RESEARCH PAPER

Synthesis, Characterization of Silver Nanoparticles from Natural Plant Gums and Its Antimicrobial Activity

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ABSTRACT
Nanotechnology is a revolutionary field that allows for the manipulation of materials at the nanoscale and has potential applications in many industries due to unique physicochemical properties. This work describes an environmentally benign and sustainable method of synthesizing silver nanoparticles (SNPs) using natural plant gums Acacia nilotica Gum, Senna auriculata Gum, Terminalia catappa Gum through a simple chemical reduction method. These plant-derived gums are good reducing and stabilizing agents found in huge amounts of polysaccharides, proteins, and phenolic compounds that can reduce Ag^{+} ions to metallic Ag^{0} NPs while preventing aggregation. The successful formation of SNPs was initially observed by the color changes from pale yellow to brownish yellow, which is due to surface plasmon resonance. UV–Visible spectroscopy was performed to confirm the identity of nanoparticles, and FTIR spectroscopy to identify the functional groups that facilitate stabilization. In order to assess the stability and quality of these nanoparticles, some key physical and chemical properties like color, solubility, water retention capacity, pH value, total ash content and molecular weight had been determined. The synthesized SNPs were screened for antibacterial activity using the agar well diffusion method against selected bacterial strains, which displayed clear zones of inhibition demonstrate good antibacterial action. Also, free radical scavenging activity was assessed using DPPH free radical method indicating powerful electron donating and free radical-neutralizing properties of the SNPs. In summary, the biosynthesized silver nanoparticles had prominent antimicrobial and antioxidant activities, thus illustrating their possible applications in biomedical, pharmaceutical, antibacterial and water purification for the benefit of innovative fields globally while facilitating green and sustainable nanotechnology

Keywords: Silver nanoparticles, Natural gums, Chemical reduction, Antibacterial activity, Biomedical applications.

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1. INTRODUCTION

Plants and plant-based products have long been essential to human needs on a daily basis. Plants have been used from the beginning of life to provide nutrition, drug, apparel, shelter, and other minor and large requirements[1]. As per the World Health Organisation(WHO) , medicinal plants are regarded as one of the most reliable ways to get all kinds of medications[2] .Gums, also known as hydrocolloids or polysaccharides, are flexible biopolymers used as ingredients and additives in pharmaceutical industries[3].The molecular makeup of these polysaccharides, which endows them with qualities like gelling, thickening, moisture retention, emulsification, and stabilization, is inherently linked to their adaptability. They are extensively utilized in confections, stabilizing agents in ice cream, food emulsions, flavor and color microencapsulation, clarifiers, and beverage stabilizers in the food sector[4]. Therefore, whether polysaccharides are isolated or in mixes, known chemical structure, thermal stability, response to water, and rheological dynamics is essential for investigating their possible applications[5].

Natural gums are macromolecules with repeating structural elements, or polymers. Additionally, it contains polysaccharides that can mix with water. When hydrated, they form three-dimensional structures that increase the viscosity of the solution by "trapping" the water inside[6]. These materials are frequently used in a variety of industries, such as food manufacturing, medicines, cosmetics, and more. Particularly in cosmetic formulations, they have a variety of uses, including modifying texture and consistency, improving the overall feel and appearance, maintaining

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the uniform distribution of insoluble components, stabilizing mixtures like emulsions, and changing the behaviour of foam in products containing surfactants[7]. They also have the ability to form films, which keeps the skin hydrated. Seaweed, animals, plants, and fungi are only a few of the origins of gum production. The main source of both natural and semi-natural gums among these is plants. Semi-natural gums, with a few notable exceptions, contain synthetic chemicals in their finished form that are prohibited in natural formulations[8].

In the fields of water treatment, medicine, catalysis, and solar energy conversion, metal nanoparticles may offer answers to environmental problems. Noble metal nanoparticle synthesis is a field of ongoing attention for uses in biology, electronics, optics, catalysis, and the environment[9]. AgNPs in particular have received a lot of attention because of their many characteristics, including chemical activity, electrical conductivity, antifungal, and antibacterial qualities. Prokaryotes like bacteria, fungi, and viruses are more poisonous to silver than eukaryotes like humans[10].

