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Review

An overview of nanoparticle production from plant gums and their action as antimicrobial agents

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Abstract

There have been various chemicals and routines for the treatment of infections. The extensive use of antibiotics has led to serious issues including antibiotic resistance and serious side effects. The use of plant gum nanoparticles (NPs) is one of the several ways that can be employed greatly for the treatment of infections and have gained so much popularity by the scientists recently due to their several advantages over chemicals including being nontoxic and providing better tolerance to the patient. Several studies have been performed recently, stressing the undeniable advantages of these substances in the treatment of illnesses compared with their chemical counterparts. There are studies suggesting that these NPs have great potential in the treatment of multi-drug-resistant bacteria and that these substances have great anti-cancer effects due to their anti-inflammatory roles. Among various plant gums, Gum Arabia, gum Karaya, Kondagogu gum, and gum Tragacanth, Guar gum, and gum Ghatti have gathered more interest as anti-inflammatory subjects for studies because of their several pros including having more tissue bio-availability, being easy to use, etc. The use of plant gums can be limited due to a series of disadvantages but this can be untangled by using natural nanoparticles which can be synthesized via several ways including ultrasonic irradiation, etc. Among various metallic NPs, the most frequent of them in these studies are Silver nanoparticles (AgNPs) and Gold nanoparticles (AuNPs). According to these studies, AgNPs have a more bactericidal effect than AuNPs which is due to them being more of an antioxidant.

Keywords: Gum, Nanoparticles, Antimicrobial Activity, Treatment Agents

1. Introduction

The treatment of infections has always been considered as a significant factor. Thus, there has been various chemicals and routines for treatment of infections. The extensive use of antibiotics has led to serious issues including antibiotic resistance [1, 2]. There are also multi-drug resistant bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant Enterococci (VRE), multidrug-resistant Gram-negative bacteria (MDR-GNB) which have led to noticeable problems in the world of medicine field [3-7]. There are also several microorganisms that can cause systematic illnesses which multi-drug therapy is used regularly for their treatment since most chemical drugs are designed to act against individual molecular targets. This itself can cause serious side effects [8, 9].

The use of plant gum nanoparticles (NPs) is one of the several ways that is employed greatly for the treatment of infections and this has been stated in

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various articles [8, 10-13]. The main source for plant gums are the gum producing trees, which they tend to grow inside the country's forests, and they can prepare various available materials. Plant-derived gums are consisted of polysaccharides and a few of them are applied medicinally for several years, including gum Tragacanth which has been used since 3rd century BC [14]. Various studies have shown the advantage of using green chemistry-based NPs for various purposes compared with using synthetic and chemical substances [15, 16]. Synthetic polymers have disadvantages, such as poor adaptation to the patient's body, high cost, and may also cause acute and chronic side effects. For example, polymethyl methacrylate (PMMA) can cause skin and eye irritation. Further disadvantages of these synthetic polymers are low biocompatibility, release of acidic products during degradation that may cause systemic or even local reactions, and prompt loss of mechanical durability [17, 18].

On the other hand, plant gums can have advantages in the pharmaceutical industry including being biodegradable, biocompatible, nontoxic, providing better tolerance to the patient and having fewer side effects [19]. They also do not cause allergies in humans, do not irritate the skin or eyes, and have low production costs [20]. There are articles showing that these plant gum nanoparticles were successful in the treatment of multi-drug resistant bacteria including MRSA [8]. Natural gums constitute a structurally diverse class of biological macromolecules with a broad range of physicochemical properties, therefore they can be loaded with various drugs and can have multi-target therapeutic effect. In this case, there won't be the need for consuming several drugs for the treatment of systemic illnesses [8].

