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Original Article

SYNTHESIS OF *TAVERNIERA NUMMULARIA*-MEDIATED SILVER NANOPARTICLES FOR ENHANCED ANTIMICROBIAL AND ANTIOXIDANT ACTIVITIES

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ABSTRACT:

This study was designed to synthesize silver nanoparticles (AgNPs) using Taverniera nummularia leaf extract through a green synthesis approach and to evaluate their antimicrobial and antioxidant activities. Silver nanoparticles were synthesized using aqueous extracts of Taverniera nummularia leaves as a reducing and stabilizing agent. Characterization of the synthesized nanoparticles was carried out using UV–visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and X-ray Diffraction (XRD). Antibacterial activity was evaluated against Klebsiella pneumoniae, Escherichia coli, and Staphylococcus aureus. Antioxidant activity was assessed using DPPH, ABTS, and hydrogen peroxide scavenging assays. The UV–visible spectrum showed a characteristic surface plasmon resonance peak at 407 nm, confirming the formation of AgNPs. FTIR analysis revealed hydroxyl functional groups from plant biomolecules responsible for the reduction of silver ions. SEM analysis confirmed spherical nanoparticles with sizes ranging from 120–200 nm. XRD patterns demonstrated the crystalline structure of the synthesized nanoparticles. The green synthesized AgNPs exhibited antibacterial activity against the tested bacterial species. Additionally, significant free radical scavenging activity was observed in DPPH, ABTS, and hydrogen peroxide assays, indicating notable antioxidant potential. Taverniera nummularia leaf extract is an effective reducing and stabilizing agent for the green synthesis of silver nanoparticles. The synthesized AgNPs demonstrate promising antimicrobial and antioxidant properties and may have potential applications in biomedical research, particularly in the development of nano-drug delivery systems and other clinical applications.

Keywords: Silver nanoparticles, Taverniera nummularia, Green synthesis, Antimicrobial activity, Antioxidant activity.

INTRODUCTION

In recent years, nanotechnology has become an important part of the scientific literature and is considered one of the most advanced technologies of today. It focuses on the production of nanoparticles (NPs) in various sizes and shapes within the nanometer range for the benefit of human health (1). In nanotechnology, the different properties, behaviors, and control of nanomaterials are examined in comparison with bulk materials (2). Due to their nanoscale size, NPs are used in many fields such as pharmaceuticals, the food packaging industry, open wound healing, and information technology (3), as well as in agriculture, food industries, chronic ulcer management, wound dressing, medicine, and cosmetics (4,5). Various types of nanoparticles have been developed, including copper (6), titanium–nickel (7), palladium (8), gold (9), and silver (10). Among these, silver nanoparticles (AgNPs) play an efficient role because of their strong antimicrobial effects against fungi (11), bacteria (12), and other eukaryotic microbes. They also function as theranostic agents (13) and possess antitumor properties (14). Colloidal silver particles possess desirable properties such as electrical conductivity, catalytic activity, chemical stability, and antibacterial effects (15). Silver ions exhibit a strong inhibitory effect against microbes and are considered permanent inhibitors (16). AgNPs are generally non-toxic to human cells when used in small amounts and may also be environmentally beneficial. Scanning electron microscopy (SEM) analysis has shown interactions between AgNPs and fungal cells, resulting in cell death due to membrane rupture (17).

Scientists show greater interest in AgNPs compared with other nanoparticles. These particles typically range from 1–100 nm in size, similar to the size of human body proteins. They play a significant role in surgical applications, wound care products, antioxidants, and antimicrobial agents (18). Through the reactivity of reactive oxygen species (O_2 species), AgNPs play an important role in cellular interactions and demonstrate inhibition comparable to the standard antioxidant drug ascorbic acid (19). Extracts of Myrtus communis have also been used to synthesize AgNPs that neutralize free radicals and enhance phenolic content (20).

However, conventional nanoparticle synthesis often involves toxic reducing agents and chemical solvents or surfactants, which may pose environmental and health risks (21). Large-scale synthesis of bulk materials can also generate harmful waste products during the nanoparticle production process (22). Therefore, biological and green synthesis methods are preferred for the biosynthesis of AgNPs, as plant extracts contain strong antioxidant phytochemicals that facilitate nanoparticle formation (23). In many cell types, AgNPs can induce necrosis or apoptosis (24). The genus Taverniera belongs to the family Fabaceae and is commonly found near small stream banks, particularly in saline soils (25). Taverniera nummularia leaves are used in poultices for sloughing wounds (26). Externally, the plant is used for treating swelling, ulcers, and abscesses (25). The roots are used orally for throat problems (27), and the seeds are used for the treatment of cough, while fried seeds are used to treat hoarseness of voice (28).

In this study, T. nummularia plant material was collected and processed to obtain an extract, which was subsequently used to synthesize silver nanoparticles (TN-AgNPs). The plant identity was confirmed, and a voucher specimen was deposited in the university herbarium. The extract was prepared by washing, drying, and grinding the plant material, followed by extraction with 80% methanol. The synthesized TN-AgNPs were characterized using various techniques, including UV–Vis spectrophotometry, X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FT-IR), and scanning electron microscopy (SEM). Factors affecting the synthesis process, such as pH and TN extract concentration, were also investigated. The results indicated successful synthesis and confirmed the crystalline nature and size of the TN-AgNPs. The antioxidant activities of TN-AgNPs were evaluated using DPPH, H_2O_2, and ABTS assays, demonstrating their potential as free radical scavengers. Furthermore, the antibacterial and antifungal activities of TN-AgNPs were assessed against various microbial strains, revealing significant inhibitory effects. Overall, this study highlights the green synthesis of TN-AgNPs and their potential applications in medicine and materials science.

METHODS

Plant Collection and preparation of extract

Taverniera nummularia, sourced from the township area of Bannu in KP, Pakistan, underwent botanical verification by Dr. Fizan Ullah Khan, Head of the Department of Botany at UST Bannu. A voucher specimen was duly archived in the university's herbarium. Upon identification, the entire plant was thoroughly washed with deionized water and left to air-dry in the shade for one month. Once fully dried, 1 kg of the plant material was finely ground into powder using a local grinder. Subsequently, 200 g of this powdered material was immersed in 80% methanol, subjected to agitation in a shaker for two days, and then filtered. The filtrate was brought to room temperature and concentrated using a Buchi Rota vapor R-200 evaporator. The resulting thick extract was measured and stored at 4°C for use in later experiments.

