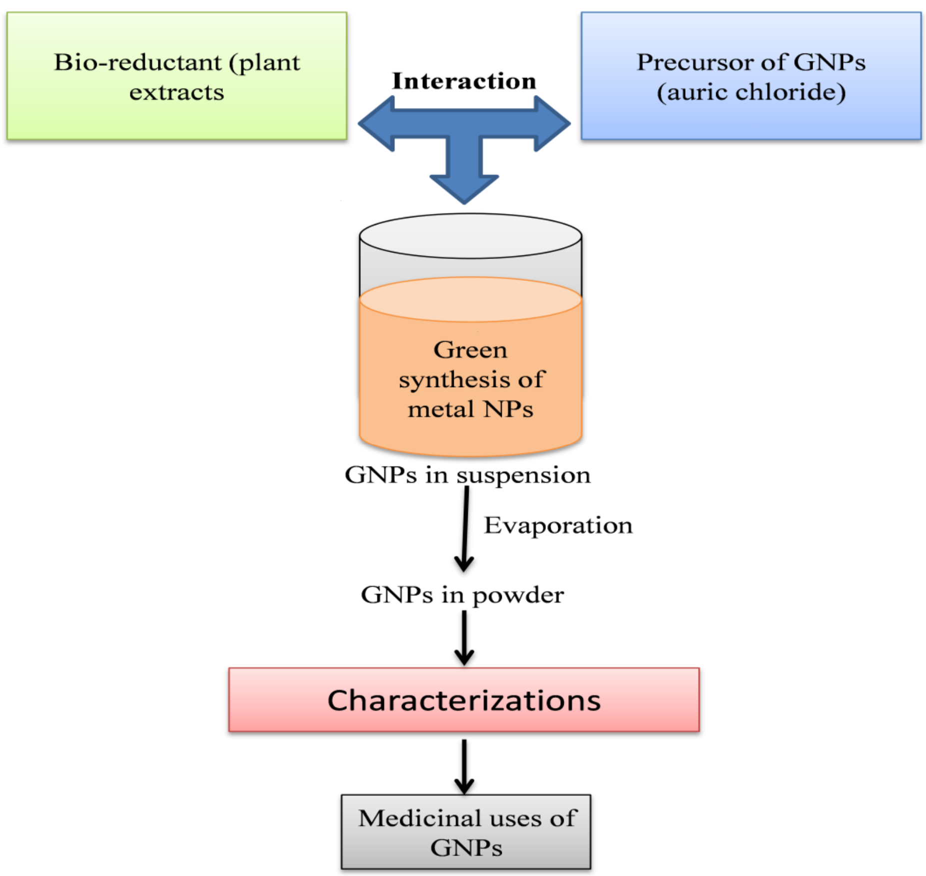

Fig. 1. Schematic representation of green synthesis of GNPs.

It is mostly the green plant enzymes or the phytochemicals with antioxidant or reducing properties that act on the respective compounds and give the desired nanoparticles. This method is major components involved in the preparation of nanoparticles using biological methods for synthesis, which utilizes the environmentally friendly reducing agent as well as a nontoxic stabilizing agent. The major advantage of using plant extracts for gold nanoparticles synthesis is that they are easily available, safe, and nontoxic in most cases, have a broad variety of metabolites that can aid in the reduction of silver ions, and are quicker than microbes in the synthesis [13]. The main mechanism considered for the process is plant-assisted reduction due to phytochemicals. The main phytochemicals involved are terpenoids, flavones, ketones, aldehydes, amides, and carboxylic acids [14, 15].

Flavones, organic acids, and quinones are water-soluble phytochemicals that are responsible for the immediate reduction of the metal ions. In the case of mesophytes, it was found that they contain three types of benzoquinones namely cyperoquinone, dietchequinone, and remirin. It was suggested that the phytochemicals are involved directly in the reduction of the ions and formation of metal nanoparticles [16]. Though the exact mechanism involved in each plant varies as the phytochemical involved varies, the major mechanism involved is the reduction of the ions (Fig. 1).

