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A Review on Terpenoid Synthesized Nanoparticle and It's Antimicrobial Activity

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ABSTRACT

Terpenoids are a broad category of chemical compounds that include the isoprene unit. They are also known as isoprenoids and are mostly produced from isoprene units with 5 carbons. Terpenoids are mostly found in plants and are a key component of plant essential oils. They are also present in some bacteria and fungi. The various terpene varieties have a variety of medical applications, including the treatment of bacterial infections, wound healing, and malaria. XRD, FTIR, SEM, TEM and UV-Visible are the techniques that have been utilised in the characterisation of the nanoparticles. These techniques are also used to determine the size of the particles. Different antimicrobial antibacterial activities utilise those applications.

Keyword: Nanoparticle, Terpenoid, Bacteria, Antimicrobial activity, Phytochemical.

INTRODUCTION

Green chemistry involves designing of chemical processes and products in a way that minimises or completely prevents the production of harmful compounds[1]. An essential component of nanoscience and nanobiotechnology is the green manufacturing of metal nanoparticles[2]. Nanotechnology and nanoscience deal with materials of particles between 1 and 100 nm in size[3]. The characteristics of nanoparticles are primarily determined by their morphology, size, content, shape, and surface area[4].

Nanotechnology is defined as the method or technique that aimed at obtaining material with novel functionalities and improved characteristics[5]. Nanotechnology is an interdisciplinary area of science which deals with the multi-dimensional aspect of nanoparticles[6].

Moreover, nanotechnology is used in the biomedical, tissue engineering, nonlinear optical devices, gene delivery, and food industries[7]. From the application point of view, biosynthesis process for the synthesis of nanoparticles could be more useful if the nanoparticles would be formed extra-cellularly[8]. In the synthesis of nanoparticles, plant extract acts as both reducing as well as stabilizing agent. Thus, the source of the plant extract influence the characteristics of nanoparticles[9]. Plant extract are used in the bioreduction of metal ions to form

nanoparticles[10]. Synthesis of nanoparticles by biological method uses microorganisms, enzymes, plant and plant extract[11]. Nanoparticles have a lot of surface area and are exceedingly small, which makes them quite interesting[12]. Synthesis of nanoparticles can also be formed by several compounds such as carbonyls groups, terpenoids, phenolics, amines and other reducing agent present in the plant extract and microbial cells[13]. Nanoparticles can also be synthesized from leaf extract, fruit extract and seed extract of various plants[14]. The process of making nanoparticles by using plant extract is readily easy as it is less expensive than the microbial method which is relatively expensive[15].Numerous industries, including catalysis, molecular sensing, environmental clean-up, and medicine, uses metal and metal oxide nanoparticles[16]. The green synthesis of metal nanoparticles via a plant-based technique has drawn the attention of many researchers[17].

The uses of nanoparticles and nanomaterials are widespread, and as a result, they are employed in many different fields, including health sciences, optics, electronics, drug-gene delivery, and a variety of other fields[18]. Nanoparticles are the advance materials in the fields of technology and science and has various application in the fields of agriculture, medical, electronic, chemical, and pharmaceutical[19].

The natural bioactive compounds that are found in plants are called as phytochemicals[20]. Nanotechnology is the name given to the branch of science that deals with the manufacture, manipulation, and application of nanoscale materials[21]. There are many technologies available for the production of nanoparticles, including electrochemistry, reduction in solution, and lately green chemistry[22]. The majority of organisms, whether single or several cells, have the ability to synthesise nanoparticles either intra-or extracellularly[23]. Many physical and chemical processes are used to create nanoparticles; these processes requires high reaction temperatures, vacuum conditions, and chemical additives[24]. Nanoscience is a multidisciplinary field that entails the design and engineering of functional systems at the molecular level[25].

Because of its numerous applications across the wide range of sectors, nanotechnology is regarded as a crucial pillar in modern scientific advancement[26]. Redox reactions are the basis of green synthesis, in which an organism's component or an extract reduces a metal ion to stable nanoparticles[27]. Since, nanoparticles have antioxidants, anti-bacterial, and antimicrobical characteristics, the are used in different biomedical applications[28].

Researchers in case of nanotechnology highlights the possibility of green chemistry pathway for the production of technologically important nanomaterials[29].

