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SYNTHESIS, CHARACTERIZATION, AND BIOLOGICAL EVALUATION OF SILVER NANOPARTICLES USING *ASPERGILLUS TAMARII* FROM *FAGONIA INDICA*

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Abstract

The manipulation of materials at the 1–100 nanometer (nm) scale is known as nanotechnology, and it has revolutionized several fields, including catalysis, environmental research, and medicine. When compared to traditional techniques, green nanotechnology, which produces nanoparticles using microbial extracts, offers a cost-effective and eco-friendly replacement. Due to its potential use in medicine, silver nanoparticles (Ag-NPs), which are known for their antibacterial properties, have garnered a lot of attention. This research investigates the biogenesis of Ag-NPs with *Aspergillus tamarii (A. tamarii*) obtained from *Fagonia indica* and assesses their antibacterial properties. UV-Vis spectroscopy revealed an absorption peak at 417 nm, confirming the production of Ag-NPs. FT-IR analysis confirmed the presence of functional groups involved in reducing and stabilizing Ag-NPs, while scanning electron microscopy (SEM) displayed oval and spherical nanoparticles averaging approximately 15.4 nm in size. Zeta potential assessment revealed a negative charge (-16.1 mV), which aids in their stability. The Ag-NPs demonstrated potent antibacterial effects, especially against *Bacillus subtilis*, achieving a peak inhibition zone of 40 ± 0.5 mm at a concentration of 5 mg/mL. Additionally, biological activities were evaluated, including antioxidant activity, total flavonoid content (TFC), and total phenolic content (TPC). Promising results were obtained from biocompatibility testing such as hemolytic assays and brine shrimp lethality assessments. This study demonstrates that the biosynthesized Ag-NPs are as effective as traditional materials used in pharmacological studies and could be used in future biotherapies and diagnosis.

Key words: Antioxidant activity; Antibacterial activity; Green formulation; Biocompatibility

Introduction

The modification of materials at the 1–100 nm scale is nanotechnology, and it has revolutionized several disciplines, including catalysis, environmental research, and medicine. It is used in consumer items, electronics, medicine, and energy generation (Maaza *et al*., 2022; Khan *et al*., 2025a). Nanoparticles (NPs) are increasingly used in various sectors due to their unique properties and are emerging as promising alternatives to conventional antibiotics in combating microbial infections (Khan *et al*., 2025b). Recent advances in nanotechnology have made it possible to create engineered nanoparticles with a variety of shapes, sizes, and kinds (Elemike *et al*., 2019; Ullah *et al*., 2025). For the formation of nanoparticles, three basic procedures/processes, physical, chemical, and biological, are used. Synthesis of nanoparticles adopting physical methods will be carried out using constant energy, pressure, and temperature. Adopting chemical methods for nanoparticles synthesis sol-gel techniques, laser pyrolysis, atomic or molecular condensation, sputtering, and spray pyrolysis are techniques used (Parmar & Chaudhary, 2022). With the comparison of chemical and physical methods, the biological synthesis of silver nanoparticles (Ag-NPs) presents a relatively simple process, with beneficial characteristics like cost-effectiveness, reduced hazardous waste production, lower energy usage, and improved yields, rendering it an attractive option in nanotechnology. Microorganisms like bacteria, yeasts, fungi, and algae and plant extract also can serve as stabilizers and reducing agents in the biological production of nanoparticles (Rani *et al*., 2023; Bibi *et al*., 2024). These organisms can change the chemical composition of metals and create less harmful nanoparticles as a result of developing defensive systems against dangerous substances (Dkhil *et al*., 2020; Pantidos & Horsfall., 2014). Biological methods have been used for the production of various nanoparticles, but silver nanoparticles have gained attention due to their enhanced utility and diverse functional properties. Compared to alternative methods, the eco-friendly synthesis of Ag-NPs using different biological materials is preferable due to its simplicity, safety, affordability, and stability (Al-Otibi *et al*., 2020). Instead of using chemicals, biogenic production of Ag-NPs uses

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reducing agents and stabilizers that are obtained from microorganisms like bacteria, fungi, and plants.

Fungi have been widely used in biological processes to manufacture metallic nanoparticles due to their ease of handling, high biomass production, and widespread secretion of metabolites, enzymes, and extracellular proteins. These biomolecules generated by fungus not only help reduce the metal precursor but also cap the nanoparticles, improving size and stability management (Azmath *et al*., 2016; Guilger-Casagrande *et al*., 2019). Numerous filamentous fungi and yeasts can be used for the biogenic synthesis of silver nanoparticles. The nanoparticles produced can vary in physicochemical characteristics and biological activities depending on the type of fungus used in the synthesis (because of the various extracellular enzyme profiles), making them promising materials for use in the health, agriculture, and environmental industries (Guilger-Casagrande *et al*., 2019; Kapoor *et al*., 2021; Vigneshwaran *et al*., 2006). Because the genus *Aspergillus* is one of the most significant filamentous fungi, we chose to focus on *A. tamarii* in this study to synthesize silver nanoparticles. Very few studies report the synthesis nanoparticles using *A. tamarii* which are AuNPs (Radhakrishnan *et al*., 2021), AgNPs (Rajesh Kumar *et al*., 2012), and Fe_3O_4 NPs (MA & RM., 2022), however, there is no report on the same species obtained from *Fagonia indica*.

This study focuses on the formation of silver nanoparticles (Ag-NPs) using *A. tamarii*, a fungus isolated in our lab from the medicinal plant *Fagonia indica*. The unique aspect of this research lies in employing *A. tamarii* as a green, biogenic agent for Ag-NP synthesis, and determination of antioxidant potential of synthesized biogenic nanoparticles offering an environmentally friendly and cost-effective alternative to traditional chemical methods.