That being said, the utilizing plant gums has it's own series drawbacks. There is a high chance of bacterial contamination there is a high percentage of moisture in their components. They may also have a decrease in viscosity if they are kept in storages because of their expositor with water [18]. There are several ways in order to reduce these disadvantages and the most pragmatic way that has been used in various researches is turning plant gums into the nanoparticles. NPs are successfully applied in various fields, including pharmaceuticals and regenerative medicines and also the main reason for that, is related to having much better qualities including mechanical, optical, thermal, biological, physical, and chemical aspects as compared to standard components [21]. They are also being used for measuring cellular organelles like liposome [22]. As a general definition, nanostructures are 1–100 nanometers in size during which case they need a high surface area-to-volume ratios and their reactivity is effected mostly by their difference in shape like spherical, conical, spiral, cylindrical, tubular, and hollow [21]. Green chemistry-based NPs are often being used for manufacturing products by adding durable components which can eliminate or decrease the existence and formation of toxic materials [10]. NPs created from plant gums may represent a nontoxic, effective and highly economical bio-resource for future medications [15]. Natural nanoparticles, improve the stability and bioavailability, as well as the biological distribution of natural products. They also significantly reduce the adverse effects of drug uptake. Therefore, gum based nano formulations are becoming much more popular [23].

Gum Arabic (GA), gum Karaya (GK), gum Tragacanth (GT), Kondagogu gum (KG), gum Ghatti (GG), and gum Guar are considered as some of the most popular plant gums that are being used regularly. So many researches has been recorded on tree gum polysaccharides, including their availability, chemical structures, and food or even medical applications. There also are several ways in order to create NPs from plant gums including mixing and agitation in a controlled environment, microwave (MW)-assisted technique, ultrasonic irradiation, etc. The biosynthesis of nanoparticles, nanofibers, and composites for supported tree gums would be very beneficial within the pursuit of relevance to medication for various health issues [24].

The purpose of this article is to review the beneficial medical aspects of these plant gum based NPs. There are several researches that have been done in order to show the advantages of these substances in infection and illness treatment. Various plant gums and routines have been used in order to create NPs with minimum side effects which will be discussed in this article.

2. Chemical property and chemical composition of plant gums

The plant gum exudates have a heterogeneous and sophisticated polysaccharides/carbohydrate polymer [25]. The dry weight of the gum exudates is consisted of 2.45% of proteins, 0.85% of fats and 92.36% of carbohydrates. Other materials are the following: arabinose, xylitol, galactose and uremic acid (46.8: 10.9: 35.5: 6.0 mass ratio, respectively) with pieces of rhamnose, mannose and glucose. Also, gum exudates are full of minerals, like sodium, potassium, magnesium, calcium and iron [26]. The physical and functional properties of plant-based gums rely on their chemical compositions and molecular structures [2]. The chemical composition of plant polysaccharides is derived either from the identical sugar monomers (cellulose and starch), two various monomer units (alginate and hyaluronan) or various monosaccharide (galactose, arabinose, rhamnose and uremic acid) like gum acacia [27].

3. Green chemistry and nanomaterials

For the generation and stability of NPs, a variety of natural compounds can act as reducing and coating mediators [14]. Green chemistry refers to a set of concepts or practices that promote the development of goods and processes that decrease or eliminate the usage and creation of hazardous compounds. In the creation of NPs, current green nanotechnology methods frequently include the use of natural sources, non-hazardous solvents, biodegradable and biocompatible materials, and energy-efficient procedures. Biopolymers including cellulose, chitosan, dextran, and tree gums, for example, are frequently utilized as reducing and stabilizing agents in metal NP production. Plant-based ingredients (extracts, stems, gums, seeds, and fruits), among other biological sources, have been shown to be an efficient constituent for synthesizing nanoparticles while maintaining other important factors such as material cost, large-scale production capacity, and potential uses in a variety of applications. The pressure, temperature, solvent, and pH of the medium all play a role in the plant-based biogenic production of nanomaterials [28].

4. The green synthesis of nanoparticles and antibacterial applications

These natural gums are hydrophobic substances mostly obtained from plants or bacteria. Because the gum molecules are biological, they have a wide range of linear chain length, branching features, molecular weight, and other characteristics [29].