The colloidal form of silver nano particles is considered among the most potent anti-bacterial agent. Colloidal silver nano particles are yielded by the production of silver ions in aqueous solution[30]. Due to increased awareness of biological processes, nanoparticles have become more significant[31].

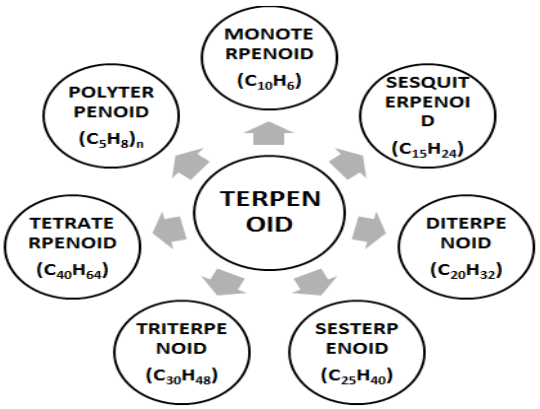
The most popular nano particles are silver nano particles due to their anti-bacterial and anti-cancer activities. Their unique properties are determined by their small size shape structure and surface functionality[32]. Metal nanoparticles including Cu, Pb, Ca, Pt, Ag, Au, and others have been synthesised and tested for techniques use in a variety of fields[33]. Hence, gold nanoparticles have found applications in the delivery and diagnosis of drugs[34].

Terpenoids makes up the majority of the group of secondary metabolites found in higher plants. Due to their application in a variety of industries, including pharmaceutical, food, and cosmetics, where they can be employed as food additives, flavourings, perfumes, and species, and among other things, they have great economic value. Moreover, they are utilised in analgesics, anti-inflammatory medications, and treatments for wounds[35].

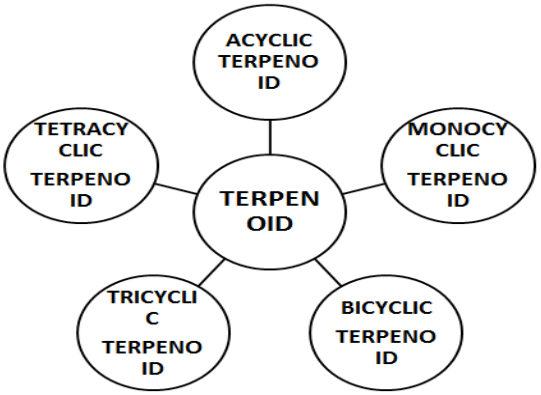
Now a day's verity of chemicals uses for many kinds of synthesis (Inorganic and Organic) and nano materials. So, for the removal of hazardous effect of chemicals, researchers move on to the eco-friendly methods but chemicals are required for any synthesis that's why researchers are attracted towards the use of phytochemicals. Many plants, herbs, shrubs and trees have a various type of phytochemicals this review work on specially focus on one phytochemical its name is terpenoid.

Classification of terpenoids

Clasification based on 'n' or number of carbon atoms



Classification according to number of rings:



Tables are available which shows the which plants, herbs, shrubs and trees have terpinoied.

Tabel 1: Botanical name of Plant which have a terpenoid phytochemical and its structure

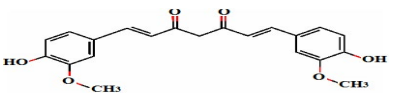
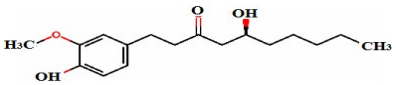
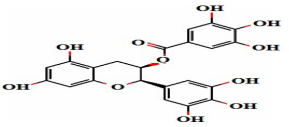
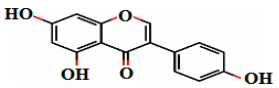
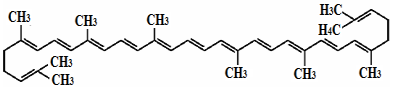
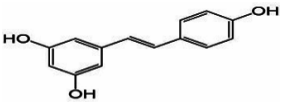
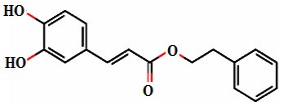
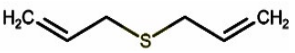
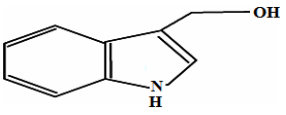
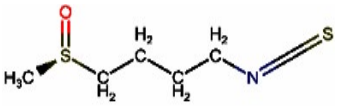
S. No	Plant Name	Botanical Name	Phytochemical	Structure
1	Turmeric	*Curcuma longa*	Curcumin	
2	Ginger	*Zingiber officinale*	[6]-gingerol	
3	Green tea	*Camellia sinensis*	Epigallocatechln-3-gallate	
4	Soyabean	*Glycine max*	Genistein	
5	Tomato	*Solanum lycopersicum L*	Lycopene	
6	Grapes	*Vitis vinifera.*	Resveratrol	
7	Honey	No botanical name	Caffeic acid phenethyl ester	
8	Garlic	*Allium sativum*	Diallyl sulphide	
9	Cabbage	*Brassica oleracea var. capitata*	Indole-3-carbinol	
10	Broccoli	*Brassica oleracea var. italica*	Sulphoraphane	