Materials and Methods

Formulation of Ag-NPs using *Aspergillus tamarii*: The Biosynthesis of silver nanoparticles was carried out using the endophytic fungus *A. tamarii* isolated from the medicinal plant *Fagonia indica* collected in Village Mulazai, Peshawar, Pakistan. All experimental procedures were performed at the Molecular Systematics and Applied Ethnobotany Lab, Quaid-i-Azam University, Islamabad. The fungal strain was cultivated in Sabouraud Dextrose Broth (SDB) and incubated at 40 °C for 72 hours under shaking conditions to promote biomass growth. The resulting biomass was filtered using Whatman No. 1 filter paper and thoroughly rinsed with sterile distilled water to remove medium residues. It was then transferred to fresh sterile distilled water and incubated again under the same conditions for 72 hours to produce a yellow-colored cell-free filtrate. After incubation, the biomass was removed, and 3 mM silver nitrate ($AgNO_3$) was added to the collected filtrate. For three days, the mixture was shaken at 100 rpm at room temperature. The successful bio-reduction of silver ions and synthesis of silver nanoparticles were demonstrated by a noticeable color shift from pale yellow to brown. The fluid containing the nanoparticles was centrifuged for ten minutes at 12,000 rpm. As a result, pellet is formed that is washed with distilled water, oven-dried, and collected as a fine powder for further characterization (Ansari & Alzohairy, 2018).

Characterization of biogenic Ag-NPs: The biogenic Ag-NPs were characterized using various methods. First, ultraviolet–visible (UV–Vis) spectroscopy was performed in the range of 300 to 800 nm to check the reduction technique used for Ag-NPs synthesis Fourier transforms infrared (FT-IR) was utilized to examine the chemical functional groups of biogenic silver nanoparticles in the range of 4000-500 cm^{-1}. The formation, crystalline behavior, and quality of the bio-reduced Ag-NPs powder was studied using X-ray diffraction. To confirm charge zeta has performed. The size, form, and morphology of the surface characteristics were described using scanning electron microscopy (SEM) examination.

Phytochemical analysis of nanoparticles

Determination of total phenolic content (TPC) and total flavonoid content (TFC): The TPC and TFC were determined by using already optimized protocols (Khan *et al*., 2025a; Khan *et al*., 2025b; Bektaş, 2025). Each analysis was performed in triplicate and results were recorded. The procedure's positive control was gallic acid.

Antioxidant activities

Total reducing power (TRP) estimation: With a few minor adjustments, the technique outlined by (Faisal *et al*., 2021) was used to estimate the reducing power. In short, 0.2 M phosphate buffer and 1% potassium ferricyanide were combined with sample (4 mg/mL). At 50°C incubation was done for few minutes then 10% trichloroacetic acid (TCA) had been added, and the mixture was centrifuged for ten minutes at 2500 rpm. Then 33.3 µL of 0.1% ferric chloride ($FeCl_3$) was added to a 96-well plate containing an aliquot (166.66 µL) of the supernatant. The ELx800 BioTek microplate reader was used to detect absorbance at 630 nm. The data were represented as µg ascorbic acid equivalents (AAE)/mg extract, and all assays were done in triplicate. Ascorbic acid was used as positive control and negative control was DMSO.

Total Antioxidant Capacity (TAC): In order to calculate the sample antioxidant capacity, the phosphomolybdenum technique was applied (Rahman *et al*., 2017). For the reaction, a phosphomolybdenum reagent was made with 20 mM sodium phosphate, 4 mM ammonium molybdate, and 0.6 M sulfuric acid. The sample was first put in 20 µL to the 96-well microplate. The same microplates were then filled with 180 µL of the TAC reagent (total antioxidant capacity). At 90°C, the solution was incubated in a water bath for 90 minutes. After the completing incubation period, solution had been cooled at room temperature, we used ascorbic acid as a positive control. A microplate reader at a wavelength of 630 nm was used to analyze the results. The assay was carried out three times.

Antibacterial activity: The antibacterial activity of silver nanoparticles has been evaluated against harmful bacterial strains using the well diffusion approach with minor changes (Hu *et al*., 2019). The extracts were evaluated on gram-negative strains include *Escherichia coli* (ATCC-15224), *Pseudomonas aeruginosa* (ATCC-9721), and *Klebsiella pneumonia* (ATCC-4619) and gram-positive

strain *Bacillus subtilis* (ATCC-6633). Then using an autoclave cotton swab to disseminate 50 µL of developed bacterial cell suspensions on Sabouraud Dextrose Agar (SDA) culture petri plates, 10 mm wells were formed at a predetermined distance from one another. After adding different doses of silver nanoparticles and positive control ampicillin to the well, the mixture was incubated 24 hours at 37°C. Using a vernier caliper, the zones of inhibition against the bacterial strains were quantified in millimeters.