The present study aims to develop an ecofriendly synthesis route for SNPs using plant natural gums. The synthesized nanoparticles are characterized for their structural and morphological features using advanced analytical techniques. Additionally, their biological efficacy is evaluated through antibacterial assay. This research aligns with then principles of green chemistry and contributes to the development of cost-effective, biocompatible, and environmentally safe nanomaterials for potential biomedical applications.

2. MATERIALS AND METHODS

2.1. Harvesting And Extraction Of Natural Gums

Natural gums are extracted from cracks in the bark of four different trees such as *Acacia nilotica Gum (Karuvelan), Senna auriculata Gum (Aavaram poo) and Terminalia catappa Gum (Padam*) were collected from Arunachala Hills Forest and Arunachala Hills Forest Tiruvannamalai, Tamilnadu, India. The dried gum crushed powder 20 g was suspended in 50 mL of 95% of ethanol until being dissolved with the assistance of a magnetic stirrer, and then refrigerated for 24 hrs. The suspension was taken out from refrigerator then robustly mixed again for 1 min. The water-insoluble compounds of the suspension were separated by spin at 12,000 rpm for 10 min, and the pellet removed further supernatant were with Whatman® membrane filters (dia is 0.2 µm). Continuous drying of the collected sample was achieved using a rotary evaporator operating at 22 °C under reduced pressure and strong vacuum. This final extract was maintained at 4°C for future analysis

3.2 Physicochemical Characteristics of Natural Gums

The physicochemical characteristics of natural gums were evaluated in terms of yield, solubility, and swelling power. For *Acacia nilotica, Senna auriculat, and Terminalia catappa*, the total percentage yield was found to be 30.23±0.52% w/w, 31.74±0.22% w/w, and 30.23±0.52% w/w. These plants had moisture contents of 0.64±0.029% w/w, 0.61±0.025% w/w, and 0.59±0.02% w/w, respectively.

2.2. Synthesis Of The Nano Particles From Natural Gums

Use an analytical balance to weigh out 0.017g of AgNO3 powder and add it to the beaker. Pour distilled or deionized water into the container to make up a final volume of 100ml.Until the silver nitrate is completely dissolved, mix the liquid with a stirrer or magnetic stirrer. Transfer the solution into amber color clean bottle for further use.Each gum samples (0.3g/ml) were added with silver nitrate solution (0.9g/ml) which was stirred mechanically at 200 × g for 2 hr at 60 °C. The formation of silver nanoparticles was identified by the color change from colorless to pale yellow, later on to light brown. The reaction mixture was magnetically stirred at 4 h at 60 °C.

2.5. Anti-Microbial Activity

Gum and AgNPs-synthesised gum were tested for their antibacterial properties against both Gram positive and negative bacteria Using a concentration of 100 µg/mL, the antibacterial activity was evaluated by the agar well diffusion method. Using a sterile cork borer, a 5 mm well was created in the agar plates. Gum and AgNPs-synthesised gum at appropriate test concentrations were added to the wells. Each plate was incubated at 37°C for 24 hours. Following incubation, the plates were examined for a distinct inhibition zone surrounding the well, which suggested the tested compounds had antibacterial activity.