The therapeutically gold are being used since the 2500 BC in Chinese medical history. Red colloidal gold is still used in the Indian Ayurvedic medicine for rejuvenation and revitalization during old age under the name of Swarna Bhasma ("Swarna" meaning gold, "Bhasma" meaning ash) [32].

Table 1: Green synthesis of Gold Nanoparticles using different plants.

Plant	Family	Plant part	Precurssor	Shape & size	References
Triticum aestivum	Poaceae	Leaves	Auric Chloride	Tetrahedral, hexagonal platelets, irregular shaped	[17]
Medicago sativa	Fabaceae	Leaves	Auric Chloride	Twinned, crystal and icosahedral 4–10 nm	[18]
Pelargonium graveolens	Geraniaceae	Leaves	Auric Chloride	Spherical rods, flat, sheets and triangular 21–70 nm	[19]
Avena sativa	Poaceae	Leaves	Auric Chloride	Multiple twinned, irregular shaped, rod shaped	[20]
Cymbopogon flexuosus	Poaceae	Leaves	Auric Chloride	Triangular, hexagonal	[21]
Tamarindus indica	Family	Leaves	Auric Chloride	Triangular	[22]
Cicer arietinum	Fabaceae	Leaves	Auric Chloride	Triangular	[23]
Medicago sativa	Fabaceae	Leaves	Auric Chloride	Tetrahedral, hexagonal platelets, decahedral multiple twined and irregular shaped- 15–200 nm	[24]
Aloe vera	Xanthorrhoeaceae	Leaves	Auric Chloride	spherical	[25]
Sesbania	Fabaceae	Leaves	Auric Chloride	Spherical, 6–20 nm	[26]
Cinnamommum camphora	Lauraceae	*Leaves*	Auric Chloride	Triangular, spherical 55–80 nm	[27]
Brassica juncea	Brassicaceae	*Leaves*	Auric Chloride		[28]
Eucalyptus camaldulensis	Myrtaceae	*Leaves*	Auric Chloride	6–20 nm	[29]
Allium cepa	Liliaceae	bulb	Auric Chloride	100 nm, with spherical and cubic shape	[30]
Memecylon umbellatum	Melastomataceae	Leaves	Auric Chloride		[31]