***In vitro* hemolytic activity of biogenic Ag-NPs:** Hemolytic activity of silver nanoparticles was performed according to the protocol described by Jadhav *et al*., 2018, red blood was obtained from healthy individual for hemolytic assay. To avoid clumping, the blood was kept separated in the EDTA tubes. Blood was transferred into an Eppendorf tube and centrifuged there for 5 minutes at 14,000 rpm. The supernatant was thrown away. Additionally, the pellet underwent three rounds of washing in PBS (phosphate buffer saline). Following the final washing, 120 µL of the 4% pellet was extracted and dissolved in 2880 µL of PBS in accordance with the samples' needs. At this point, the erythrocyte suspension was prepared for usage. Serial dilution of Ag-NPs samples was taken in the Eppendorf tubes and erythrocytes suspension were added to all the tubes and incubated at 37°C for 1 hour. The tubes were centrifuged at 2500 rpm for 10 minutes following the incubation. Then 100 µL of the supernatant was transferred to 96-well plates, where hemoglobin release was measured using an ELx800BioTek microplate reader at a wavelength of 540 nm. It was assumed that 100% hemolysis had occurred when RBCs and 0.5% Triton X-100 were lysed as well. The formula was applied to calculate the percent hemolysis.

$$\% \text{ Hemolysis} = \frac{\text{O.D of samples - O.D in PBS}}{\text{O.D in 0.5\% Triton X-100 - O.D in PBS}} \times 100$$

Brine shrimp assay for cytotoxicity screening: Shrimp, seawater, and nanoparticles were the main components of this test. To make the sea water for hatching, 31 g of sea salt is dissolved in 1000 mL of distilled water. Before usage, it was properly swirled for an hour, allowed to cool, and then stirred once more for 30 minutes. The assay was run in a series of dilutions. The samples were placed on the 96-well plates, and the seawater was then prepared and added to the wells containing the NPs samples. 10 shrimp were subsequently added to each well using a dropper. It was then fitted with the right proportion of light and oxygen. After 24 hours, the number of living and dead shrimp was tallied (Dilshad *et al*., 2020).

Results

Morphological and microscopic features of *A. tamari:* To assess its morphological traits, the previously identified endophytic fungal strain *A. tamarii* was cultured on SDA. The culture displayed normal growth patterns with thick, powdery colonies with a yellowish-brown surface, which is typical of *A. tamarii*, as shown in Fig. 1. The fungus complicated structural characteristics were discovered through microscopic inspection. Consistent with distinguishing characteristics, the hyphae were septate and branching, and conidiophores carried vesicles with radiating phialides. Additionally, conidia clusters were seen, indicating vigorous sporulation and a robust fungal culture fit for other uses.

Different characterization

UV-Vis spectra and FTIR analysis: The visual color changes from pale yellow to dark brown shows silver ion reduction to Ag-NPs. Ag-NPs were basically synthesized by treating extract of *A. tamarii* with $AgNO_3$ salt. Yellowish brown to darkish brown color in conical flask indicates the formation of silver nanoparticles as shown in Fig. 2a. A very strong plasmon response was centered at approximately 417 nm as shown in Fig. 2b confirmed the silver nanoparticles formation by UV spectroscopy. FT-IR spectroscopy analysis was performed to study the chemical composition of biosynthesized silver nanoparticles surface that confirmed presence of different bioactive components and metabolites in fungal extracts. Basically FT-IR analysis provides information about functional groups present in synthesized silver nanoparticles which basically stabilize the formation of nanoparticles. FT-IR spectrum showed different peaks ranges from 500-4000 cm^{-1} having different highest peaks (Fig. 2c). The FTIR spectra revealed different peaks at 962.87, 1062.30, 1227.55, 1524.42, 1637.45, 3278.47, 3734.15 cm^{-1} in which C=C show presence of disubstituted bond, C-N show as amines presence, N-O show as nitro compounds presence, O-H show as alcohol group presence. These various peaks revealed that these synthesized silver nanoparticles have many groups that are involved in stability (Table 1 & Fig. 2c).

Zeta potential analysis: The size of nanoparticles and zeta potential of the produced nanoparticle are the major elements that prevent biological processes and their interaction with other active charge surfaces. Their antibacterial processes can vary depending on differences in particle size and zeta potential of nanoparticles (Bihari *et al*., 2008; Silva *et al*., 2015). The Ag-NPs were measured to have surface zeta potential values of -16.1 mV, which are slightly negative as shown in Fig. 3a and 3b. Ag-NPs negative charge helps to boost their stability, avoids aggregation, and improves their antibacterial properties.

Table 1. FTIR spectra of silver nanoparticles.

S. No.	Wavelength cm^{-1}	Functional group	Type of vibration	Intensity	Compound types
1.	962.87	-C=C	Bending	Strong	Disubstituted
2.	1062.30	-C-N	Stretching	Medium	Amine
3.	1227.55	-C-N	Stretching	Strong	Amine
4.	1524.42	-N-O	Stretching	Strong	Nitro compound
5.	1637.45	-C=C	Stretching	Strong	Alkene
6.	3278.47	-O-H	Stretching	Weak	Alcohol
7.	3734.15	O-H	Stretching	Sharp	Alcohol