Table 2 HERBS: Parts of plants and available terpenoid

S. No	Plant name	Parts of plants	Terpenoid
1	Ginger	Root	Neral and geranial
2	Garlic	Bulb	Nerolidol and terpinolene
3	Peppermint	Leaf, oil	L-limonene, alpha-pinene, beta-pinene, Cinesol
4	Brahmin	Whole plant	Triterpenoids Saponins
5	Bhringaraj	Seed/whole plant	Triterpenoids

Table 3 Tree: Parts of tree and available terpenoid

S. No	Plant name	Parts	Terpenoid
1	Tea	Leaf	Myrcene
2	Lemon	Whole	Limonene
3	Pine	Leaves	Alpha-pinene Beta-pinene
4	Lavender	Whole	Linalool
5	Clove	Leaves	Beta-caryophyllene

METHOD

A mix of methods that we utilised to describe terpenes. Therefore, such nanoparticles cannot be properly characterised by a single method. The product yield from the reaction of plant extract and silver salts are at evaluated by UV-Vis spectroscopy. Terpenes are present if the peak is between 410 and 450. Yet, different wavelengths may reveal terpenes that are distinct in size and form. The methods employed are energy dispersive spectroscopy (EDS), X-ray photo-electro spectroscopy (XPS), and diffraction spectroscopy (XRD) (EDS). These methods are employed for the investigation of crystal size, face composition, and crystal structure. The elemental analysis, chemical characterisation, and electronic states of terpenes are also done using these.

The method which we get from paper "Green Synthesis and antibacterial effect of aqueous colloidal solutions of silver nano-particles using camomile terpenoids as a combined reducing and capping agent"[38].

The extraction of camomile was made by combining 500 mL de-ionized water and 100 g of dried Camomile flower. Then the mixture was kept for 5 h at 90°C without boiling After the mixture was cooled it was filtered with filter paper. Then, at room temperature, 500 mL of silver nitrate was added to the 5 mL of floral extract.

The combination was then left undisturbed in a dim location. The hue of the mixture changes to reddish-brown, which was connected with the creation of silver nanoparticles. With help of centrifugation nanoparticles were collected.

The process was utilised to create silver nanoparticles, which were then used as a reference sample to assess the camomile's antibacterial characteristics. 100 mL of silver nitrate and 50 mL of glucose solution were combined at room temperature. The mixture was left undisturbed in a dark environment for two hours until it turned grey.

The method which we get from the paper "Synthesis and characterisations of zinc oxide nano-particles using terpenoid fractions of Andrographis paniculate leaves"[37].

The plant A. Paniculate was initially collected. It was created using chemicals and solvents such silica gel, $CDCl_3$, zinc nitrate tetrahydrate, sodium hydroxide, ethanol, and chloroform.

Extract preparation

A paniculate leaves were gathered, cleansed with tap water, rinsed with distilled water, dried, cut into little pieces, and ground into a fine powder.

Preparation of terpenoid fractions from A. paniculate

Column Chromatography was used to separate the terpenoid fractions. In this procedure, ethanol was diluted to the desired strength by adding 25 g of silica gel powder to a column apparatus. When the solution had been thoroughly blended, a 50% combination (65 mL $CHCl_3$ and 1 mL methanol) was added. 10 mL of the ethanolic sample was then added. The remaining mixture was then incorporated. Within 12 h of the solution being eluted, terpenoid was collected in a test tube.

