Pharmacogn. Res., 2027; 19(2):605-614.
https://www.phcogres.com

Original Article

Green Synthesis and Pharmacological Assessment of Silver Nanoparticles using Medicinal Plant Extract of *Farsetia jacquemontii*

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ABSTRACT

Background: *Farsetia jacquemontii* plant material is locally used as herbal medicine for many diseases indicating its significant potential. This study aimed to synthesize the eco-friendly green Silver Nanoparticles (AgNPs) using *Farsetia jacquemontii* and to investigate its medicinal uses. **Materials and Methods:** The AgNPs was prepared using 80% methanolic extract of *Farsetia jacquemontii* and evaluates their antioxidant, antibacterial, and antidiabetic activities. The biosynthesized AgNPs were characterized using UV-visible spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, and Scanning Electron Microscopy (SEM), confirming successful nanoparticle formation through a characteristic surface plasmon resonance band and predominantly spherical morphology. FTIR analysis indicated the involvement of plant-derived biomolecules in the reduction and stabilization of silver ions. **Results:** The synthesized AgNPs exhibited potent antioxidant activity, achieving 96.4% DPPH radical scavenging at 250 µg/mL, markedly exceeding the activity of the crude plant extract. Antibacterial evaluation demonstrated broad-spectrum efficacy, with pronounced zones of inhibition against *Staphylococcus aureus* (25.2±0.06 mm) and *Escherichia coli* (21.8±0.08 mm). *In vivo* assessment using an alloxan-induced diabetic mouse model revealed significant reductions in fasting blood glucose levels, along with notable improvements in hepatic enzyme markers, renal function indices, lipid profile, and antioxidant status compared with diabetic controls ($p<0.05$). Collectively, these findings demonstrate that *F. jacquemontii*-mediated AgNPs possess multifunctional pharmacological properties, including antioxidant, antibacterial, antidiabetic, hepatoprotective, and nephroprotective effects. **Conclusion:** This work highlights the potential of plant-derived AgNPs as a sustainable and effective nanotherapeutic platform for managing diabetes and its associated complications. Further investigations focusing on molecular mechanisms, pharmacokinetics, and long-term safety are warranted to support translational and clinical development.

Keywords: Antidiabetic Activity, Antioxidant Activity, Blood Glucose, *Farsetia jacquemontii*, Green Synthesis, HDL, LDL, Lipid Profile, Silver Nanoparticles (AgNPs).

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Received: 08-07-2026;
Revised: 18-08-2026;
Accepted: 28-10-2026.

INTRODUCTION

The use of medicinal plants for the prevention and treatment of human diseases dates back to the earliest stages of civilization. Extensive scientific evidence now confirms that a wide range of bioactive chemical compounds derived from medicinal plants play critical ecological and therapeutic roles. These compounds protect plants against herbivores, pathogenic microorganisms, and insect attacks, while simultaneously providing pharmacological benefits to humans (Khan *et al*., 2025). Several well-established pharmaceutical agents, including gaultheria (Michel, 2025), digitoxin, quinine, and opium, have their origins in medicinal plants (Alamgir, 2017). Notably, plant-based therapeutics are often associated with fewer adverse effects compared with synthetic drugs, further supporting their continued relevance in modern medicine (Gupta *et al*., 2019).

The escalating global burden of antibiotic-resistant pathogens has intensified the search for novel antimicrobial agents, particularly those derived from natural sources (Eggleston *et al*., 2010). In response, increasing attention has been directed toward the identification and development of plant-based antimicrobial compounds with broad-spectrum activity (Bibi *et al*., 2011). Medicinal plants also represent a rich source of antioxidant biomolecules capable of neutralizing free radicals

DOI: 10.5530/pres.20270133

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and preventing oxidative damage to cellular components, which is implicated in the pathogenesis of numerous chronic diseases (Chaudhary *et al.*, 2023). According to the World Health Organization, approximately 80% of the global population relies on plant-derived medicines for primary healthcare, underscoring their indispensable role in contemporary and traditional medical systems alike (Arunkumar and Muthuselvam, 2009).