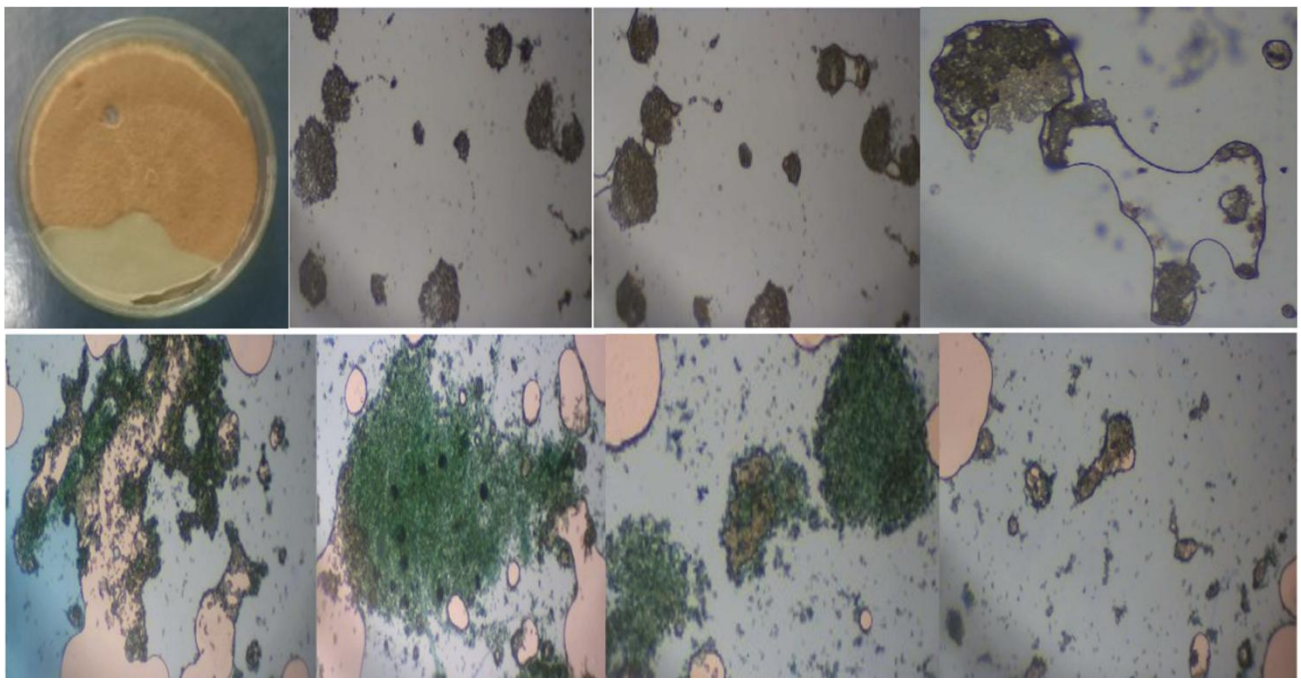

Fig.1. Pure culture of isolated *A. tamarii* grown on SDA (top left), followed by its microscopic structures showing hyphal network, conidiophores, vesicles, and conidial arrangement.