2.6. ANALYTICAL CHARACTERIZATION OF *Acacia Nilotica*, *Senna Auriculata*, *Terminalia Catappa*

Natural plant gums such as *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa* gums are gaining interest for use in green synthesis of silver nanoparticles (SNPs) due to their biocompatibility, reducing agents, and stabilizing properties. This study focuses on the physical and chemical comparison between the gums and their SNPs counterparts, with spectral validation through **UV-Vis spectroscopy.**

3. RESULTS AND DISCUSSION

3.1 Collection of Natural Gums

The collected natural gums were air dried for 2 days and store at room temperature. The crude natural gums are grounded into a fine powder. To get rid of fibers and unwanted material, it is sieved through a mesh screen. The powder of two samples were stored at room temperature for future studies. The natural gums *Acacia nilotica* and *Senna auriculata tree* appeared as Solidand Dark brown in color, similarly the another tree *Terminalia catappa*appeared as Solid and Light brown

At different temperatures (30°C-90°C), the solubility and swelling power of *Acacia nilotica, Senna auriculata and Terminalia catappa* plant gums dispersion varied from 91.3 ± 0.03% to 96.8 ± 0.05%, and 2.19 ± 0.05% to 3.84 ± 0.04%, respectively, based on the weight of natural gum used for determination.

The decreased swelling is related to the polysaccharide's greater degree of intermolecular interactions, making it suitable for controlled release medication administration. Natural gums solubility upturn gradually from pH 1.2 to 7.2, indicating that solubility increases with increasing pH from 1.2 to 7.2 by phosphate buffer. This indicates that the solubility of CGPS natural gums is pH dependent[11].

3.3 Phytochemical Composition

Many studies reported the phytochemical analysis *Acacia nilotica , Senna auriculata, Terminalia catappa gum* sample contains alkaloids, flavonoids, tannins, saponins, Terpenoids, glycosides, and phenols.

All plant gums contain flavonoids, but only *Terminalia catappa* contains steroids. *Acacia nilotica* has glycosides; and *Senna auriculata* contains terpenoids and. The phytochemical examination of plant gums is explained in detail in Table 1.

Table 1 Phytochemical analysis of plants gums

Chemical test	Acacia nilotica	Senna auriculata	Terminalia catappa
Alkaloids	-	-	-
Flavonoids	+	+	+
Tannins	+	+	+
Saponins	+	-	-
Glycosides	-	+	+
Phenol	+	+	+
Steroids	-	-	+
Terpenoids	-	+	-

+ implies Present, - implies absent.

3.4 UV-Vis Spectral Study For Characterization For Natural Gums Snps

UV-Vis spectrophotometry is one of the finest instrument to measure absorption behavior comes from surface plasmon resonance, through electromagnetic field. Findings from high performance double beam UV-1800. The maximum absorption range for SNP through *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa* between 300-400 nm, a good Plasmon resonance band (PRB) of SNPs. Similarly, Zandpour, reported that single broad peak developed at 450 nm, which was attributed to the distinctive peak of the produced SNPs, matching to surface plasmon resonance SNPs established at this wavelength. There is no peak found after 350 nm that confirms absence of nanoparticles aggregation[12]. Findings from high performance double beam UV-1800, Shimadzu are presented in Alzahrani studied UV-Vis spectra of the Acacia gum–stabilised SNPs, Which shows sharp single peak between 400 to 410 nm.This research showed that employing a sonication bath resulted in a larger reduction of silver ions and a greater generation of SNPs[13].