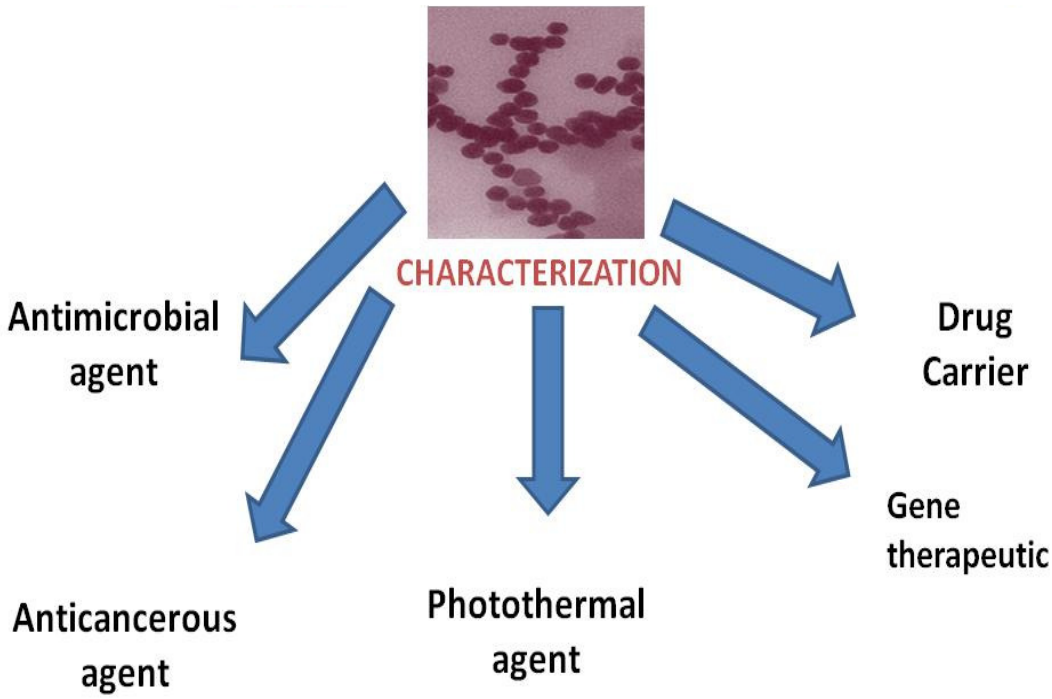

Fig. 2. Various applications of Gold Nanoparticles.

Gold also has a long history of use in the western world as nervine, a substance that could revitalize people suffering from nervous conditions. In the 16th century gold was recommended for the treatment of epilepsy. In the beginning of the 19th century gold was used in the treatment of syphilis. Following the discovery of the bacteriostatic effect of gold cyanide towards the tubercle bacillus by Robert Koch, gold based therapy for tuberculosis was introduced in 1920s [33]. The major clinical uses of gold compounds are in the treatment of rheumatic diseases including psoriasis, juvenile arthritis, planindromic rheutamitism and discoid lupus erythematosus [34]. There are various therapeutic applications of Gold Nanoparticles such as photothermal agent, antimicrobial agent, anti-cancerous agent, gene therapeutic agent, as drug carrier etc. (Fig. 2)., but antimicrobial application of GNPs explored in this review.

IV. ANTIMICROBIACTERIAL APPLICATION OF GNPs

The antimicrobial potential of GNPs is attributed to the unique surface chemistry, smaller size, polyvalent and photothermic nature, which makes them easier to adhere with the cell wall. Gold NPs exert their antibacterial activities mainly by two ways: one is to collapse membrane potential, inhibiting ATPase activities to decrease the ATP level; the other is to inhibit the subunit of ribosome from binding tRNA. Au NPs primarily react with sulfur or phosphorus-holding bases, which are the most ideal spots for GNPs attack. On the attachment of GNPs to thiol functional groups of enzymes [nicotinamide adenine dinucleotide (NADH) dehydrogenases], they interpose the respiratory chains by generation of high amount of free radicals, leading to cell death.

GNP may also inhibit the binding of tRNA to ribosomal subunit. While a study has reported on killing *Leishmania*, an higher number of electrons are produced by GNPs which yield ROS (O^{-2} and $^{\bullet}OH$) [35]. The cause for cellular death induced by most bactericidal antibiotics and nanomaterials [36]. These radicals terminate DNA and other cellular components of the pathogen. Another probable mechanism is that these GNPs hinder the transmembrane H^{+} efflux [37]. From the results of Kumar *et al.,* 2016, it is evident that that chemically synthesized and stabilized gold nanocolloids could be also applied as a potent agent against water borne bacterial pathogens bacterial strain or they can be utilized in the development of some water purifier system [38].