Synthesis of T. nummularia silver nanoparticles (TN-AgNPs)

With a minor modification, we employed established methods to synthesize silver nanoparticles (AgNPs) from plant materials (29). A 0.01 M silver nitrate solution was prepared by dissolving it in 50 mL of deionized water, which was then serially diluted tenfold by adding 1 mL of the solution to 9 mL of deionized water. Separately, 2 g of plant extract was dissolved in 100 mL of methanol, and the pH was adjusted using NaOH before the mixture was incubated overnight on a shaker. Another solution was prepared by mixing 1 mL of AgNO3 with 9 mL of deionized water, followed by pH adjustment with NaOH. Subsequently, 1 mL of the crude plant extract was added to the AgNO3 solution, and the mixture was allowed to react for 24 hours or until a brownish color appeared, indicating the formation of silver nanoparticles.

Factors affecting synthesis rate, size, and shape of AgNPs

We investigated several factors that could influence the formation of AgNPs, including pH, concentrations of silver nitrate and plant extract, temperature, and reaction time. The pH was adjusted from 8 to 12 using sodium hydroxide and hydrochloric acid, as it significantly affects nanoparticle size. By controlling the pH, we were able to modulate the size of the nanoparticles (30). Different volumes of plant extract, ranging from 100 to 1000 μL, were also tested to evaluate their effect on nanoparticle formation. Variations in silver nitrate concentration similarly influenced the size and morphology of the nanoparticles, with higher concentrations yielding smaller nanoparticles and lower concentrations producing larger ones. Our primary objective was the eco-friendly synthesis of silver nanoparticles using the plant extract (31).

Characterization of Silver AgNPs

The concentration of TN-AgNPs synthesized via green methods was measured using a SHIMADZU UV SPECTROPHOTOMETER (UV-1800). The presence of various phytochemicals in the purified TN-AgNPs and TN-extract was analyzed using a Fourier Transform-Infrared (FT-IR) spectrometer (Shimadzu, IR Prestige-21, Japan). The crystalline nature of TN-AgNPs and TN-extract was examined using an X-ray diffractometer (XRD) (Model D-8 Advance, Germany) with a wavelength of 1.54 Å. The size and morphology of TN-AgNPs were determined using a JEOL Scanning Electron Microscope (SEM) (MIRA3 TESCAN model). Additionally, Energy-Dispersive X-ray spectroscopy (EDX) was employed to confirm the presence of elemental silver in the TN-AgNPs.

Activities of in vitro antioxidants:

1,1-diphenyl-2-picrylhydrazyl Activity

A 3 mg amount of 1,1-diphenyl-2-picrylhydrazyl (DPPH) was accurately weighed and dissolved in 50 mL of methanol. The initial absorbance of the DPPH solution at 0.765 nm was determined using Formula 1. The free radical scavenging activity of the plant extract, AgNPs, and ascorbic acid was evaluated using a modified method adapted from Brand-Williams, Cuvelier, & Berset, 1995 (32). A stock solution of the plant extract (1 mg/mL in water) was prepared, which also included the silver nanoparticles and ascorbic acid. Serial dilutions were then made to obtain concentrations of 20, 40, 80, and 100 µg/mL. For each concentration, 100 µL was mixed with 900 µL of DPPH solution in separate test tubes, thoroughly shaken, and incubated in low light for 30 minutes. The absorbance was measured at 517 nm using water as a blank. The percentage of DPPH inhibition was calculated by comparing the absorbance after reaction with the original DPPH absorbance.

% Scavenging=Ac-As/Acx 100 (1)

Ac = Controlled absorbance

As = Sample absorbance

H_2O_2 Scavenging Activity

The method described by Pick & Mizel, 1981 (33) was slightly modified. A 50 mM phosphate buffer (pH 7.4) containing 2 mM hydrogen peroxide was prepared. Various concentrations (20, 40, 80, and 100 µg/mL) of ascorbic acid, silver nanoparticles, and plant extract were tested. For each sample, 0.2 mL was mixed with 0.6 mL of hydrogen peroxide and 0.4 mL of phosphate buffer. The mixtures were shaken, and absorbance was measured at 230 nm after 15 minutes. For samples with an initial absorbance of 0.81, the hydrogen peroxide scavenging activity of silver nanoparticles and plant extract was calculated.

ABTS Radical Scavenging Activity

The ABTS assay was performed based on Mathew & Abraham, 2006 (34) with minor modifications. A stock solution was prepared by mixing equal volumes of 7 mM ABTS and 2.45 mM potassium persulfate and incubated in darkness at 37°C for 24 hours to generate ABTS radicals. The stock solution was then diluted with 50% methanol to prepare the working solution. At 30°C, the initial absorbance was approximately 0.936. Different concentrations (25, 50, 75, and 100 µg/mL) of the plant extract were tested by adding 0.2 mL of each concentration to 0.8 mL of ABTS solution (initial absorbance 0.836). After 6 minutes of mixing, the decrease in absorbance was recorded. The experiment was performed in duplicate, with ascorbic acid as a positive control.

Antimicrobial Screening of AgNPs

The antibacterial activity of silver nanoparticles was evaluated against Staphylococcus aureus, Escherichia coli, and Klebsiella pneumoniae. S. aureus showed no inhibition, whereas E. coli and K. pneumoniae (Gram-negative) were affected. Nutrient agar was prepared by dissolving 7 g of nutrient agar powder in 250 mL distilled water (pH 7), autoclaved, and cooled to 45°C. Plates were poured with 40 mL of agar under sterile conditions. Fresh bacterial cultures were spread using sterile cotton swabs, and four wells were made in each plate using a cork borer. A 1 mg/mL stock solution of AgNPs was prepared and further diluted to 150 and 300 µg/mL for testing. Erythromycin served as a positive control and DMSO as a negative control. Plates were incubated at 37°C for 24 hours, and inhibition zones around the wells were measured to assess antibacterial activity at different concentrations.

RESULTS

Concentration Study

AgNPs were synthesized by utilizing a plant extract. Ten solutions were prepared by combining a pH 11 1x10^{-3} M AgNO3 solution. Subsequently, varying volumes of methanolic plant extract solution ranging from 100 µL to 1 ml were added to these solutions. After a 24-hour incubation period, the color of these solutions transformed to a yellowish-brown, indicative of the successful synthesis of AgNPs.