Phytochemicals such as phenols, alkaloids, terpenoids, steroids, carbohydrates, and flavonoids are naturally occurring compounds known for their potent free radical-scavenging activity and therapeutic potential (Altemimi *et al.*, 2017). Additional plant-derived constituents, including lignins, tannins, lycopene, indoles, and resveratrol, contribute to human health by mitigating oxidative stress and cellular damage. Although many of these secondary metabolites are not directly involved in plant growth or metabolism, they exhibit strong antimicrobial activity against drug-resistant pathogens (Compean and Ynalvez, 2014). Collectively, these phytochemicals serve as natural defense systems against reactive species generated during metabolic processes that lead to cellular deterioration and disease progression (Forni *et al.*, 2019).

Farsetia jacquemontii (family Brassicaceae or Cruciferae) is a small, erect shrub measuring approximately 20-44 cm in height. The plant is densely branched, covered with fine white hairs, and characterized by linear sessile leaves (1-5 cm) and racemose inflorescences bearing orange-yellow to pale-purple flowers approximately 1 cm in diameter (Rashid and Rahman, 2011). This species is widely distributed across India, Pakistan, Iran, and Afghanistan (Shaheen *et al.*, 2014). Extracts of *F. jacquemontii* prepared using various solvents have demonstrated significant antioxidant, antibacterial, antifungal, and antidiabetic activities, highlighting its potential as a valuable medicinal resource (Khan *et al.*, 2020).

Nanotechnology, which involves the design and manipulation of materials at the molecular and atomic scale, enables the development of structures typically ranging from 1 to 100 nm in size (Farokhzad and Langer, 2009). Nanoparticles with diverse sizes, morphologies, and compositions have found applications in medicine, electronics, catalysis, and environmental remediation. In particular, metallic nanoparticles composed of gold, silver, and platinum have gained prominence due to their unique physicochemical properties and biomedical relevance (Koperuncholan, 2015).

Among the various nanoparticle synthesis strategies, green synthesis has emerged as a preferred approach owing to its eco-friendly, cost-effective, and biocompatible nature. Unlike conventional physical and chemical methods, green synthesis employs plant extracts as both reducing and stabilizing agents, thereby eliminating the need for hazardous chemicals (Ramesh *et al.*, 2014). The resulting nanoparticles exhibit significant potential for applications in catalysis, biosensing, and the treatment of infectious diseases and cancer (Nath and Banerjee, 2013). This approach has facilitated the integration of nanotechnology into biomedical research by leveraging medicinal plants as sustainable and renewable resources (Chauhan *et al.*, 2012).

Silver nanoparticles, typically ranging from 1 to 100 nm in size, have attracted considerable interest due to their distinctive physicochemical, optical, and antimicrobial properties. Historically, colloidal silver has been used for more than three centuries in medicine and art (Chouhan, 2018). Silver exhibits strong antibacterial, antiviral, and antioxidant activities (Khan *et al.*, 2020) and has been widely utilized in textiles, wound dressings, and water purification systems (Sharma *et al.*, 2009). Green synthesis of AgNPs has been successfully achieved using extracts from plants such as *Azadirachta indica* (Bar *et al.*, 2009), *Carica papaya* (Ceylan *et al.*, 2006), and *Capsicum annuum* (Tomar and Garg, 2013). In these systems, plant-derived biomolecules function as both reducing and capping agents, enabling safe, economical, and environmentally sustainable nanoparticle production (Koperuncholan, 2015). Consequently, green-synthesized AgNPs are emerging as promising candidates for a wide range of biomedical applications.

MATERIALS AND METHODS

Collection and extraction of plant

The aerial parts (excluding roots) of *Farsetia jacquemontii* were collected from Ahmad Mir Patool Khel, Tehsil Domail, District Bannu, Pakistan. The plant material was taxonomically identified and authenticated by Dr. Tahir Iqbal, Department of Botany, University of Science and Technology (UST), Bannu, Pakistan. The specimen, locally known as Milangai, was air-dried under shade for approximately two weeks to minimize photodegradation of bioactive constituents. The dried plant material was subsequently ground into a fine powder using an electric grinder, yielding approximately 2 kg of powdered sample.

The powdered material was exhaustively extracted with 80% methanol, followed by repeated filtration to remove particulate matter. The combined filtrates were concentrated under reduced pressure using a rotary evaporator at a controlled temperature until a thick crude extract was obtained. The resulting methanolic crude extract was stored at 4°C until further use for nanoparticle synthesis.