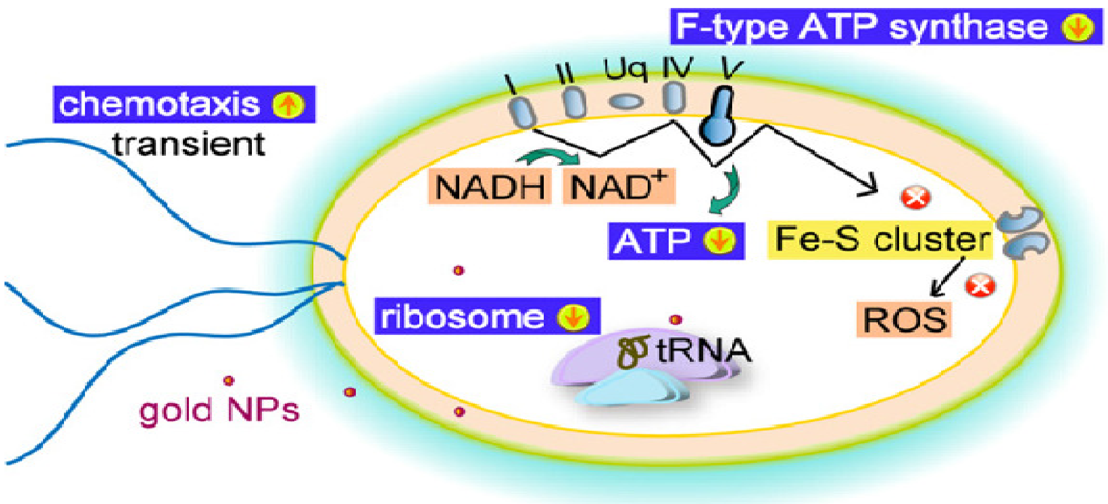

Fig. 3. Schematic diagram of mechanism of action of bactericidal gold nanoparticles on bacterial cell source [39].

V. CONCLUSION

Gold has always been used for the number of purposes from ages. The unique physical and chemical properties of gold nanoparticles increase the propababilty of medical application of Gold. Chemical and physical methods of gold nanoparticles synthesis were being followed over the decades, but they are found to be expensive and the use of various toxic chemicals for their synthesis makes the biological synthesis the more preferred option. The plant extract source can be used for nanogold synthesis as it is advantageous over chemical process in being nontoxic, eco-friendly, and safe process. Therefore, these potential properties of green synthesized gold nanoparticles can open new horizons in future due to their inherent elemental properties may be suitable for the formulation of new types of bactericidal materials equivalent to the antibiotics against microbial infections. But detail investigation is needed to explore the mechanisms of antimicrobial activity, so that it can revolutionize the era of medicinal treatment.

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REFERENCES

[1]. Joseph, T. and Morrison, M. (2006). *Nanotechnology in Agriculture and Food. Europian Nanotechnology Gateways.*

[2]. Liu, W.T. (2006). Nanoparticles and their biological and environmental applications *J Biosci Bioeng,* **102**(1): 1–7, 2006.

[3]. Garg, J., Poudel, B. and Chiesa, M. (2008). Enhanced thermal conductivity and viscosity of copper nanoparticles in ethylene glycol nanofluid. *J Appl Phys,* **103**: 074301.

[4]. McNeil, SE. (2005). Nanotechnology for the Biologist. *J Leukoc Biol*, **78**: 585–94.

[5]. Kumar, R., Shukla, S. K., Pandey, A., Srivastava, S. K., & Dikshit, A. (2015). Copper oxide nanoparticles: An antidermatophytic agent for *Trichophyton* spp. *Nanotechnology Reviews,* **4**, 401–409.

[6]. Ahmad, A., Senapati, S., Khan, M.I., Kumar, R. and Sastry, M. (2005). "Extra-intracellular, biosynthesis of gold nanoparticles by an alkalotolerant fungus, *Trichothecium.*" *J. Biomed. Nanotechnol.*, **1**: 47-53.

[7]. Gaffet, E, Tachikart, M, El Kedim, O, Rahouadj, R. (1996). Nanostructural materials formation by mechanical alloying: morphologic analysis based on transmission and scanning electron microscopic observations. *Mater. Charact*, **36**, 185-190.

[8]. Amulyavichus, A, Daugvila, A, Davidonis, R, Sipavichus, C (1998). Study of chemical composition of nanostructural materials prepared by laser cutting of metals. *Fizika Met. Met.* **85**, 111–117.

[9]. Zhou Min , Baoxiang Wang, Zbigniew Rozynek, Zhaohui Xie, Jon Otto Fossum, Xiaofeng Yu and Steinar Raaen (2009). Minute synthesis of extremely stable gold nanoparticles. *Nanotechnology,* **20**.

[10]. Kalishwaralal, K, Deepak, V, Ramkumarpandian, S, Nellaiah, H, Sangiliyandi, G (2008). Extracellular biosynthesis of silver nanoparticles by the culture supernatant of *Bacillus licheniformis*. *Mater. Lett.* **62**, 4411–4413.