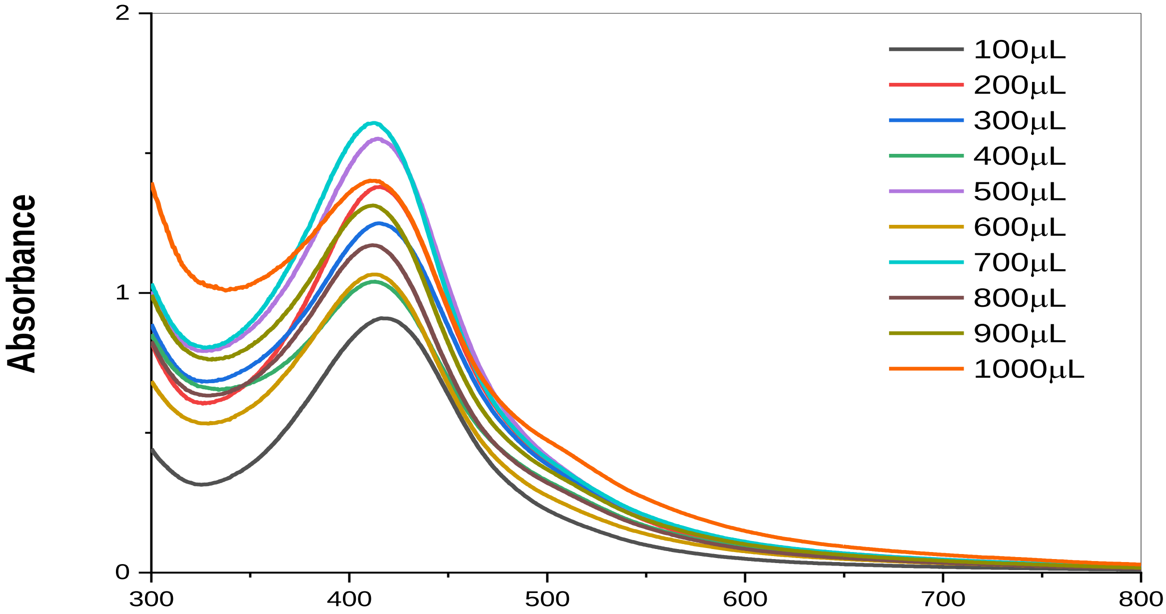

Figure 1. Impact of Taverniera nummularia plant extract concentration on the synthesis of AgNPs.

UV-visible spectrophotometric analysis of TN-AgNPs

The TN-AgNPs aqueous solution show yellowish brown colour due to surface plasmon resonance (SPR). The mixing of TN- extract and $AgNO_3$ solution the appearance of light brown colour indicate the Ag^+ bio reduction by the TN active molecules. At the range of 200 – 800 nm at a temperature of 40C, after 24 hr. incubation, pH 11, 1mM salt concentration and 1mL TN- extract concentration spectrophotometer indicate a peak of 2.0 At absorbance of 407 nm for the TN- AgNPs.

(A) **(B)**

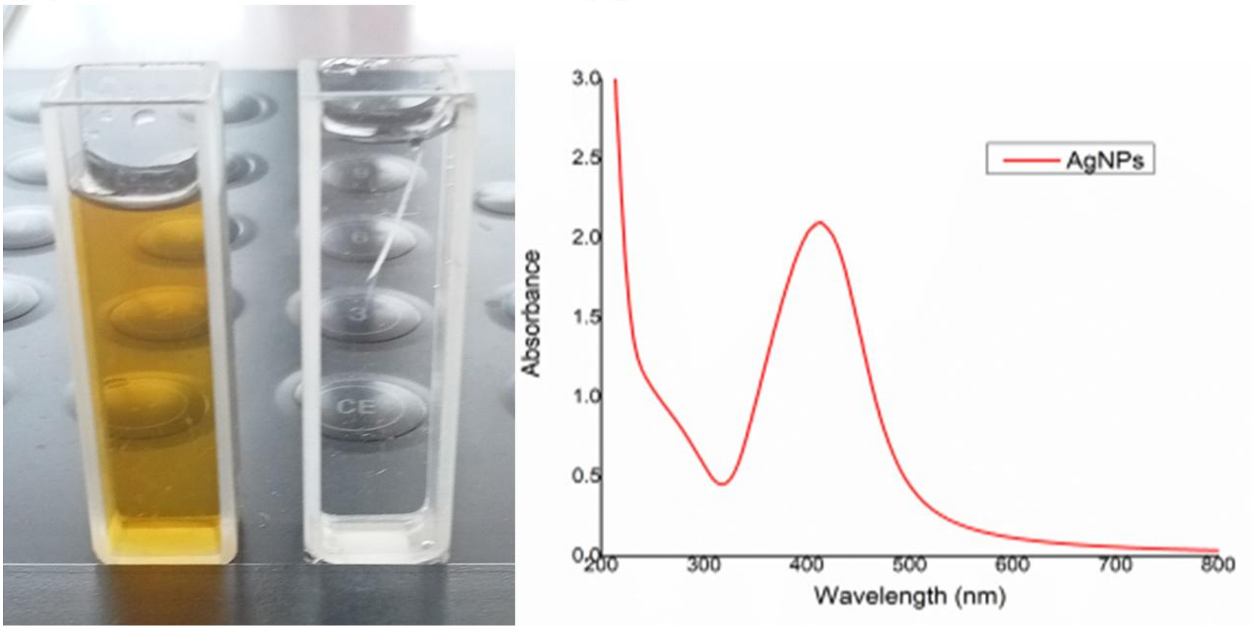

Figure 2. (A) Yellowish brown colour of AgNps. (B) The UV-vis absorption spectrum of TN-AgNPs

FT-IR analysis of TN-extract and TN-AgNPs

Fourier Transform Infrared(FTIR) spectrum analysis of TN-extracts and AgNPs (Silver Nanoparticles) prepared in water. The analysis involves identifying peak values and probable functional groups present in the TN-extracts and AgNPs. The characteristic absorption band were demonstrated in the range exist in FTIR chart. The observed FTIR peaks of TN-extracts and AgNPs values were compared to standard values in the FTIR chart to identify the exact functional groups responsible for the bio reduction process. Figure 4 showed peaks at 3772, 3415, 2957, 2568, 2262, 2147, 1638, 861, and 644 cm^{-1} by TN-extracts. 3766, 3510, 3167, 2606, 2153, 1714, 1440, 1045, and 765 cm^{-1} by AgNPs. Different functional groups correspond to these peaks. The peak at 3772 and 3766 in FT-IR indicates that there must O-H group of alcohol compounds; peak at 3415, 3510 and 3167 cm^{-1} corresponded to N-H stretching functional group of primary amine, aliphatic primary amine, and secondary amine; 1714, 1638, and 1440 cm^{-1} band corresponds to C=O stretching correspond to carboxylic acid, C=C stretching correspond to alkene and O-H bending correspond to carboxylic acid respectively. Different vibrating stretching of functional groups correspond to all other peaks.