Biosynthesis of Green nanoparticles

For silver nanoparticle synthesis, 0.5 g of the methanolic crude extract was dissolved in 100 mL of methanol and stirred continuously for 3 hr using a magnetic stirrer to ensure complete solubilization. The solution was then filtered to obtain a clear extract. A 0.01 M Silver Nitrate ($AgNO_3$) solution was prepared by dissolving the appropriate amount of $AgNO_3$ in 10 mL of deionized water, and the pH was adjusted to 9.0 using

Sodium Hydroxide (NaOH) to facilitate the reduction process. Subsequently, 0.2 mL of the filtered plant extract was added dropwise to the $AgNO_3$ solution under continuous stirring. The gradual color change from light yellow to dark yellow indicated the successful formation of silver nanoparticles. The reaction mixture was incubated at room temperature for 1 hr, confirming the complete reduction of silver ions into AgNPs.

Chemical Characterization

Green synthesized nanoparticles were checked through UV-visible spectroscopy, FTIR and SEM.

Biological investigation of green nanoparticles

Various biological markers methods were used to check the green nanoparticles prepare from plants extract and silver. Among them are *in vitro* antioxidant and antibacterial procedures while antidiabetic investigation protocol was used as *in vivo* method.

Ethical Certificate and approval

All animal experiments were conducted in accordance with institutional guidelines and approved by the Institutional Animal Care and Use Committee (IACUC) under ethical certificate No. USTB/230.

Statistical analysis

Statistical analysis was performed using SPSS/GraphPad Prism. Data are expressed as Mean±SEM. Differences were analyzed using one-way ANOVA with $p<0.05$ considered significant.

RESULTS

Chemical characterization of $AgNO_3$

Fourier transforms infrared Analysis

FFTIR spectroscopy is a widely employed analytical technique in nanoscience for identifying functional groups and biomolecules involved in the reduction and stabilization of nanoparticles. In green-synthesized silver nanoparticles, FTIR analysis provides critical insight into the molecular interactions between silver ions and plant-derived compounds, including proteins, phenolics, alcohols, and other phytochemicals. Comparative analysis of FTIR spectra before and after nanoparticle synthesis allows confirmation of biomolecular participation through shifts, appearance, or disappearance of characteristic absorption bands. In this study, FTIR spectra of the plant extract prior (Figure 1) to silver nitrate addition (S2) and after (Figure 2) silver nanoparticle formation (S2-$AgNO_3$) was analyzed to elucidate the functional groups responsible for nanoparticle synthesis and stabilization.

The FTIR spectrum of the pre-synthesis sample (S2) exhibited a broad absorption band at 3298 cm^{-1}, attributable to O-H stretching vibrations of alcohols and phenols and/or N-H stretching of amide groups in proteins, indicating extensive hydrogen bonding. The band observed at 2931 cm^{-1} corresponded to aliphatic C-H stretching vibrations, suggesting the presence of long-chain hydrocarbons or lipid-associated biomolecules. A prominent peak at 1603 cm^{-1} was assigned to C=O stretching of amide linkages and possible aromatic C=C vibrations of polyphenolic compounds. Additional absorption bands at 1259 cm^{-1} and 1053 cm^{-1} were attributed to C-O-C and C-N stretching vibrations, respectively, indicating the presence of carbohydrates, glycosides, and amine-containing compounds. Weak bands in the fingerprint region (600-400 cm^{-1}) were associated with bending vibrations and possible metal-oxygen interactions. Collectively, these features confirm the presence of biomolecules capable of acting as reducing and stabilizing agents.

Following the addition of silver nitrate and subsequent nanoparticle formation, notable spectral changes were observed. The O-H/N-H stretching band shifted from 3298 cm^{-1} to 3322 cm^{-1}, indicating the involvement of hydroxyl and amine groups in nanoparticle stabilization. The aliphatic C-H stretching band shifted from 2931 cm^{-1} to 2921 cm^{-1}, accompanied by the emergence of a new peak at 2856 cm^{-1}, reflecting alterations in the hydrocarbon environment upon interaction with silver ions. The amide I band shifted from 1603 cm^{-1} to 1585 cm^{-1}, confirming coordination between carbonyl groups and silver. The appearance of a new band at 1354 cm^{-1}, corresponding to amide III vibrations, further supports the involvement of proteinaceous compounds. Enhanced intensity of the band around 1100 cm^{-1} suggests stronger C-O and C-N interactions, consistent with nanoparticle capping by carbohydrates and proteins.

In the fingerprint region, intensified absorption bands between 600-400 cm^{-1} were attributed to Ag-O and Ag-N bond formation, confirming direct coordination between silver and biomolecules. These observations indicate that the plant extract components serve a dual role by reducing Ag^+ ions to metallic Ag^0 and stabilizing the resulting nanoparticles against aggregation.