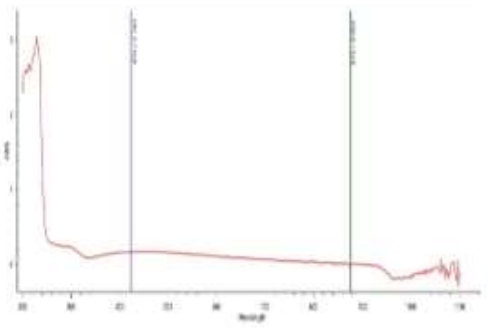

Figure 1 UV Vis spectrum of *Terminalia catappa* AgNO3 nanoparticles

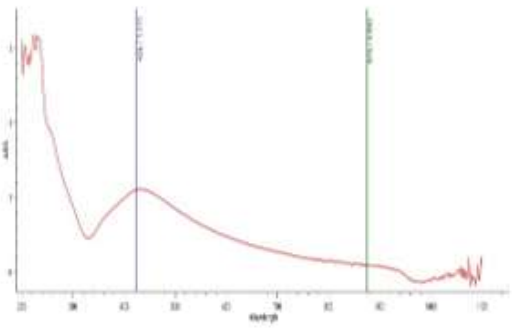

Figure 2 UV Vis spectrum of *Sennaauriculata* AgNO3 nanoparticles

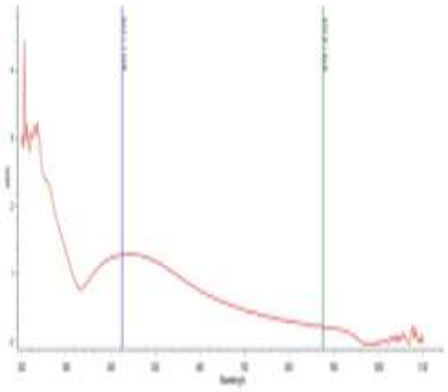

Figure 3 UV Vis spectrum of *Acacia nilotica* nanoparticles

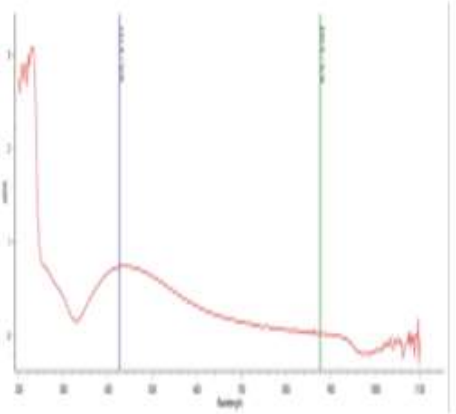

Figure 4 UV Vis spectrum of AgNO3 nanoparticles

The first obvious sign of the reduction of Se metal ions to elemental Se NPs was a color shift from a colorless solution to a ruby red solution due to the surface plasma resonance effect (SPR). The Se NPs generated by green synthesis from *Terminalia catappa, Senna auriculata, Acacia nilotica*, and AgNO3 nanoparticles were further examined using UV-Vis absorption spectra between 200 and 600 nm. The UV-visible spectra of *Terminalia catappa, Senna auriculata, Acacia nilotica,* plant gums and AgNO3 nanoparticles peak between 420 and 420 nm and decrease between 870 and 880 nm.

UV-Vis spectroscopy investigation of cashew gum verified the production of the nanoparticles produced in situ in CMC hydrogels, with the development of plasmonic bands in the 380–420 nm range, which are typical of AgNPs. The greatest absorbance for the PhCG-AgNPs gel was at 404 nm, whereas the detected plasmon band for the NCG-AgNPs hydrogel was centered at 408nm. The NCG-AgNPs showed a greater intensity in the plasmon band and a lower absorbance in the 500–700 nm range, suggesting the creation of a more monodisperse sample[14].

3.5 Scanning Electron Microscope Analysis Of Nanoparticles

The morphology of biosynthesized silver nanoparticles was investigated using a scanning electron microscope (Hitachi S-4500). Thin films of the sample were produced on the SEM grid by simply dropping an adequate quantity of the material onto the grid and gold-coated with a sputter coater. The synthesised nanoparticles are poly-disperse spherical in nature, according to the Scanning Electron Microscopy illustration. The nanoparticles that were synthesised have irregular shapes and no fixed geometry. Figure 5,6,7 to shows the Scanning Electron Microscopic image of SNP through *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa*