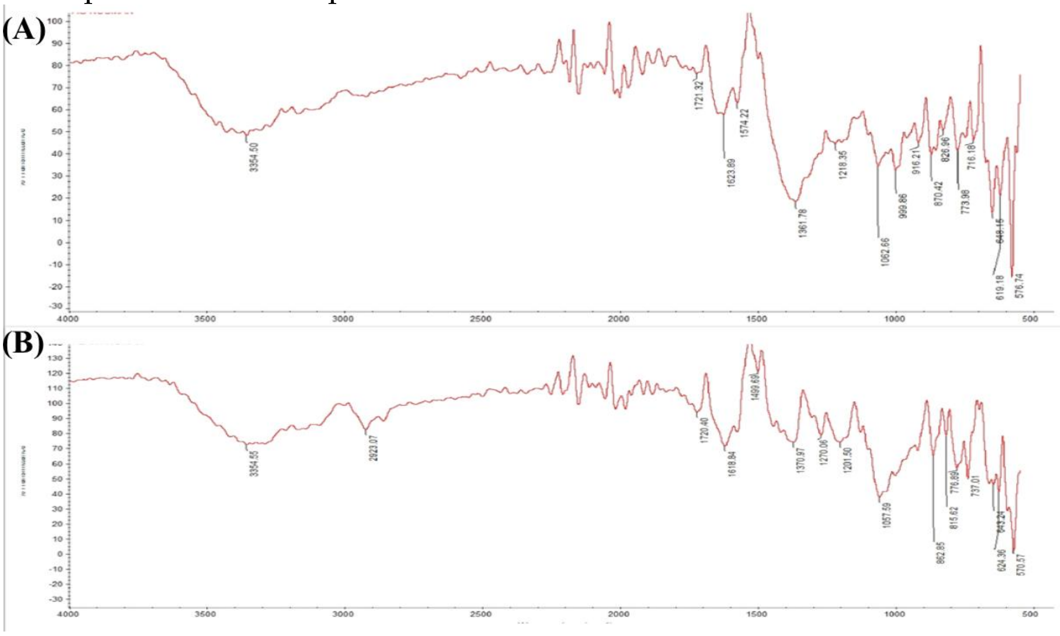

Figure 3. FTIR analysis of (A) TN-extract (B) AgNPs

XRD analysis of TN-AgNPs

The sample of TN-AgNPs were analyzed by XRD. Figure 3. show Bragg reflections at angles of 38.21(111), 46.29(200), 64.64(220), and 77.55(311) showed the varius diffrection peaks respectively (Sathiyaraj et al., 2021). The face-centered cubic crystal structure of the silver ions in these reflections can be confirmed by indexing the faces. Interplanar spacing (d) and Miller constants (a) values are then calculated using Debye-Sherrer's equations 3 and 4 respectively:

$$Dhkl = \frac{\pi}{2\mathrm{Sin}\theta hkl} \qquad (3)$$

$$å = dhkl\ (h2 + k2 + l2)1/2 \qquad (4)$$

By using Debye-Sherrer's formula 5, the average crystalline size of TN-induced AgNPs is calculated

$$D = \frac{K\lambda}{\beta\cos\theta} \qquad (5)$$

D = the average crystalline size,
k = geometric factor (0.9),
λ = wavelength of the X-ray radiation source, and
β = angular FWHM (full-width at half maximum) Here is a more casual summary:

To calculate the average crystal size of the silver nanoparticles, we measured the full-width at half maximum (FWHM) of some of the major peaks in the XRD pattern. Specifically, we looked at the peaks around 38.21°, 46.29°, 64.64°, and 77.55°. The FWHM is related to the crystalline size by a formula that includes the Bragg diffraction angle (θ). By plugging in the FWHM and θ values for each of those 4 peaks, we were able to calculate the crystalline size. The average size we calculated from those peaks was around 110 nanometers. So based on the XRD analysis, the silver nanoparticles produced had an average crystalline domain size of 110 nm.

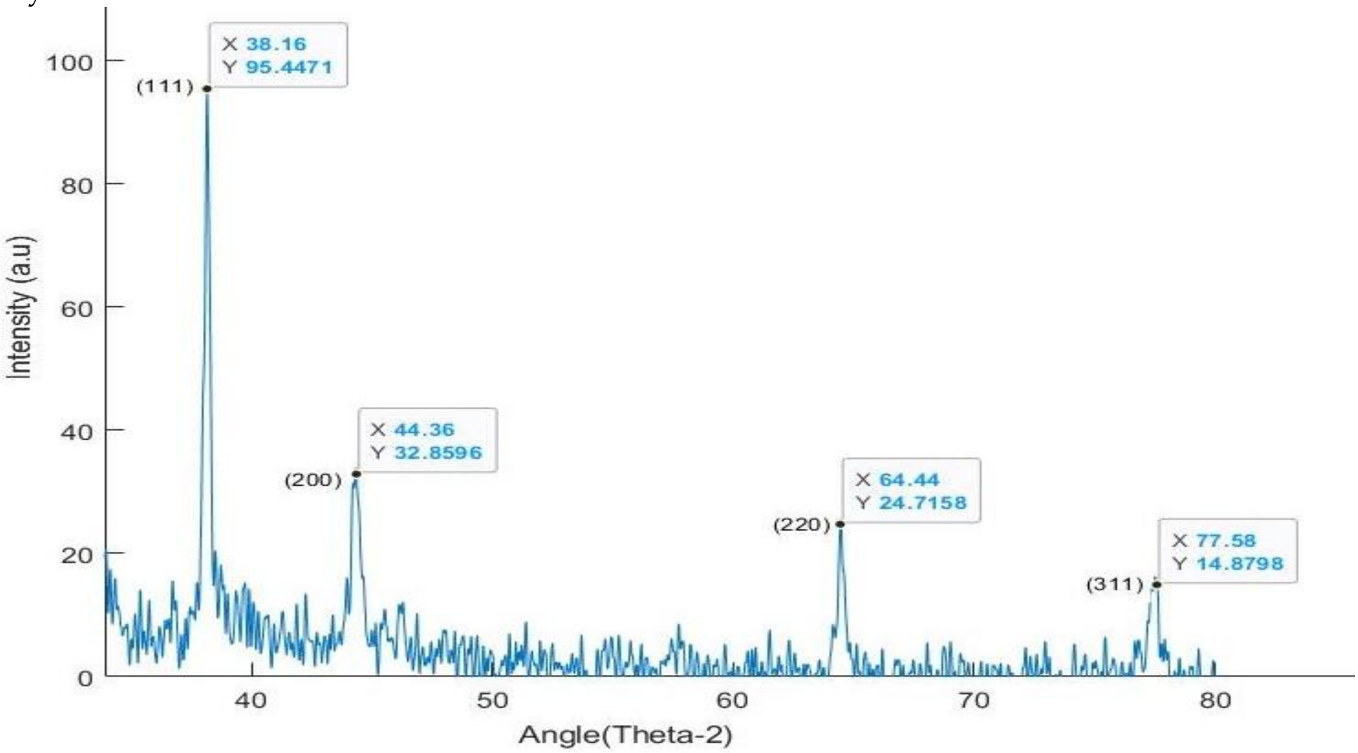

Figure 4. XRD analysis for Taverniera nummularia-derived AgNPs.