[11]. Parashar, UK, Saxena, SP, Srivastava, A (2009). Bioinspired synthesis of silver nanoparticles. *Dig. J. Nanomat. Biostruct.* **4**, 159–166.

[12]. Umesh Kumar Parida, Birendra Kumar Bindhani, Padmalochan Nayak (2011). Nanoparticles Using Onion (*Allium cepa*) Extract. *World Journal of Nano Science and Engineering*, **1**, 93-98.

[13]. Elavazhagan, T and Arunachalam KD, (2011). "Memecylon elude leaf extract mediated synthesis of silver and gold nanoparticles" *Int. J Nanomedicine*, **21**(6): 1265-78.

[14]. Qidwai A, Pandey M, Kumar R, Dikshit A. (2017). Comprehensive evaluation of pharmacological properties of *Olea europaea* L. for Cosmeceuticals prospects. Clinical Phytoscience: *International Journal of Phytomedicine and Phytotherapy*. **3**: 12.

[15]. Qidwai A, Pandey M, Shukla SK, Kumar R, Pandey A, Dikshit A. (2016). Antibacterial activity of *Mentha piperita* and *Citrus limetta* against *Propionibacterium acnes* (anaerobic bacteria). *International Journal of Pharmaceutical Sciences and Research*. **7**: 2917.

[16]. Jha, AK, Prasad, K, Prasad, K, Kulkarni, AR, (2009). Plant system: nature's nanofactory. *Colloids Surf. B Biointerfaces*, **73**, 219–223.

[17]. Gardea-Torresdey, J.L., Tiemann, K.J., Gamez, G., Dokken, K., Tehuacanero, S. and Jos´e-Yacam´an, M. (1999). Gold nanoparticles obtained by bio precipitation from gold (III) solutions. *J Nanopart Res* **1**: 397–404.

[18]. Gardea-Torresdey, J.L., Parsons, J.G., Gomez, E., Peralta-Videa, J., Troiani, H.E. and Santiago, P. (2002). Formation and growth of Aunanoparticles inside live alfalfa plants. *Am Chem Soc.,* **2**: 397–401.

[19]. Armendariz, V., Gardea-Torresdey, J.L., Jose-Yacaman, M., Gonzalez, J., Herrera, I. and Parsons, J.G. (2002). Gold nanoparticles formation by oat and wheat biomasses, in *Proceedings –Waste Research Technology* Conference at the Kansas City, Mariott-Country Club Plaza.

[20]. Armendariz, V., Herrera, I., Peralta-Videa, J., Jose-Yacaman, M., Troiani, H. and Santiago, P. (2004). Size controlled gold nanoparticle formation by *Avena sativa* biomass: use of plants in nanobiotechnology. *J Nanopart Res.,* **6**: 377–382.

[21]. Shankar, S.S., Rai, A., Ahmad, A. and Sastry, M. (2005). Controlling the optical properties of lemongrass extract synthesized gold nanotriangles and potential application in infrared-absorbing optical coatings. *Chem Mater.,* **17**: 566–572.

[22]. Ankamwar, B., Chaudhary, M. and Sastry, M. (2005a). Gold nanotriangles biologically synthesized using tamarind leaf extract and potential application in vapor sensing. *Synth React Inorg Metal-Org Nano- Metal Chem.,* **35**: 19–26.

[23]. Ghule, K., Ghule, A.V., Liu, J.Y. and Ling, Y.C. (2006). Microscale size triangular gold prisms synthesized using Bengal gram beans (*Cicer arietinum* L.) extract and $HAuCl_4 \times 3H_2O$: a green biogenic approach. *J Nanosci Nanotechnol,* **6**: 3746–3751.

[24]. Singh, A., Chaudhary, M. and Sastry, M. (2006). Construction of conductive multilayer films of biogenic triangular gold nanoparticles and their application in chemical vapour sensing. *Nanotechnology,* **17**: 2399–2405.