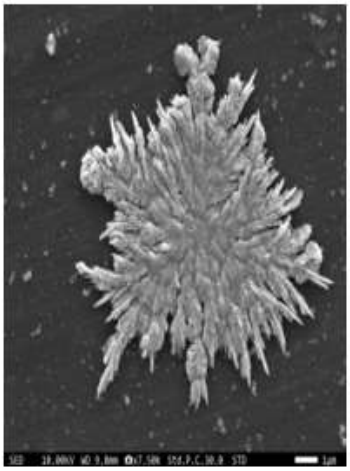

Figure 5 SEM analysis of *Terminalia catappa* - AgNPs

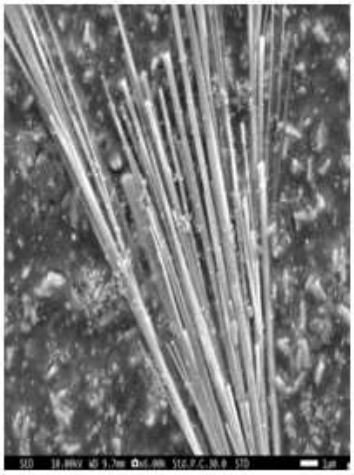

Figure 6 SEM analysis of *Senna auriculata* – AgNPs

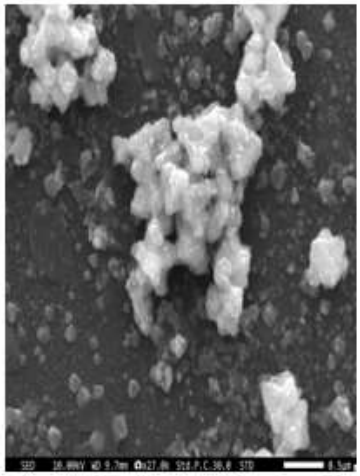

Figure 7 SEM analysis of *Acacia nilotica* - AgNPs

Table 2 SEM analysis of plant Gum - AgNPs

Sample	Surface Morphology	Particle Size Range	Aggregation	Structural Features
***Acacia nilotica* - AgNPs**	Oval, dispersed	30–80 nm	Moderate	agglomerated
Senna auriculata* - *AgNPs	Rod shaped	20–70 nm	Low	Uniform
Terminalia catappa* - *AgNPs	Spherical and aggregation	35–90 nm	Moderate	Partially agglomerated

3.6 Ftir Analysis

FTIR spectroscopy identifies the functional groups present in biomaterials and monitors chemical interactions involved in the synthesis of silver nanoparticles. The FTIR spectra of *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa*indicate the presence of functional groups characteristic of polysaccharides as well as phenolic compounds validating their biopolymeric nature. The wider bands related to O–H stretching regions are observed at 3390–3415 cm^{-1} in case of the gums, and after AgNPs formation, they shifted toward lower wavenumbers (3360–3370 cm^{-1}), showing the participation of –OH groups in hydrogen bonding and effective capping of silver NPs

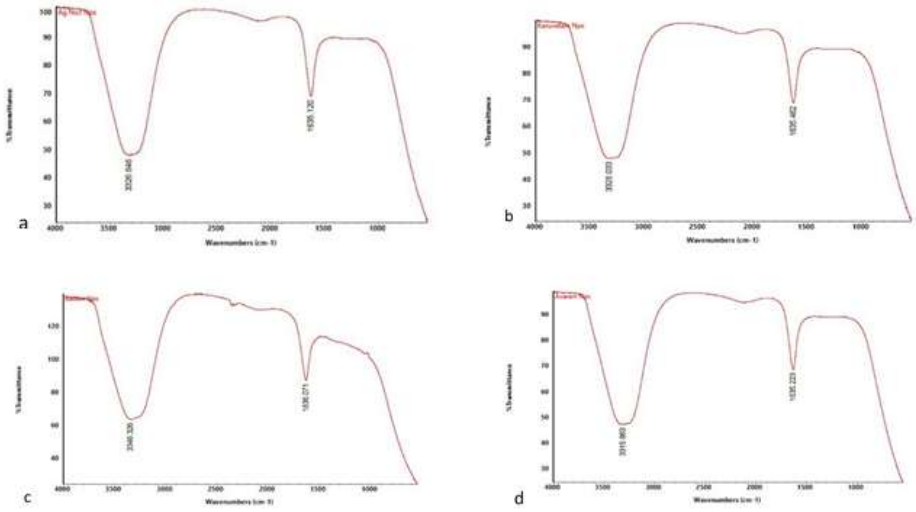

Figure 8 FTIR spectrum a) *Terminalia catappa* AgNO3 Nanoparticles, b) *Senna auriculata* AgNO3 Nanoparticles, c) *Acacia nilotica* AgNO3 Nanoparticles, d) AgNO3 Nanoparticles