Phytochemical test for terpenoid fractions from A. paniculate

Confirmative test for terpenoids

Salkowski's test TAP was combined with a small amount of sulphuric acid and chloroform. Terpenoids are present when yellow colours appear, which shows their presence. The extract was then treated with one millilitre each of $CHCl_3$ and CH_3COOH,

as well as a few drops of concentrated sulphonic acid. The brown ring formation represents terpenoids.

Synthesis of zinc oxide nanoparticles (Zn-NPs):

Using green synthesis, zinc oxide nanoparticles were created. 50ml of distilled water were added to a 0.1 N zinc nitrate tetrahydrate aqueous solution by vigorously shaking the mixture. Following that, 0.1N NaOH was applied for 1 h with a 10 min interval. With the NaOH solution added, the time interval grew longer. For two hours, the process was repeated. At ph. 12, the white solution was agitated for two hours. It was washed with distilled water and ethanol to get the finished product. It was then allowed overnight to dry.

The method which we get from the paper "Formulation, evaluation and bioactive potential of Xylariaprimorskensis terpenoid nanoparticle from it's major compound xylaranic acid"[51].

The X. Primorskensis fruiting bodies were first collected, and then 10 g of the species were weighed and soaked in alcohol for 24 hours. The mixture was filtered after 24 h, the solid residues were taken out, and the filtrate was extracted with petroleum ether for 6 h while being continuously shaken. Two layers were created after it was treated with warm aq. KOH. After drying, the petroleum ether layer underwent comprehensive terpenoid treatment. Salkowski text and HPTLC were used to qualitatively evaluate the isolated terpenoid. The extracted terpenoids were then put via silica gel column chromatography using 100% methanol as the final solvent, followed by hexane/ethyl acetate.

Further, for the synthesis of AgNP, 30 mL of $AgNO_3$ solution and 1.5 mL of xylaranic acid from X. primorskensis were combined, and the mixture was stirred at 1000°C until the colour changed from transparent yellow to dark brown. It indicates that Ag NPs have formed. The surface Plasmon Resonance phenomenon is what causes the colour change.

The method which we get from the paper "Antioxidant, antibacterial and cytotoxic potential of silver nano-particles synthesized using terpenes rich extract of *Lantana camara L.* leaves"[39].

The *Lantana camara L*. Plant was initially gathered. The leaves were properly cleaned with purified water (distilled water) to get rid of any dust, after which they were dried and ground into powder. Then, about 10 g of dried powder of leaves of *Lantana camara L*. Was extracted with petroleum ether for 6 h at room temperature with continuous shaking. Then two layers were created by shaking it with 30 mL of a heated 10% aqueous KOH solution. After that, the petroleum ether layer was dried at a lower pressure to produce stick mass. As a result, this petroleum ether extract that had not been saponified was thought to be high in terpenes (TRE). Further, for the synthesis of silver nanoparticles, At room temperature, 1 mL of TRE was combined with 6 mL of 1 mM $AgNO_3$ in an Erlenmeyer flask. The mixture was then left in the dark for 24 hours. Once AgNP has been synthesised, the solution's colour shifts from greenish to reddish over time. The NPs were subsequently cleaned using centrifugation and numerous washings. The concentrated slurry was then collected and the liquid was thrown away. It was collected after drying under suction.

The method which we get from the paper "Green Synthesis of silver nanoparticles using Azadirachta indica leaf extract and its anti-microbial study"[47].

Neem leaves that had just been picked up were thoroughly cleaned with distilled water to remove any dirt or dust that had accumulated on their surface. The leaves were then roughly cut and weighed 20 g. 20 g of neem leaves were cooked for around 10 minutes with 100 millilitres of purified water. The extract was then filtered, cooled, and stored for further use. As a result, this solution was utilised to reduce silver ions or to synthesise silver nanoparticles in a greener manner.

Synthesis of silver nanoparticles

100 mL of a 1 mM silver nitrate solution were made using silver nitrate. After that, 5 mL of silver nitrate solution received separate additions of 1, 2, 3, 4, and 5 mL of a neem extract. After that, the samples were kept in the dark to reduce the amount of room-temperature photoactivation of silver nitrate. As a result, the colour changes from colourless to brow indicates that the silver ions have been reduced.

Different Plants give a different phytochemical and by the use of phytochemical researchers prepared different type of NPs. List of prepared NPs available in Table 4 with references.