Various techniques can be used in order to create green nanoparticles by utilizing plant extracts for instance: (a) mixing and agitation in a controlled environment, (b) controlled heating in a certain temperature and pressure, (c) autoclaving, (d) microwave (MW)-assisted technique, (e) ultrasonic irradiation, and (f) UV/visible light irradiation. The use of ecologically benign solvent media (water and ionic, liquid-based green solvents) for the production of NPs shows that tree gums follow the cardinal principles of green chemistry. The presence of several functional groups (e.g., –OH, –COOH, –CO, and CH_3CO–) in the gum's structure, turns them into reducing agents. Natural gum fibers produce and stabilize NPs that are non-toxic to cells, making them ideal for a variety of functions such as medication administration, molecular imaging, and biomedical diagnostics. The usage of metal NPs (such as Ag, Au, Cu, CuO, and Fe_3O_4, among others) as coating materials in biomedical equipment requires both biocompatibility and antibacterial activity [24] .

Plant gums such as gum Arabic, gum Karaya, gum Kondagogu, gum Tragacanth, gum Ghatti, Guar gum, Cashew gum, Gellan gum, Xanthan gum and Gum olibanu have been used as stabilizers and reducing agents in the production of metal/ metal oxide nanoparticles. Numerous studies have been conducted in this regard, which are briefly showed in Table 1 [10, 30-89].

Different studies have illustrated the benefits of using plant gum NPs as antibacterial agents which will be discussed in Table 2. There are several local (Iranian) plant gums that can be used as nanoparticles which can have great effect as antibacterial agents. These plant gums are including gum Arabia, Prunus armeniaca (Apricot), Neem gum, gum Kondagogu, gum Karaya, etc. [10]. Some of these plant gums and the bacteria that they have effect on has stated in Table 2. [8, 11, 61, 67, 90-94].

Table 1 Studies showed the green synthesis of NPs using plant gums.

Plant gums	Nanoparticle	Reference
Gum Arabic	Au, Zn, Magnetite, Cu, Ag, Se, Zein-curcumin, Chitosan/GA, Fe_3O_4	[30-47]
Gum Karaya	Ag, Cu, Au, Magnetite, Pt, Fe_3O_4	[31, 48-52]
Gum Kondagogu	Ag, Au, Cu, Pd, Ti, Pt, Fe3O4, Ag2S	[53-63]
Gum Tragacanth	Ag, ZnO, TiO2, Carbon dots, Au	[64-71]
Gum Ghatti	Pd, Magnetite, Ag, Au	[10, 72-74]
Guar gum	Ag, Au, Pt, Pd, Magnetite, Zn, Palmshell extract/ chitosan	[75-82]
Cashew gum	Ag, ZnO	[83, 84]
Gellan gum	TiO_2, Ag	[85, 86]
Xanthan gum	Au	[87, 88]
Gum Olibanu	Ag	[89]

Table 2. Studies showed antibacterial effects of plant gums

Plant based NP	Preparation and essay	Results	Antibacterial activity	Reference
Prunus domestica gum loaded silver NPs	Disc diffusion method was used for antibacterial assay with using Gram-positive (*S. aureus*), Gram-negative (*E. coli*) and *P. aeruginosa*, three independent experiments were carried out for each bacterial strain with streptomycin as the positive control. Au/Ag-NPs (5 µg) were dissolved in DMSO and incubated at 30 °C for 24 h.	*P. domestica* gum-loaded silver nanoparticles can have potential antibacterial effect against *S. aureus* (19.7 ± 0.4 mm) and *E. coli* (14.4 ± 0.7 mm), and *P. aeruginosa* (13.1 ± 0.2 mm). Although this study suggests that streptomycin has an antibacterial effect of higher magnitude as compared to *P. domestica* gum-loaded silver nanoparticles against the tested bacterial strains (23.6 ± 0.8 mm, 21.8 ± 0.2 mm and 18.6 ± 0.3 mm).	Gram-positive (*S. aureus*), Gram-negative (*E. coli* and *P. aeruginosa*)	[8]
P. domestica gum loaded gold NPs	Preparation and assessment performed like *P. domestica* gum loaded silver NPs.	Gum loaded gold nanoparticles had the least effect on foregoing bacteria (*S. aureus* (10.5 ± 0.6 mm), *E. coli* (10 ± 0.4) mm and *P. aeruginosa* (8.2 ± 0.3 mm)) compared to *P. domestica* gum loaded silver NPs and streptomycin.	Gram-positive (*S. aureus*), Gram-negative (*E. coli* and *P. aeruginosa*)	[8]