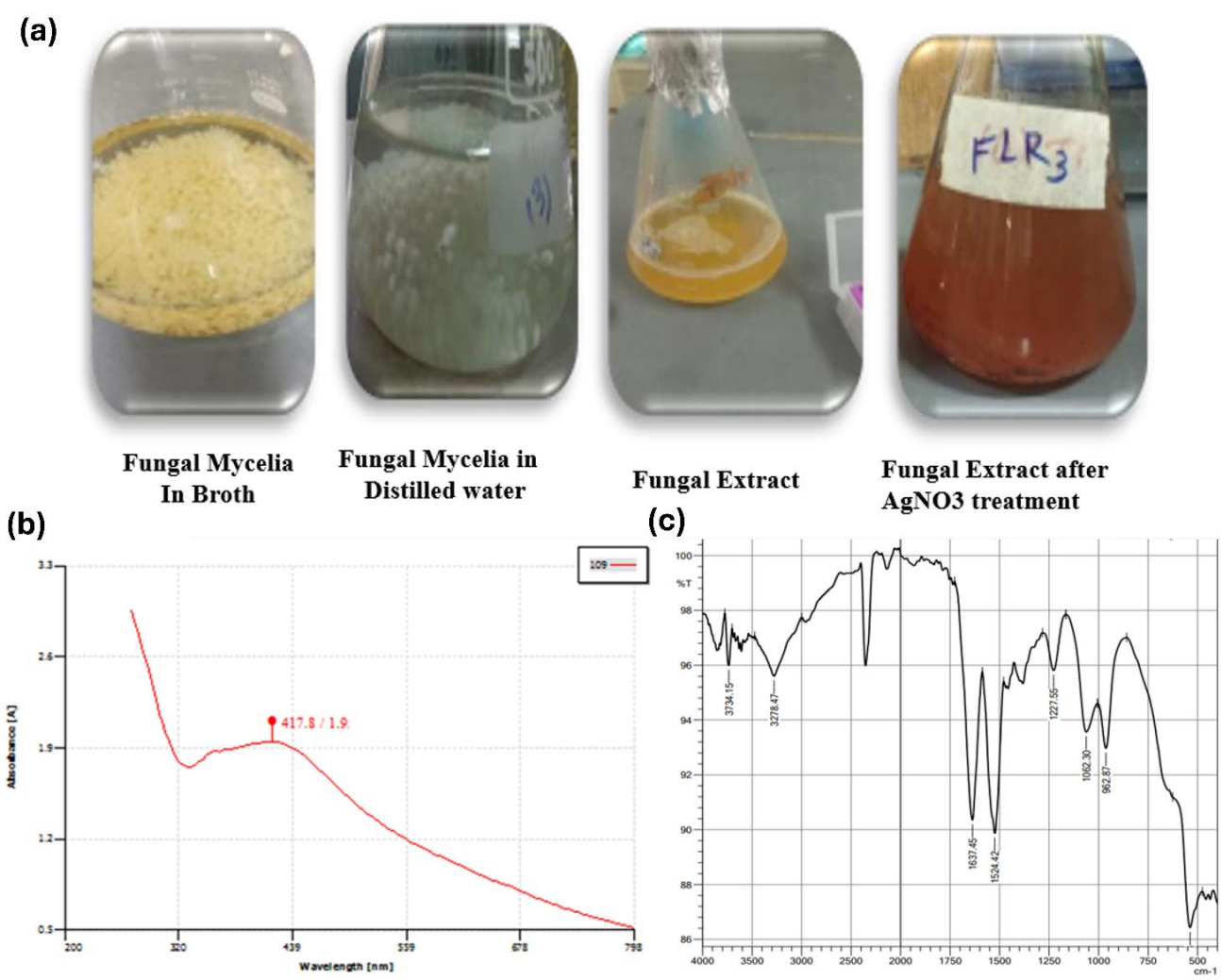

Fig. 2. Characterization of silver nanoparticles synthesized by *A. tamarii*. (a) Color change in culture filtrates of fungal isolates after $AgNO_3$ treatment showing the most intense brown color. (b) UV–Vis spectrum showing a surface plasmon resonance peak at 417.8 nm. (c) FTIR spectrum indicating functional groups (–OH, –NH, –CO) involved in nanoparticle stabilization.

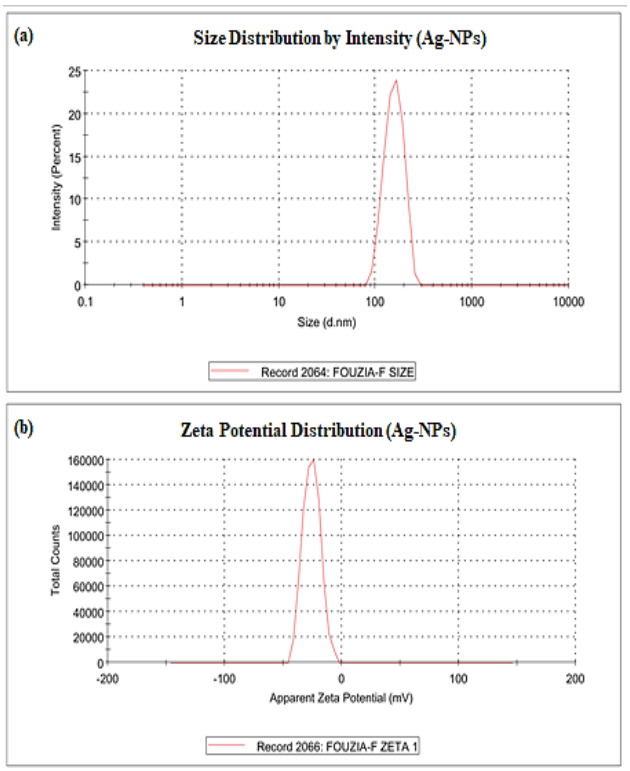

Fig. 3. Zeta potential of Ag-NPs from *A. tamarii*. (a) shows size distribution by intensity and (b) represents Zeta Potential distribution.

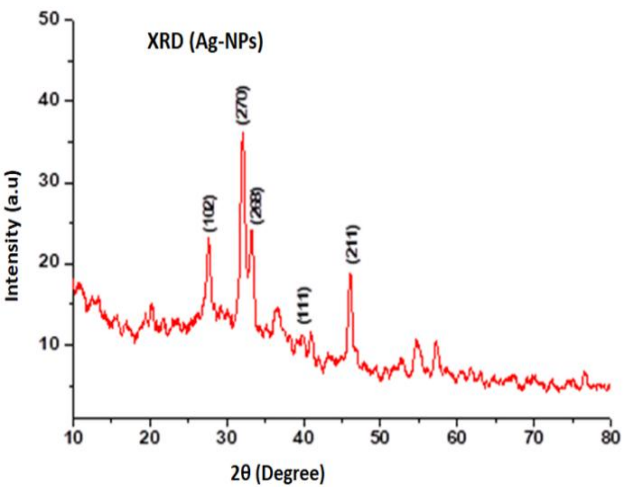

Fig. 4. XRD spectra of Ag-NPs from *A. tamarii*.

SEM analysis: For synthesized silver nanoparticles scanning electron microscopy (SEM) was performed to confirm the shape and size of nanoparticles. Images of the SEM revealed that nanoparticles formed were very dispersed and were rounded, oval and spherical in shape as illustrated in Fig. 5.

XRD analysis: Ag-NPs were subjected to powdered X-ray diffraction (XRD). The XRD spectra of biogenic Ag-NPs annealed at temperatures 500°C is demonstrated in Fig. 4. Average nano crystallite sizes were calculated using Debye-Scherrer ($D = K\lambda / (\beta\cos\theta)$ approximation. Interestingly, the average sizes of 15.4 nm were calculated for crystallites of silver nanoparticles of silver nitrate, annealed at 500°C (Fig. 4). XRD analysis showed different peaks at the range of (102), (270), (268), (111), and (211) at the range of 2 theta.

Antibacterial activity: Silver nanoparticles biosynthesized from *A. tamarii* were checked against 4 different bacterial strains (gram negative and gram positive) to check their antibacterial property through disc diffusion method carried out at various concentrations i.e., 0.5, 1, 2, 3, 4 and 5 mg/mL (see Fig. 6). The Ag-NPs concentration 5 mg/mL and 4 mg/mL were found to be most effective against all gram-positive bacteria, and negative bacteria. Ag-NPs showed significant result in *Bacillus subtilis* (ATCC: 6633) with 16.5 ± 1,16 ± .8, 15 ± 0.5, 14.5 ± 1, 14 ± 0.5, 13 ± 0.6 zone of inhibition (ZOI) at concentration of 5 mg/mL, 4 mg/mL, 3 mg/mL, 2 mg/mL, 1 mg/mL, 0.5 mg/mL respectively as compared to other bacteria.