SEM analysis of TN-AgNPs

SEM was used to examine the surface morphology of TN-AgNPs. The SEM findings reveal that TN-AgNPs exhibit a monodispersed and spherical-shaped structure, reaching maximum density (Figure 5). The average particle size was determined using Nano Measurer software by analyzing 100,000 particles and was found to be 0.1 nm.

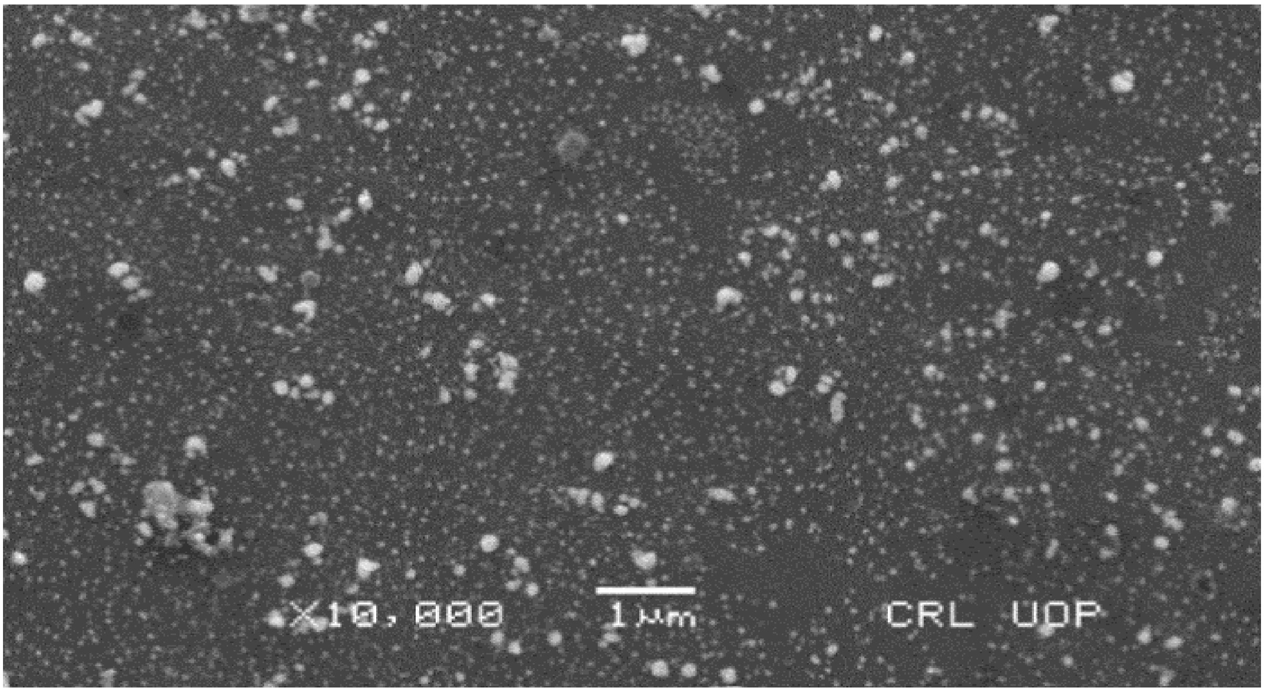

Figure 5. SEM examination of AgNPs made from plant extract of *Taverniera nummularia*.

Antioxidant assays

DDPH scavenging assay

The antioxidant capability of the produced AgNPs was assessed through the DPPH activity method as outlined by Brand-Williams et al. (35). As a reference, ascorbic acid, a well-known free radical scavenger, demonstrated the highest inhibition in Figure 6 (blue bars). Notably, the synthesized AgNPs exhibited superior antioxidant properties compared to the plant extract alone, with the gray bar indicating plant extract inhibition and the yellow bar representing nanoparticles. The figure illustrates the DPPH activity using AgNPs synthesized from the plant extract of TM.

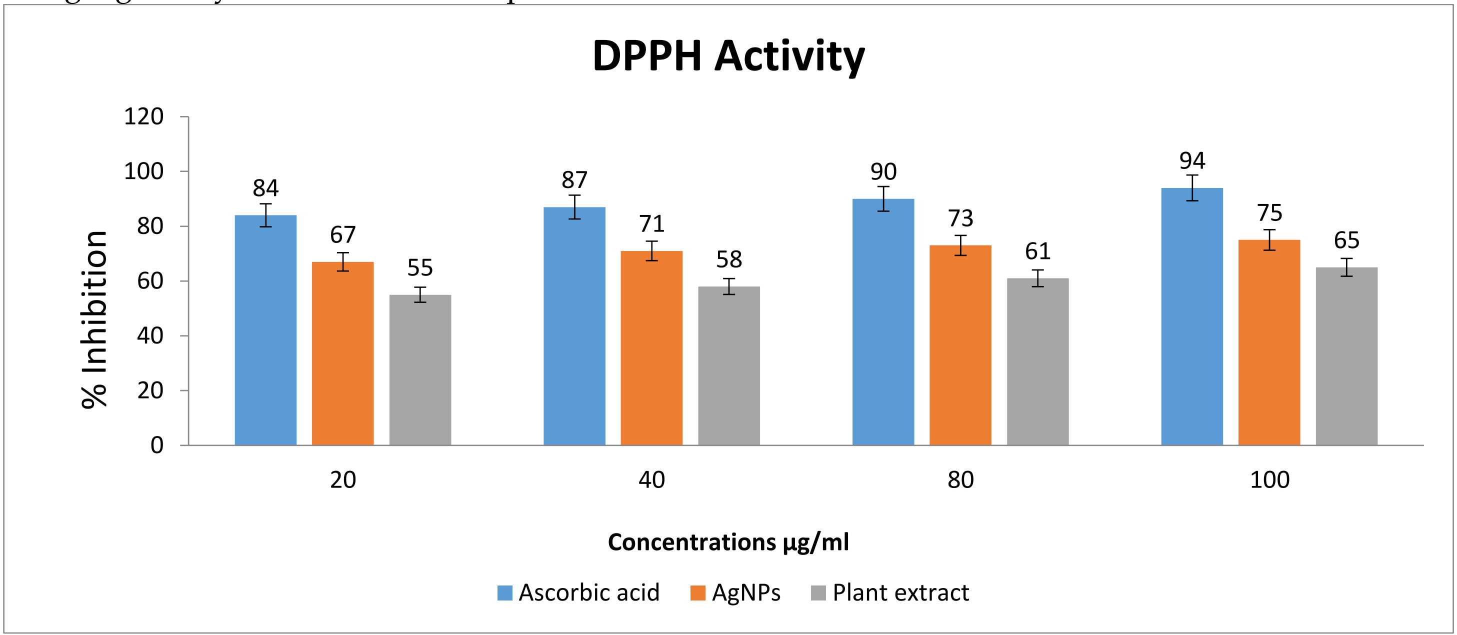

Figure 6. Evaluating the effectiveness of ascorbic acid, synthetic AgNPs, and *Taverniera nummularia* plant extract in scavenging DPPH free radicals.