[25]. Chandran, P.S., Chaudhary, M., Pasricha, R., Ahmad, A. and Sastry, M. (2006). Synthesis of gold nanotriangles and silver nanoparticles using *Aloe vera* plant extract, *Biotechnology Prog.*, **22**: 577-583.

[26]. Sharma, N.C., Sahi, S.V., Nath, S., Parsons, J.G., Gardea-Torresdey, J.L. and Pal, T. (2007). Synthesis of plant-mediated gold nanoparticles andcatalytic role of biomatrix-embedded nanomaterials. *Environ Sci Technol.,* **41**: 5137–5142.

[27]. Huang, J., Li, Q., Sun, D., Lu, Y., Su, Y., Yang, X., Wang, H., Wang, Y., Shao, W., He, N., Hong, J. and Chen, C. (2007). Biosynthesis of silver and gold nanoparticles by novel sundried *Cinnamomum camphora* leaf. *Nanotechnology*, **18**: 105104-105114.

[28]. Haverkamp, R.G., Marshall, A.T. and Van Agterveld, D. (2007). Pick your carats: nanoparticles of gold–silver–copper alloy produced *in-vivo*. *J Nanopart Res.,* **9**: 697–700.

[29]. Haratifar, E., Shahverdi, H.R., Shakibaie, M., Moghaddam, K.M., Amini, M. Montazeri, H. and Shahv, A.R. (2009). Semi-Biosynthesis of Magnetite-Gold Composite Nanoparticles Using an Ethanol Extract of *Eucalyptus camaldulensis* and Study of the Surface Chemistry. *Journal of Nanomaterials*, doi:10.1155/2009/962021.

[30]. Parida U. K., Bindhani B. K. and Nayak P., (2011). Green Synthesis and Characterization of Gold Nanoparticles Using Onion (*Allium cepa*) Extract. *World Journal of Nano Science and Engineering*, **1**, 93-98.

[31]. Mukherjee S., Vinothkumar B, Prashanthi S., Prakriti Ranjan Bangal, Sreedharb B. and Patra C. R., (2013). "Potential therapeutic and diagnostic applications of one-step in situ biosynthesized gold nanoconjugates (2-in-1 system) in cancer treatment3" *RSC Advances.* **3**, 2318–2329.

[32]. Higby GJ. (1982). Gold in medicine: a review of its use in the West before 1900. *Gold Bull.*, **15**: 130–140.

[33]. Shaw IC. Gold-based therapeutic agents. *Chem. Rev.* 1999; **99**: 2589–2600.

[34]. Felson DT, Anderson JJ, Meenan RF. (1990). The comparative efficacy and toxicity of second-line drugs in rheumatoid arthritis. Results of two meta analyses, *Arthritis. Rheum.*, **33**: 1449–1461.

[35]. Ahmad A, Syed F, Imran M, Khan AU, Tahir K, Khan ZUH, Yuan Q. (2015). Phytosynthesis and Antileishmanial Activity of Gold Nanoparticles by *Maytenus royleanus. J. Food Biochem*., **40**(4), 420–427.

[36]. Qidwai A, Pandey M, Pathak S, Kumar R, Dikshit A. (2017). The emerging principles for acne biogenesis: A dermatological problem of puberty. *Human Microbiome Journal.* **4** (2017) 7–13.

[37]. Nadeem M, Abbasi BH, Younas M, Ahmad W, Khan T. (2017). A review of the green synthesized and anti-microbial applications of gold nanoparticles. *Green chemistry letters and reviews*. 216-227.

[38]. Kumar R, Shukla SK, Pandey M, Pandey A, Pathak A and Dikshit A. (2016). Synthesis and antimicrobial effects of colloidal gold nanoparticles against prevalent waterborne bacterial pathogens. *Cogent Chemistry*, **2**: 1192522. http://dx.doi.org/10.1080/23312009.2016.1192522.

[39]. Cui Y., Zhao Y, Tian Y, Zhang W, Lü X, Jiang X (2012). "The molecular mechanism of action of bactericidal gold nanoparticles on *Escherichia coli*". *Biomaterials,* **33:** 2327-2333.