Table 4: Synthesized different NPs through terpenoid.[36-45]

S. No	Plant name's	Part of the plant used	Nanoparticles	Reference
1	Turmeric	Leaves	Silver nanoparticles	Singh, D. *et al.,*[36]
2	Turmeric	Tubers	Cu nanoparticles	Ayarambabu, N., *et al.,*[37]
3	Ginger and garlic	Bulbs of ginger and rhizomes of garlic	Metal nanoparticles (silver, zinc, copper and iron)	El-Refai, A. A. *et al.,*[38]
4	Green tea	Leaf's	Zinc oxide nanoparticles	Senthilkumar, S. R. *et al.,*[39]
5	Soya bean	Textured soya	Copper nanoparticles	DeAlba-Montero, I. *et al.,*[40]
6	Tomato	Whole	Silver nanoparticles	Maiti, S. *et al.,*[41]
7	Grapes	Seed	Silver nanoparticles	Xu, H. *et al.,*[42]
8	Honey	Liquid	Au and ag nanoparticles	Sreelakshmi, C. H. *et al.,*[43]
9	Cauliflower and cabbage	Whole Part	Silver nanoparticles	Tamileswari, R., *et al.,*[44]
10	Broccoli	Whole Part	Gold nanoparticle	Piruthiviraj, P. *et al.,*45

After the preparation of Nps. It's required for characterisation for conformation of prepared Nps. Researchers use the different analytical technique for observation of morphological structure of Nps. Observed values is available in Table 5 with references.

Table 5: Different analytical techniques (UV-Visible, TEM/SEM, FTIR) for analysis of Prepared NPs[36-45]

S. No	Plant	Part	Characteristics			References
			UV-Visible	TEM/SEM	FTIR	
1	Turmeric	Leaves	UV-Visible Range: 420nm-450nm	Size 25nm	Range:1074 –3290 cm^{-1}	Singh, D. *et al.,*[36]
2	Ginger &Garlic	Bulbs of ginger and rhizomes of garlic	UV-Visible Range: 240-440nm	Size Range of garlic: 13.13nm–22.69nm Size Range of ginger: 10.10nm–18.33nm		El-Refai, A.A. *et al.,*[38]
3	Green Tea	Leaves	UV-Visible Range: 325nm and 385nm	-	Range: 3394 cm^{-1}	Senthilkumar, S. R. *et al.,*[39]
4	Soya Bean	Textured soya	UV-Visible Range: 400-550nm	5.67±0.5337 nm (Quasi-Spherical shape)		DeAlba-Montero, I. *et al.,*[40]
5	Tomato	Pulp of tomato	UV-Visible Range: Smooth and narrow absorption band observed in 410nm (Concentration1:1 extract composition) And 415 nm (Concentration 3:2 composition)	TEM was confirmed by the Spherical shape Size Range: 10 to 40nm		Maiti, S. *et al.,*[41]
6	Grape	Seed	UV-Visible Range: 200nm–800nm	Size Range-25nm–35nm (Spherical and polygonal shape)		Xu, H. *et al.,*[42]
7	Cauliflower and Cabbage	Whole part	UV-Visible Range: Sharp peak observed in 420nm	Size Range-30-50nm (for both)		Tamileswari, R., *et al.,*[44]
8	Broccoli	Whole part	UV-Visible Range: 400–750nm	Size Range-13nm–22nm	Range: 500 –4000 cm^{-1}	Piruthiviraj, P. *et al.,*[45]

Table 6: Antimicrobial result of various plant observed by different authors in a paper[36-45]