Hydrogen peroxide scavenging (H_2O_2)

For the evaluation of hydrogen peroxide scavenging activity, we utilized a modified version of Pick & Mizel (36). AgNPs and plant extracts both demonstrated free radical scavenging abilities, with ascorbic acid exhibiting the highest capacity for scavenging free radicals.

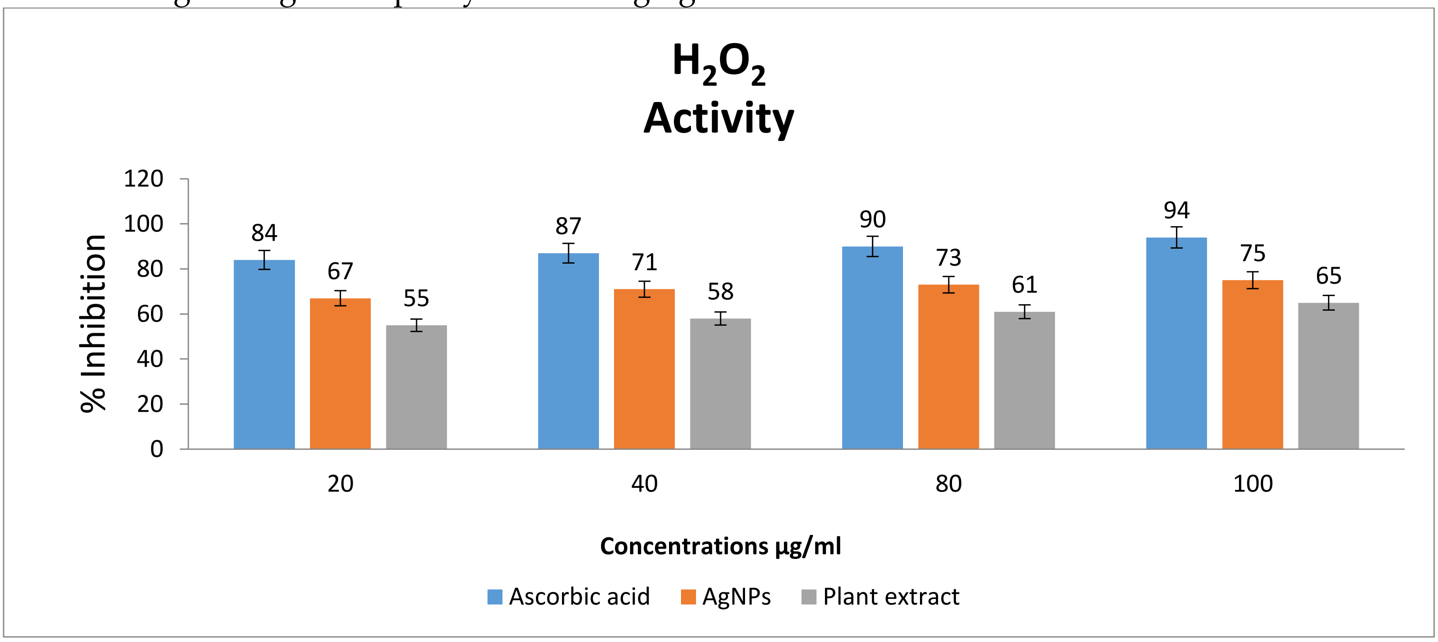

Figure 7. Evaluating the scavenging activity of hydrogen peroxide free radicals.

ABTS screening assay

ABTS is used similarly to DPPH to measure antioxidant effects. We made an ABTS stock solution and diluted it. Then mixed different amounts of the test samples with the ABTS and measured any decrease in absorbance over time. A lower final absorbance means more ABTS radicals were scavenged, indicating better antioxidant effects. We did this with some modifications to the typical ABTS method given by Mathew & Abraham, 2006).

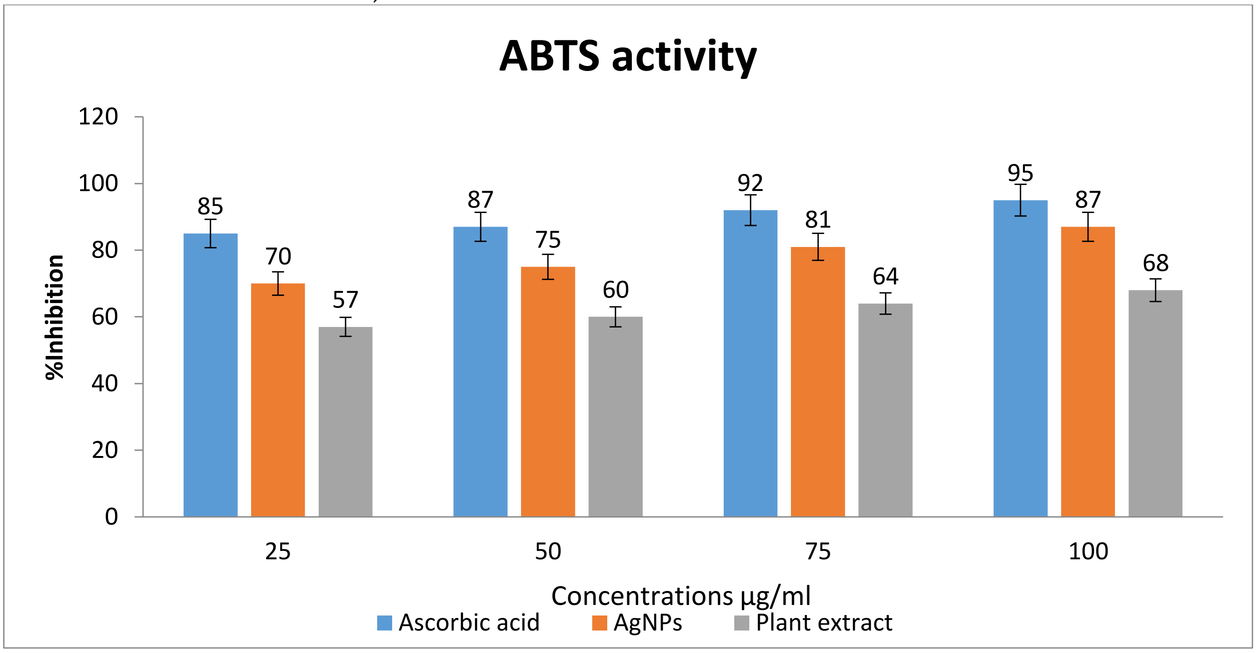

Figure 8. Ascorbic acid, AgNPs, and a *Taverniera nummularia* plant extract demonstrate ABTS free radical scavenging capabilities.