Table 3 FTIR Analysis of SNP

Functional Group	Terminalia catappa	Senna auriculata	Acacia nilotica	AgNO3	Group Type & Role
O–H Stretch (broad)	~3316	~3328	~3346	~3327	Alcohols, phenols – hydrogen bonding & capping
C=O Stretch (carbonyl)	~1635	~1635	~1636	~1635	Aldehydes, ketones – involved in reduction

The C–H stretching peak of alkanes shows no significant change (2920–2926 cm^{-1}) before and after reactions, indicating that these groups are quite stable structurally and no direct participation in the reduction process. Finally, the C=O stretching bands are significantly shifted from 1725–1730 cm^{-1} of gums to lower wavenumbers (~1702–1710cm^{-1}) for the AgNP composites, indicating that carbonyl groups are involved in reduction of Ag^{+} ions.

Also, the carboxylate (COO^{-}) asymmetric stretching bands change from 1602–1605 to 1580–1588 cm^{-1} upon AgNP(s) production, and this provides evidence of a coordination bond between carboxylate groups and silver ions. The C–O–C/C–OH stretching bands of polysaccharides also shift to lower wavenumbers after the AgNP formation, which indicates this material as capping and stabilizing agent. Crucially, the emergence of additional bands at ~440–455 cm^{-1} is observed in these AgNP samples that are ascribed to vibrations involving Ag–O, confirming the formation of silver nanoparticles.

3.7 Antimicrobial Activity

The SNP were active against both Gram-negative and Gram-positive bacteria. A zone of inhibition was observed in all concentration investigations, and it was concentration-dependent. The mechanism of action of SNPs on bacterial cells to involve the interaction of silver ions with sulfur and phosphorus present in DNA upon their entry into the bacterial cell. The nanoparticles can then act on these soft bases and

destroy the DNA, resulting in cell demise. Additionally, it inhibits the replication of DNA and arrest the proliferation of microorganisms[15]. The agar well diffusion assay technique was used to assess the generated Ag NPs' antibacterial activity[16]. In this study fig 9, Table 4 shows the zone of inhibition for activity against SNP and *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa* SNPs