Determination of total flavonoid content, phenolic content and antioxidant activities: The antioxidant potential of synthesized silver nanoparticles was determined by performing TFC, TPC, TAC and reducing power assays. Two different concentrations (2 mM and 3 mM) were used and compared with positive control as shown in Fig. 7.

Hemolytic assay: The assessment of the hemolytic activity of silver nanoparticles obtained from *A. tamarii,* which were synthesized using distilled water as a solvent, was carried out through the analysis of red blood cell lysis. Hemolysis can be measured by the removal of hemoglobin following red blood cell rupture following sample analysis. The results obtained vary from 0.931 ±0.5, 0.93 ± 0.7, 0.929 ± 0.5, 0.928 ± 0.7 µg/ml. The current findings demonstrate that biogenic silver nanoparticles exhibit non-hemolytic properties throughout different concentrations (100, 200, 300, and 400 µg/ml), as depicted in Fig. 8.

Brine shrimp assay: The study investigated the mortality rate percentage of shrimp. The cytotoxicity of Ag-NPs was confirmed through brine shrimp testing, possibly which demonstrated their great effectiveness on concentration of 400 µg/ml. The lethality rate decreased as the concentration decreased as illustrated in Fig. 9. The concentration of fungal extracts was found directly proportional to its degree of toxicity.

Discussion

Biosynthesis of nanoparticles has been found to be the most advantageous method over the physical and chemical means in terms of its cost effectiveness and environment friendly property. The application of silver nanoparticles has experienced an increase in utilization in recent years. This demands a constant evaluation of the toxicity level of nanoparticles (Hemalatha *et al*., 2023). The present study aims to synthesize nanoscale Ag-NPs from *A. tamarii,* an endophyte obtained from *fagonia indica*, using water as solvents. Several investigators have previously reported the successful green synthesis of silver nanoparticles using endophyte (Nanda *et al*., 2018).

Nanoparticles formation is confirmed by different characterization specifically, UV-visible spectroscopy was utilized to confirm the formation of silver nanoparticles (Nanda *et al*., 2018). UV visible spectroscopy reveals the broad peaks observed at 417 nm for Ag- NPs as shown in Fig. 2 which clearly demonstrates the presence of silver nanoparticles. The nanoparticles were subjected to X-ray diffraction (XRD) analysis to investigate their crystallinity and size. XRD analysis showed different peaks at the range of (102), (270), (268), (111), and (211) at the range of 2 theta was strongly matched with previous study and calculated size was 15.4 nm (Alam *et al*., 2021). These findings indicate that the nanoparticles possess a crystalline structure. FT-IR analysis was conducted to verify the biomolecules responsible for the capping and reduction of silver nitrate. Endophytic aqueous extract also consists of a variety of phytochemicals such as alcohols, amines, nitro group, carboxylic group, proteins, and aldehydes which become the cause of reduction of silver nitrate precursor as well as stability of silver nanoparticles. In this study various absorption peaks were shown by silver nanoparticles through FTIR analysis which represents many functional groups. These absorption peaks were located between a range of 962.87 to 3734.15 for the biosynthesized silver nanoparticles which represents functional groups like alcoholic O-H stretching (Sukirtha *et al*., 2012), C-0 of carboxylic anions (Vivek *et al*., 2012), C-H stretching (Peter Amaladhas *et al*., 2013). The study of the morphology of silver nanoparticles that were synthesized biologically was conducted using scanning electron microscopy The SEM was found with oval, spherical rounded shape was related to previous findings that mostly all nanoparticles having rounded shape and spherical (Bagur *et al*., 2022). Mostly all nanoparticles have oval, round shape and spherical (Bagur *et al*., 2022). Zeta potential value of biosynthesized silver nanoparticles was measured in the colloidal solution. The surface zeta potential values of Ag-NPs were measured to be slightly negative and were -16.1 mV shown in Fig. 3. The negative charge of Ag NPs prevents their aggregation and increases their stability while improving their antibacterial properties. A possible reason for the negative surface charge of the synthesized Ag NPs is the absorption of free nitrate ions present during the reduction of AgNO3 (Barapatre *et al*., 2016; Hamouda *et al*., 2019; Mohanta *et al*., 2020).