In-vitro antifungal and antimicrobial activities

We tested different concentrations of AgNPs and the TN plant extract against fungal and bacterial strains. For fungi, both 150 and 300 µg/mL of AgNPs and TN showed significant inhibition compared to the control, with AgNPs inhibiting more (zones 30-41 mm vs 39-57 mm for TN). For bacteria, AgNPs also exhibited stronger antimicrobial activity than TN based on larger inhibition zones (12-20 mm vs 3.4-9.1 mm). Both AgNPs and TN were effective against all strains tested. DMSO was negative and levofloxacin/terbinafine positive controls confirmed the results. So in summary, AgNPs and TN demonstrated notable antifungal and antibacterial properties in this study.

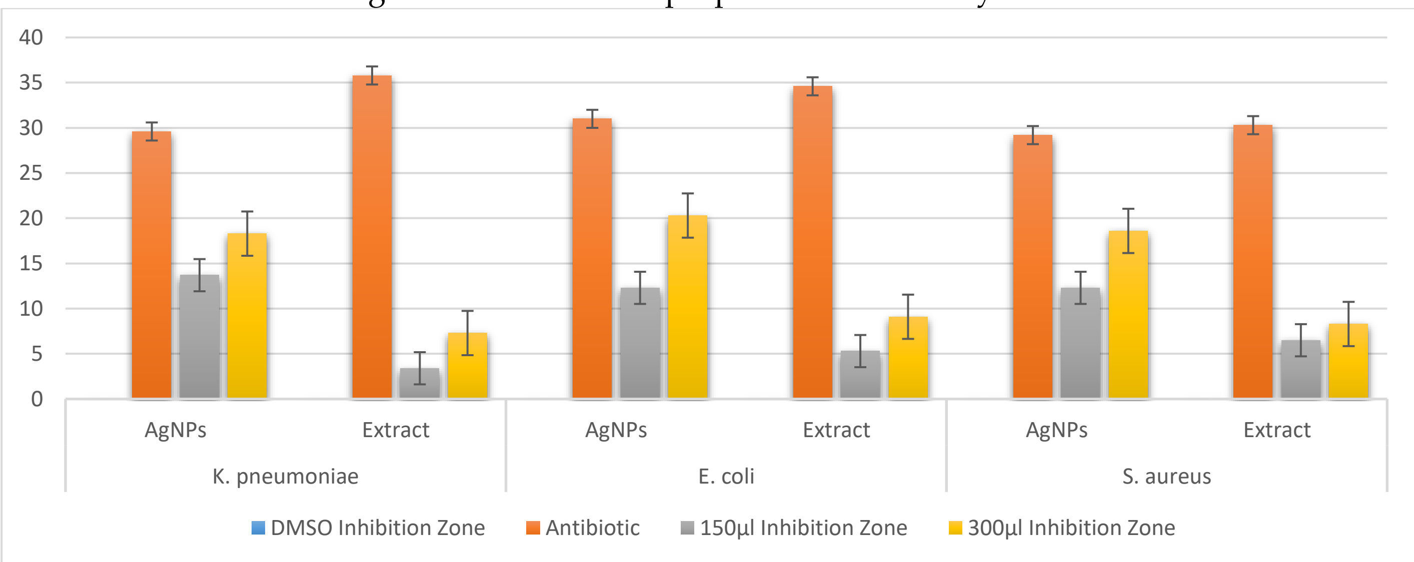

Figure 9. The antibacterial properties of *T. nummularia* plant extract and synthesized AgNPs were observed against the three bacterial strains.

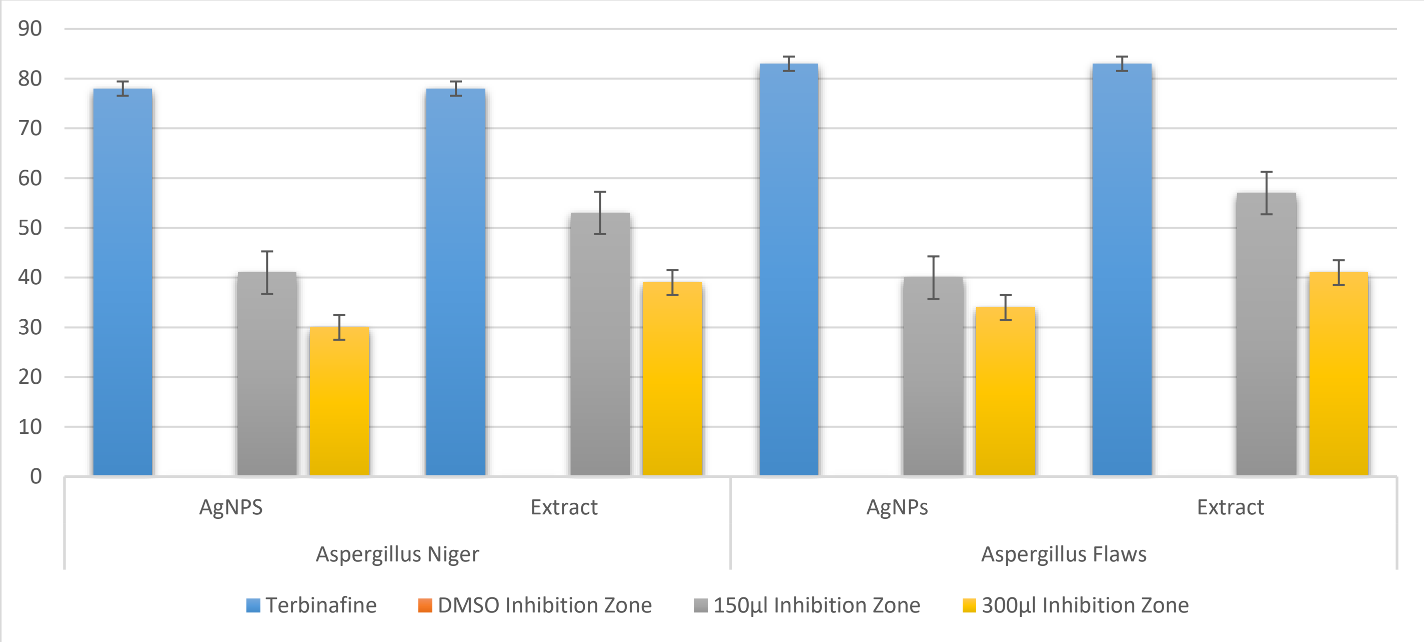

Figure 10. The antifungal activity of the plant extract and the synthesized silver nanoparticles from *T. nummularia* was assessed against the aforementioned fungal strains.