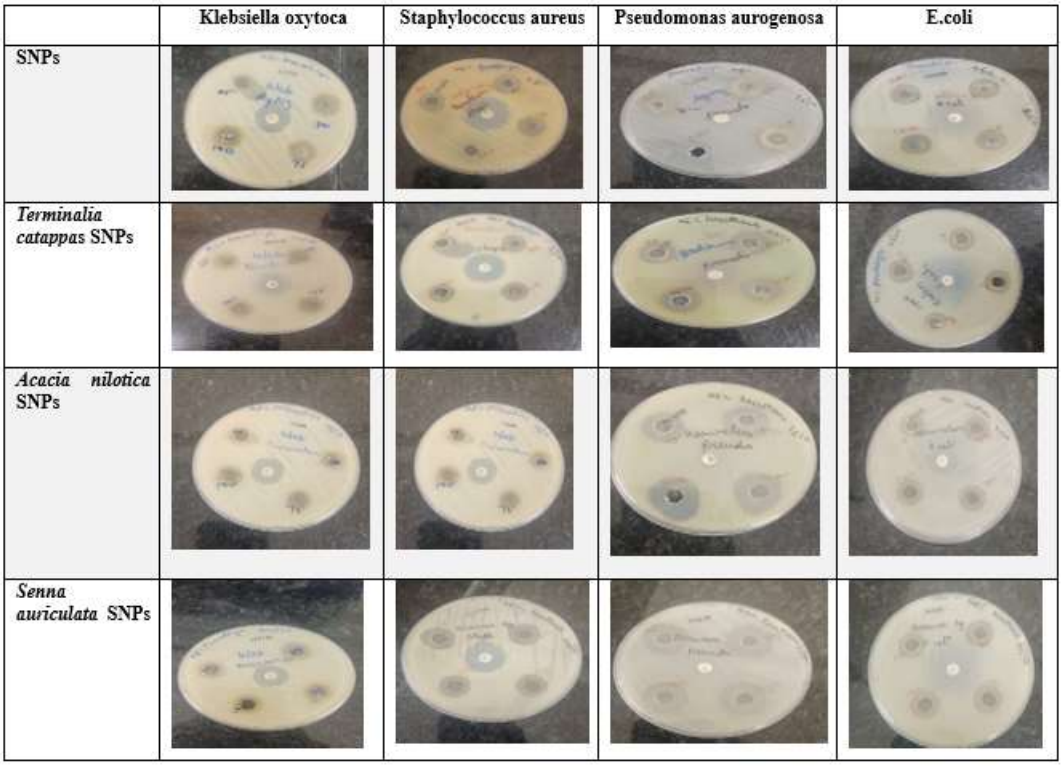

Fig 9 Antibacterial activity against SNP and *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa* SNPs

		25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100
1.	*Escherichia coli*	14	15	14	16	11	15	14	16	14	15	15	15	13	15	14	15
2.	*Klebsiella* sp.	0	15	15	15	15	14	16	13	0	0	0	16	15	19	16	16
3.	*Pseudomonas aurogenosa*	21	19	17	0	16	19	18	17	19	20	23	26	20	20	21	20
4.	*Staphylococcus aureus*	15	16	17	0	22	14	14	12	16	17	17	17	17	15	16	15

Table 4 Antibacterial activity against *Acacia nilotica*, *Senna auriculata*, *Terminalia catappa*

The antibacterial activity of SNPs, *Terminalia catappa* SNPs, *Acacia nilotica* SNPs and *Senna auriculata* SNPs is displayed in table 4 through utilizing bacteria such as E. *coli, Pseudomonas aurogenosa*, *Staphylococcus aureus*, and *Klebsiella sp*. Samples were collected for antibacterial activity in volumes of 25 µl, 50 µl, 75 µl, and 100 µl. According to these findings, the antibacterial activity of plant gums ranges from 11 to 26 mm for every gum.

The antimicrobial activity of SNPs s against Escherichia coli was demonstrated in the ground breaking[18], wherein SNPs -treated *E. coli* cells displayed the accumulation of SNPs in the cell wall and the formation of "pits" in the bacterial cell walls, ultimately resulting in cell death. Smaller particles with a higher surface-to-volume ratio demonstrated more effective antibacterial activity than larger particles in the same strain of *E. coli*. Additionally, SNPs antibacterial effectiveness depends on both size and structure. Four distinct types of saccharides with an average size of 25 nm were used to create SNPs, which shown strong antibacterial and bactericidal activity against both Gram-positive and Gram-negative bacteria, including extremely multi-resistant species like methicillin-resistant Staphylococcus aureus[17].

CONCLUSION:

Nanotechnology has emerged as a transformative field by enabling the manipulation of materials at the nanoscale, where unique physicochemical properties can be exploited for diverse applications. Generally, silver nanoparticle has a more medicinal uses and other applications. Synthesis of silver nanoparticle from plant gum is a novel approach of nanoparticles synthesis. In this

study, we compare green synthesised nanoparticle from *Acacia nilotica*, *Senna auriculata*, *and Terminalia catappa* plant gum. We study their morphology by using SEM, characterization like FTIR and its Antibacterial activity using *Escherichia coli, Klebsiella* sp., *Pseudomonas* sp., *Staphylococcus aureus* bacilli. By comparing these analysis, we can conclude that silver nanoparticle which is synthesised from *Terminalia catappa* is more efficient than other plant gums.

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CONFLICTS OF INTEREST
The authors declare that there is no conflict of interest.

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