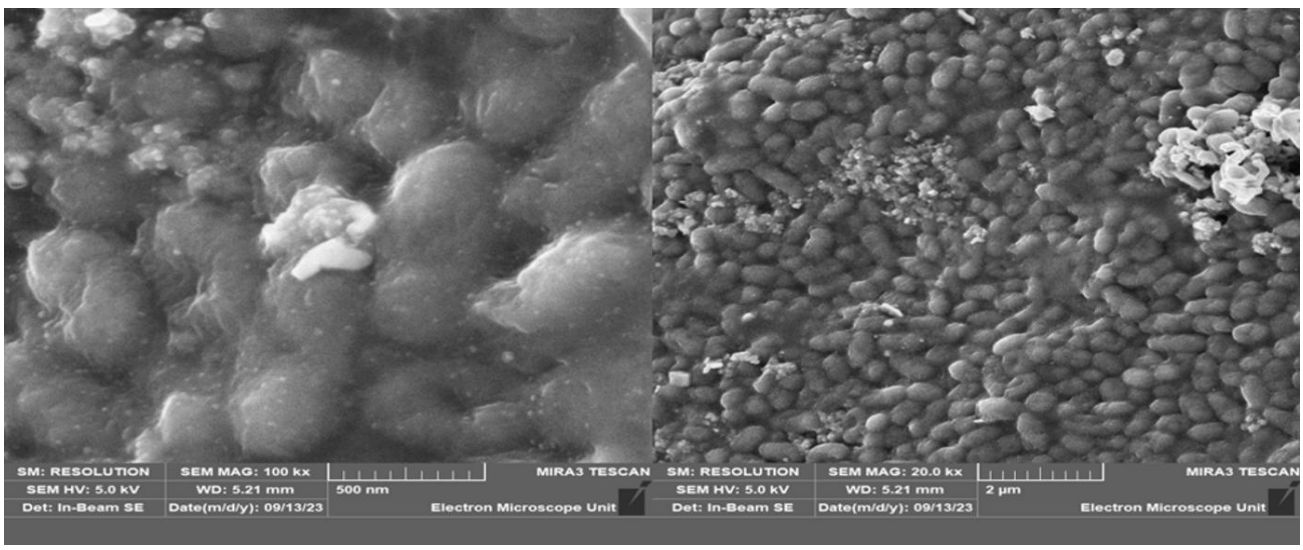

Fig. 5. Transmission electron microscopy of synthesized silver nanoparticles at 2µm and 500 nm magnification.

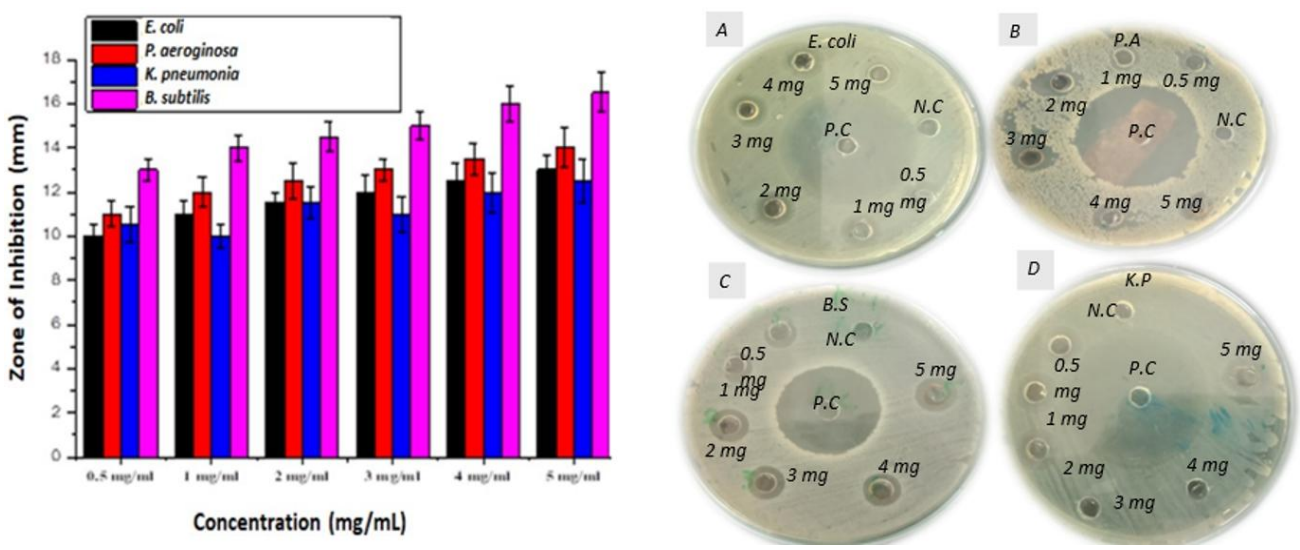

Fig. 6. Antibacterial activity of Ag-NPs from *A. tamarii*. Left side of figure shows graphical representation while right side of the figure shows pictorial view.

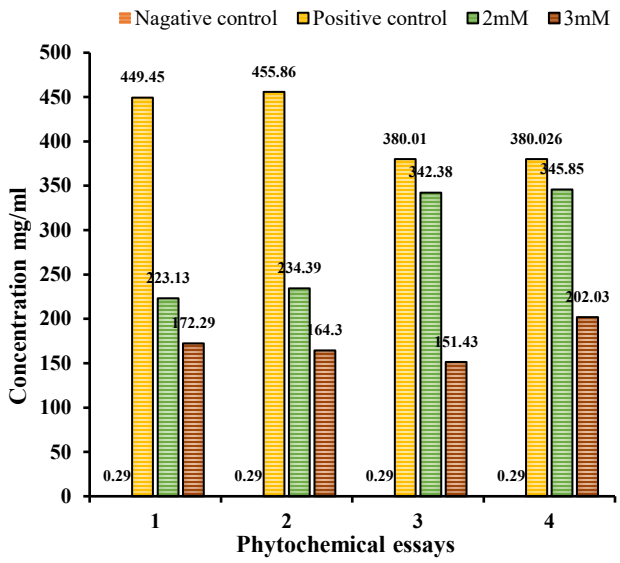

Fig. 7. Phytochemical assays of biogenic $AgNO_3$.

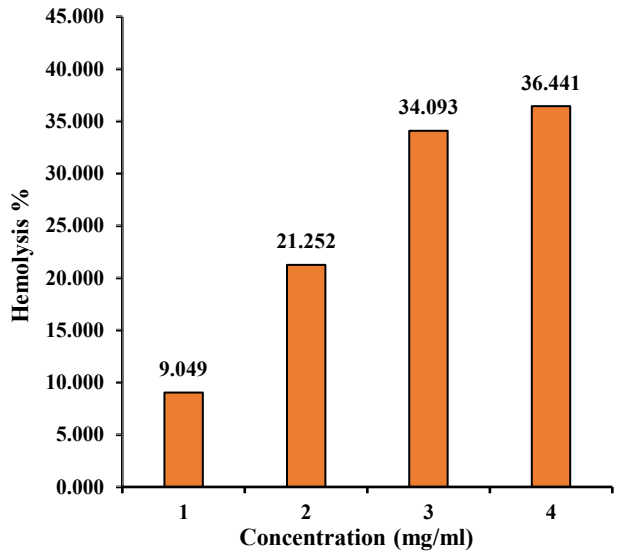

Fig. 8. Hemolytic activities of Ag-NPs biosynthesized from Entophytic fungi.