DISCUSSION

This study looked at synthesizing AgNPs using T. nummularia leaf extract, which has potential benefits in pharmaceuticals. The synthesis of AgNPs involved the use of silver nitrate as the reducing agent and leaf extract as the starting material. We investigated various factors that influence AgNP formation. Factors like temperature, silver nitrate concentration, the ratio of leaf extract to silver nitrate solution, pH, and reaction time were considered. The confirmation of AgNP formation involved identifying the functional groups responsible for reducing silver nitrate and the capping agents present in the leaf extract. The leaf extract used in AgNP synthesis was then characterized using UV-Vis spectroscopy, FTIR, EDS, and TEM to analyze its properties and composition. The goal was to optimize the AgNP synthesis process using this leaf extract as a natural, eco-friendly method.

The antibacterial activity of the produced AgNPs against Escherichia coli (E. coli) was also investigated. The research demonstrated that the synthesized AgNPs from T. nummularia exhibit a spherical shape, as confirmed by SEM analysis. FTIR analysis revealed the presence of various phytochemical components in the plant extract, contributing to the stability and mediation of nanoparticles. It was found that FTIR analysis is a valuable tool for identifying functional groups, and the results indicated the existence of hydroxyl, carboxyl, and amide groups, which play a crucial role in reducing metal ions to produce nanoparticles, as supported by previous scientific studies (37,38). Green-synthesized nanoparticles and phyto-components play a significant role in nanoparticle stabilization and exhibit applicative properties (39).

The crystalline structure and size of AgNPs were analyzed using X-ray diffraction (XRD), revealing distinct diffraction peaks at 2Θ values of 38.16° (111), 44.36° (200), 64.48° (220), and 77.56° (311). These peaks confirmed the crystalline nature of the produced particles and indicated an average size of approximately 110 nm. XRD analysis of TN-AgNPs unveiled four distinct peaks, providing additional confirmation of the crystalline nature of the AgNPs. Consistent findings were reported in previous studies (40).

The antioxidant properties of AgNPs synthesized from T. nummularia plant extract were assessed using the DPPH assay and ROS determination techniques. No unfavorable inflammatory responses were observed. Chitosan, chosen for its beneficial biological characteristics such as non-toxicity, biocompatibility, biodegradability, and antibacterial capacity, also serves as a cell proliferation booster and drug delivery carrier.

The DPPH activity test utilized AgNPs derived from the T. nummularia plant extract as a baseline to assess the antioxidant capability of the synthesized AgNPs. Ascorbic acid served as a standard reference because of its outstanding free radical scavenging properties. Increasing concentrations of AgNPs, plant extract, and ascorbic acid enhanced their efficiency in scavenging free radicals. At a concentration of 100 µg/mL, ascorbic acid demonstrated 98% activity, outperforming both plant extract (67%) and AgNPs (79%). Both AgNPs and plant extract exhibited the ability to scavenge free radicals, with AgNPs showing superior scavenging activity compared to the plant extract (41). The addition of AgNPs to the solution caused a color change, representing the donation of electrons to DPPH, which stabilizes the radical (Molyneux, 2004). The efficiency of the green-synthesized AgNPs was attributed to the presence of various phytochemicals in the extract (42).

Hydrogen peroxide, an inorganic and highly reactive oxidant, is known to cause severe damage to the cell membrane of living systems. In the current study, the hydrogen peroxide assay was conducted using different concentrations of AgNPs and TN-extract ranging from 20 to 100 μg/mL. The results revealed 94%, 75%, and 64% inhibition by ascorbic acid, AgNPs, and TN-extract, respectively, at the highest concentration of 100 μg/mL. This study aligns with previous research on AgNPs derived from Iresine herbstii, indicating enhanced antioxidant and biological activities (43). Relative to previous results (44), ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)) exhibits significant potential in scavenging free radicals, with maximum absorbance typically observed at 734 nm. In the current study, a decrease in absorbance was noted with increasing concentrations of AgNPs (45). The scavenging ability of bio-synthesized AgNPs and TN-extract against the ABTS free radical was evaluated. The results demonstrated an effective free radical % scavenging potential of 86% for AgNPs and 69% for TN-extract (46). Numerous studies have focused on silver nanoparticles (AgNPs) to augment the antibacterial features of medical items, particularly wound dressings. Research has explored integrating AgNPs into chitosan-based membranes to assess their impact on wound healing efficacy. Notably, AgNPs demonstrated substantial antimicrobial activity against both Gram-positive and Gram-negative bacteria, with the most significant zone of inhibition observed against Gram-negative bacteria (47). The synthesized TN-AgNPs extract was assessed for its antibacterial properties using three bacterial strains—Klebsiella pneumoniae, Escherichia coli, and Staphylococcus aureus. The zones of inhibition (mm) exhibited by AgNPs were measured, with the most effective performance observed at a concentration of 300 μg/mL AgNPs. Klebsiella pneumoniae demonstrated the greatest zone of inhibition, specifically 18.3 ± 0.78 mm. The study also suggests the potential use of AgNPs as an antifungal agent in drug therapy for human infections (Panácek et al., 2009). Different concentrations of AgNPs on various fungal strains showed significant growth inhibition, as reported previously (48).

CONCLUSION

The recent experimental findings highlight the promising potential of *Taverniera nummularia* (*T. nummularia*) as an efficient and environmentally friendly method for the rapid synthesis of silver nanoparticles, offering versatility for various clinical applications. In-depth analysis via Fourier Transform-Infrared (FT-IR) spectroscopy indicates that the crude methanolic extract from *T. nummularia* exhibits key functional groups essential for nanoparticle synthesis. The resulting silver nanoparticles, as evidenced by X-ray diffraction (XRD) and scanning electron microscopy (SEM), display crystalline properties and distinctive aggregate characteristics. Moreover, the synthesized silver nanoparticles demonstrate noteworthy antimicrobial activity, showing significant efficacy against both bacterial and fungal strains. Additionally, they exhibit substantial antioxidant properties, with strong free radical scavenging capabilities. These findings underscore the multifaceted applications and promising attributes of *T. nummularia* in silver nanoparticle synthesis, contributing to advancements in both medical and environmental domains.

Conflict of Interest

Authors declare no conflict of interest.

Ethical consideration

The study was approved by local research ethics committee.

Author contributions

SNS conceptualization and experiments, YMH supervise and review it. OA review and manage the writing scientifically.

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