Plant based NP	Preparation and essay	Results	Antibacterial activity	Reference
GA-AgNPs (Gum acacia silver NPs) loaded with NP structures of HDN (fruit flavonoid)	Bactericidal assay was performed by incubating 10^8 colony-forming units per mL of foregoing bacteria with various concentrations of GA-AgNPs-HDN and respective controls. For negative controls untreated bacterial culture were incubated with phosphate buffer saline (PBS), while 100 µg/mL gentamicin treated bacteria were used as positive control.	Bactericidal effect of this nanoparticle was more significant on *Escherichia coli* K1 infections than MRSA infections, indicating that this component is more effective on Gram negative bacteria than Gram positive but overall these NPs have more bactericidal effects than chemicals.	Multi-drug resistant bacteria MRSA and Uropathogenic *E. coli* K1	[11]
Gum Kondagogu Copper nanoparticles (CuNPs)	The synthesized CuNPs are characterized by using Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), UV visible spectroscopy, X-Ray Diffraction (XRD), FT-Raman spectroscopy and Fourier Transform Infrared Spectroscopy (FTIR) experimental methods.	Anti-biofilm effect of gum Kondagogu extract stabilized copper NPs against clinical isolate *Klebsiella pneumoniae* was demonstrated in this study.	*K. pneumoniae*	[61]
Gum Tragacanth (Astragalus gummifer) Silver nanoparticles	The well-diffusion method was used to study the antibacterial activity of the synthesized silver nanoparticles. Mueller Hinton agar plates were inoculated with 0.5 McFarland standard bacterial suspension, and 5 µg of silver nanoparticles were added to the center well with a diameter of 6 mm. The nanoparticles used here were prepared with 0.1% gum solution containing $AgNO_3$. Culture plates loaded with discs of antibiotic, erythromycin (15 µg/disc) were included as positive controls.	The inhibition zone of around 11. 5 ± 0 mm was observed for the Gram-positive bacteria. For Gram-negative bacterial strains *E. coli* and *Pseudomonas aeruginosa* the inhibition zone was reported 9.5 ± 0.4 and 10.5 ± 0 respectively. Whereas, the negative control plates loaded with autoclaved gum did not produce any inhibition zone. In the case of positive control plates loaded with erythromycin discs, growth inhibition was noted.	Gram-positive bacterial strain *Staphylococcus aureus* and Gram-negative bacterial strains *E. coli* and *P. aeruginosa*	[67]
Chitosan/poly (vinyl alcohol)/guar gum (CS/PVA/GG)	After the preparation of a mixture of chitosan/poly (vinyl alcohol)/guar gum (CS/PVA/GG), the ratio of swelling, together with antimicrobial properties, was studied. These components were characterized by SEM, FTIR, and XRD.	SEM results showed that surface morphology was more affected by mixing and bonding ratios. Also, the FTIR and XRD confirmed the strong intermolecular bonding between polymers. The study suggests that these blends have great potential to be used against *Pasteurella multocida*, *S. aureus*, *E. coli*, and *Bacillus subtilis.*	*P. multocida*, *S. aureus*, *E. coli*, and *B. subtilis*	[90]