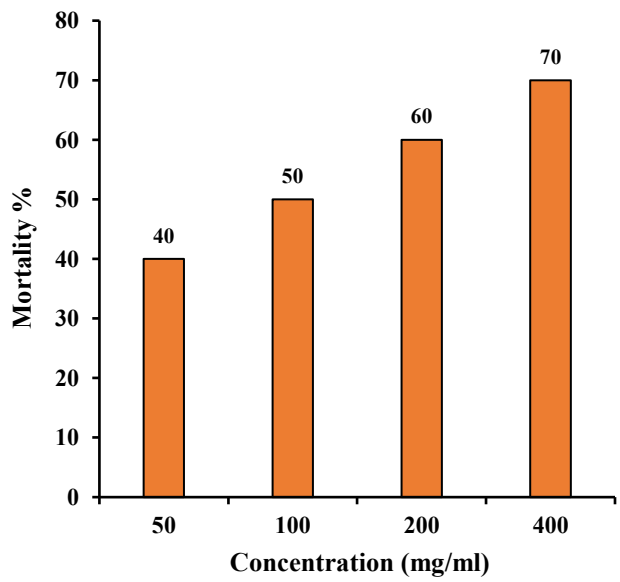

Fig. 9. Brine shrimp assay of Ag-NPs from *A. tamarii*.

After physical characterizations, this research was continued by subjecting these biosynthesized nanoparticles to biological assays i.e., antimicrobial including antibacterial assay. Silver nanoparticles biosynthesized from *A. tamarii* were checked against 4 different bacterial strains (Gram negative and Gram positive) to check their antibacterial property through disc diffusion method carried out at different concentrations i.e., 0.5, 1, 2, 3, 4 and 5 mg/ml. The Ag-NPs concentration 5 mg/ml and 4 mg/ml were found most effective against both gram-positive bacteria, Bacillus subtilis (ATCC: 6633) which agrees with the previously reported study (Aljarbou, 2025).

Phenols that are high molecular weight compounds and flavonoid compounds have an important role associated with antioxidant activity (Sun & Shahrajabian, 2023). Results revealed that 2 mM nanoparticles concentration showed markedly higher antioxidant activity compared to the 3 mM particles. The TFC and TPC values for the 2 mM treatment were recorded as 223.13 µg/ml and 234.39 µg/ml, respectively, whereas the 3 mM treatment showed comparatively lower values (TFC: 172.29 µg/ml; TPC: 164.30 µg/ml). This indicates that smaller particle size enhances the availability of flavonoids and phenolic compounds (Ben Salah *et al*., 2021; Taghavizadeh Yazdi *et al*., 2022).

The fungal extract exhibited a similar pattern for Total Antioxidant Capacity as 2 mM particles exhibiting significantly higher activity than 3 mM particles. This higher TAC indicates that smaller particles are better able to scavenge free radicals. This was confirmed by the reducing power assay, which showed that the 2 mM particles had a stronger reducing ability than the 3 mM particles, indicating a larger capacity to donate electrons. Strong reducing power compounds are superior to neutralizing reactive oxygen species; hence this is an important indicator of antioxidant efficacy. These results have been published (Chakraborty *et al*., 2021).

RBC lysis was used to measure the hemolytic activity of *A. tamarii* silver nanoparticles made with water as a solvent. According to the current research, biogenic silver nanoparticles show non-hemolytic characteristics at concentrations of 100, 200, 300, and 400 µg/ml. Testing on brine shrimp revealed the possible harmful action of Ag-NPs, confirming their cytotoxicity.

The effectiveness of Ag-NPs was found to be particularly high at a concentration of 400 µg/ml, with a decrease in concentration resulting in a related reduction in lethality rate (Sampath *et al*., 2021).

Conclusion

In summary, the biosynthesis of silver nanoparticles using an aqueous extract of *A. tamarii* has been completed successfully. The phytochemicals in the extract are essential for the reduction and capping of the nanoparticles, ensuring their stability and low polydispersity. These biogenic Ag-NPs were efficient at comparatively low doses and showed strong antibacterial activity against several harmful pathogens. Additionally, its biocompatibility points to possible uses in lowering inflammation and pain. The use of a green synthesis approach not only minimizes the reliance on harmful chemicals but also opens new pathways to produce nanoparticles as diagnostic and therapeutic agents in various medical conditions.

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Author's Contributions: Fouzia Bibi: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing – original draft. Lubna Rehman: Formal analysis, Validation, Writing – review & editing. Amjid Khan: Conceptualization, Formal Analysis, Methodology, Validation, Writing – review & editing. Muhammad Ali: Conceptualization, Resources, Writing – review & editing. Hassan Javed Chaudhary: Resources, Supervision, Writing – review & editing. Zabta Khan Shinwari: Conceptualization, Resources, Supervision, Project administration, Funding acquisition, Writing – review & editing.

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Declarations

Competing Interest: The authors declare no competing interests.

Conflict of Interest No conflict of Interest among authors.

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