S. No	Plant	Antimicrobial Activity	Value	Reference
1	Turmeric	Antimicrobial activity observed against pathogenic bacteria– *Ps. Aeruginosa* *K. pneumoniae* *S.typhimurium* and *E. aerogenes* *E. coli*	Inhibition Zone of AgNPs with (80µL Concentration) Concentration– *Ps. Aeruginosa*-21mm *K. pneumoniae*-15mm *S.typhimurium* and *E. aerogenes*–14mm *E. coli*-13mm	Singh, D. *et al.,*[36]
2	Ginger and garlic	Antibacterial activity observed against– *Gram+ve*-bacteria (*B. subtilis* and *S. aureus*) and *Gram–ve*-bacteria (*E. carotovora*, *P. vulgaris* and *K. pneumoniae*). Antifungal activity observed against- *C. albicans* strain	Garlic extract made AgNPs shows the highest inhibition zone observed against *P. vulgaris* 12.6mm.	El-Refai, A. A. *et al.,*[38]
3	Green tea	*Gram-negative* bacterial-, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Gram-positive-Staphylococcus aureus* Antifungal test: *A. fumigatus* *Penicillium sp* *A. flavus* *A. niger*	Highest antifungal activity observed against *C. albicans* strain–15mm. 10.3±0.57 (20µg/mL) 3.3±0.57 (20µg/mL) 2.3±0.57 (10 µg/mL) Antifungal Test: 5.3±0.57 6.6±0.57 2.6±0.57 3.0±1.00	Senthilkumar, S. R. *et al.,*[39]
4	Soya bean	Antimicrobial activity observed against *Escherichia coli*, *Staphylococcus aureus*, and *Enterococcus faecalis* strains	At conc. of 10mM, 20mM, and 40mM it give the 100% inhibition rate, but at 5mM conc. of CuNPs only *Enterococcus faecalis* shows the 100% inhibition rate.	DeAlba-Montero, I. *et al.,*[40]
5	Tomato	Antimicrobial activity observed against-*E. coli*	Varying concentration variation of AgNP is 0.2 to 100 µg/mL. By the use of increased conc. of AgNP, bacterial concentration observed decrease. At concentration 50 µg/mL of AgNP, the growth of *E. colli* was inhibited.	Maiti, S. *et al.,*[41]
6	Grape seed	Bacterial observation- *Escherichia coli* *Staphylococcus aureus* *Shigella dysenteriae* *Pseudomonas aeruginosa* *Vibrio anguillarum* *Vibrio alginolyticus* *Aeromonas punctata*	Observed Inhibition zone- 12.7mm 12.1mm 12.1mm 11.5mm 14.0mm 13.4mm 13.3mm	Xu, H. *et al.,*[42]

		Vibrio parahaemolyticus	13.3mm	
7	Cauliflower and cabbage	*Klebsiella pneumoniae* *Bacillus subtilis* *Staphylococcus aureus* *Escherichia coli*	Standard (inhibition value): 16mm 20mm 16mm 16mm	Tamileswari, R., *et al.,*[44]
8	Broccoli	Anti-Bacterial Test : *Gramme-negative*: *Klebsiella pneumonia* *Gramme-positive* *Staphylococcus aureus* Anti Fungal Test : Aspergillus flavus Aspergillus niger Candida albicans	Anti Bacterial Test: *Gram-negative Klebsiella pneumonia* 12mm(10µg/mL) 18mm(25µg/mL) 22mm(50µg/mL) *Gram-positive Staphylococcus aureus* 10mm(10µg/mL) 14mm(25µg/mL) 20mm(50µg/mL) Anti Fungal Test: *Aspergillus flavus* 5mm(10µg/mL) 7mm(25µg/mL) 9mm(50µg/mL) *Aspergillus niger* 5mm(10µg/mL) 8mm(25µg/mL) 9mm(50µg/mL) *Candida albicans* 5mm(10µg/mL) 7mm(25µg/mL) 12mm(50µg/mL)	Piruthiviraj, P. *et al.,*[45]

CONCLUSION

A broad class of naturally occurring substances known as terpenoids is generated from five carbon isoprene units. Thus, through terpenoids synthesis of nanoparticles can be done easily. Because they are carried out using green extract. Based on a number of factors, green technology-produced nanoparticles are considerably superior to those produced via physical and chemical processes. Green methods, for instance, don't utilise costly chemicals, use less energy, and produce products and by-products that are good for the environment. By using a clean, safe, economical, and eco-friendly method, green synthesis creates nanomaterials. The green synthesis of nanomaterials uses microorganisms like bacteria, yeast, fungi, algal species, and some plants as substrates. The main benefits of green nanotechnology include increased energy efficiency, less waste, and a reduction in the use of non-renewable raw resources. Green nanotechnology provides a fantastic opportunity to prevent negative impacts from happening in the first place. Terpenoids are present in a variety of herbs, shrubs, and plants, including ginger, garlic, tea, lemon, and lavender, among others, and are afterwards employed as phytochemicals for the production of nanoparticles. Hence, the creation of nanoparticles can be exploited in the future. Terpenoids provide us with nanoparticles such as zinc, copper, and silver.

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Conflict of Interest

We, authors of this research article declare no conflict of interest.

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