Plant based NP	**Preparation and essay**	**Results**	**Antibacterial activity**	**Reference**
Gum Karaya copper oxide (CuO) nanoparticles	The CuO nanoparticles were synthesized by a colloid-thermal synthesis process. The synthesized CuO was purified and dried to obtain different sizes of the CuO nanoparticles. The well diffusion method was used to study the antibacterial activity of the synthesized CuO nanoparticles. The zone of inhibition, minimum inhibitory concentration, and minimum bactericidal concentration were determined by the broth micro-dilution method.	The study suggests that gum Karaya copper oxide (CuO) nanoparticles can have significant bactericidal effect on both Gram-negative and positive cultures, specially smaller NPs (4.8 ± 1.6 nm) which are highly stable and have maximum zone of inhibition compared to the larger size of synthesized CuO nanoparticles (7.8 ± 2.3 nm).	Gram-negative and positive cultures	[91]
Kondagogu gum Gold nanoparticles (AuNPs)	After the preparation of these NPs, their concentration, and reaction time on the synthesis of AuNPs were investigated by using techniques like UV − visible spectroscopy, FTIR, DLS, TEM, and powder XRD.	The AuNPs showed good antibacterial activity against *E. coli* and *B. subtilis*.	*E. coli* and *B. subtilis*	[92]
Kondagogu Silver nanoparticles (AgNPs)	Variety of susceptibility assays were done in this study in order to demonstrate the antibacterial effects including: microbroth dilution, anti-biofilm activity, growth kinetics, cytoplasmic content leakage, membrane permeabilization, etc. The production of reactive oxygen species (ROS) and cell surface damage during bacterial nanoparticle interaction were also demonstrated using dichlorodihydrofluorescein diacetate, N-acetyl cysteine; and scanning electron microscopy and energy dispersive X-ray spectra.	The MIC values were lower by 3.2- and 16-folds for Gram-positive *S. aureus* and Gram-negative *E. coli* strains, respectively. The MBC values were lower by 4 and 50-folds. Thus, the biogenic AgNPs were found to be more potent bactericidal agents in terms of concentration. Results implies that this NPs has strong effects on biofilms, indicating that it can have great effect on drug resistant bacterial infections caused by biofilms. Also the growth curve stated a faster inhibition in Gram-negative bacteria as compared to Gram-positive.	Gram-positive *S. aureus* and Gram-negative *E. coli*	[93]

Plant based NP	Preparation and essay	Results	Antibacterial activity	Reference
Gum kondagogu Selenium nanoparticles (SeNPs)	Role of gum on synthesis and mean particle size was studied using ultraviolet-visible spectroscopy and dynamic light scattering. Size of the NPs were determined (from 44.4 to 200 nm) and mean particle size was 105.6 nm. Antibacterial potential of NPs was checked with well diffusion assay.	In this study, NPs exhibited growth inhibition activity against Gram-positive bacteria only. *B. subtilis* and *Micrococcus luteus* showed respective inhibition zones of 6.3 and 8.6 mm at 12 µg. this study implies that the tree gum stabilised Se NPs has more applicability as a potent antioxidant nutrition supplement at a much lower dose, in comparison with ionic Se.	*B. subtilis* and *M. luteus*	[94]

5. Conclusions and future prospects

Plant based synthesis and stabilization of metal/metal oxide NPs have been successfully implemented by many researchers worldwide. These techniques have various advantages including being more affordable physically and financially, having better drug distribution and having easier production. Based on these articles, using plant gums alone is less effective than their NP counterparts and in some occasions, they even may have side effects on human's body [95].

Various metallic or non-metallic NPs can be created and added to these plant gums. Most frequent of them in these studies are silver nanoparticles (AgNPs) and gold nanoparticles (AuNPs). AuNPs have exceptional stability against oxidation and therefore the may play a significant role in the advancement of clinically useful diagnostic and therapeutic nanomedicines. However, according to various studies, they are less effective against microorganisms than AgNPs. AgNPs have a strong bactericidal and catalytic effect according to various studies, they are extremely beneficial for preventing drug resistant bacteria which will be a huge issue in the future [96-98].

The influence of different parameters such as gum particle size, concentration of gum, concentration of silver nitrate and reaction time on the synthesis of nanoparticles is quite significant in various studies [11, 99, 100]. The influence of the nanoparticles size on their effectiveness is well defined for a NP like copper oxide which smaller NPs can have more bactericidal effects compared to their bigger counter parts [101]. Thus using the right concentration and technique for making these NPs is very important and it should be considered.

The future use of tree gums also relies on the development of ultralight weight, high, strength, bio-based, biodegradable, porous, etc. Each year scientists are getting keener on researching about these green NPs because of various reasons including the significant growth in the number of antibiotic resistant bacteria or climate change.

Authors' contributions

Study design, supervision, conceptualization, and critical revisions: DM. Searching, data collection and drafting: MM, AT. The final manuscript has been read and approved for submission by all the named authors.

Conflict of interests

The authors reported no potential conflict of interest.

Ethical declarations

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