Overall, FTIR spectral comparison before and after synthesis clearly demonstrates the involvement of hydroxyl, amine, carbonyl, and carbohydrate functional groups in silver nanoparticle formation and stabilization. The presence of surface-bound proteins and polyphenols explains the enhanced stability, dispersity, and biocompatibility of the synthesized AgNPs. These findings are consistent with previous reports describing plant-derived biomolecules as effective reducing and capping agents in green nanoparticle synthesis. The observed molecular interactions further support the suitability of these AgNPs for biomedical and environmental applications, including antimicrobial therapy, catalysis, and drug delivery.

UV-vis Spectroscopy Analysis

Ultraviolet-visible (UV-vis) spectroscopy is a fundamental technique for confirming the synthesis of AgNPs, providing direct evidence of nanoparticle formation through the detection of Surface Plasmon Resonance (SPR) bands. The SPR phenomenon

arises from the collective oscillation of conduction electrons on the nanoparticle surface upon interaction with incident light, and its spectral position and intensity are strongly influenced by particle size, shape, distribution, and the surrounding medium.

In the present study, UV-vis spectroscopy was employed to monitor the reduction of Silver Ions (Ag^+) to Metallic Silver (Ag^0) following the addition of silver nitrate to the *Farsetia jacquemontii* extract. A distinct visual color change from pale yellow to dark brownish-yellow was observed during the reaction (Figure 3), indicating nanoparticle formation due to surface plasmon excitation of silver nanoparticles. The progressive intensification of color with reaction time suggests increasing nanoparticle concentration and stabilization, a qualitative hallmark commonly reported in green synthesis of AgNPs.

The UV-vis absorption spectrum of the synthesized AgNPs exhibited a prominent SPR band in the range of 430-450 nm (Figure 3), which is characteristic of silver nanoparticles. The sharp and relatively symmetrical nature of the SPR peak indicates a narrow particle size distribution and good dispersion of the nanoparticles. The absence of broad secondary absorption bands at longer wavelengths suggests minimal aggregation, implying effective capping and stabilization by biomolecules present in the plant extract. Minor peak broadening observed in the visible region may be attributed to slight variations in particle size or anisotropy, which are commonly associated with biologically synthesized nanoparticles.

These findings are consistent with previous reports in which, green-synthesized silver nanoparticles display SPR bands between 400 and 450 nm, confirming efficient reduction of Ag^+ to Ag^0. The intensity of the SPR peak further correlates with nanoparticle concentration, supporting the high yield of the synthesis process. Moreover, the stability of the absorption band without significant wavelength shifts over time indicates that the nanoparticles remained well dispersed and resistant to agglomeration.

The UV-vis spectroscopic analysis provided clear and direct evidence of silver nanoparticle formation and stability. The observed color transition and the distinct SPR band around 430-450 nm confirms successful synthesis and effective biomolecular capping. When considered alongside FTIR analysis, these results validate the eco-friendly and efficient nature of the green synthesis approach and highlight the suitability of the produced AgNPs for biomedical, catalytic, and environmental applications.

Scanning Electron Microscopy Analysis

SEM was employed to examine the surface morphology, particle shape, and size distribution of the biosynthesized silver nanoparticles. The SEM micrograph recorded at 10,000× magnification revealed a high density of nanosized particles uniformly distributed across the surface (Figure 4). The nanoparticles appeared predominantly spherical with relatively consistent morphology, a characteristic commonly reported for green-synthesized AgNPs.

The estimated particle size ranged from approximately 20 to 80 nm, indicating nanoscale dimensions with mild polydispersity. While most particles were well separated, limited aggregation was observed, likely resulting from van der Waals interactions during synthesis and drying. Nevertheless, the overall dispersion remained uniform, suggesting effective stabilization by plant-derived biomolecules acting as capping agents. This observation is consistent with FTIR analysis, which identified hydroxyl, amine, and carbonyl functional groups involved in nanoparticle stabilization.

The smooth and spherical morphology observed indicates isotropic growth and efficient reduction of silver ions without significant structural irregularities. The presence of distinct, well-separated particles further confirms good colloidal stability and minimal clustering. The nanoscale nature of the particles was confirmed by the 1 µm scale bar, supporting the successful formation of AgNPs through the green synthesis approach.

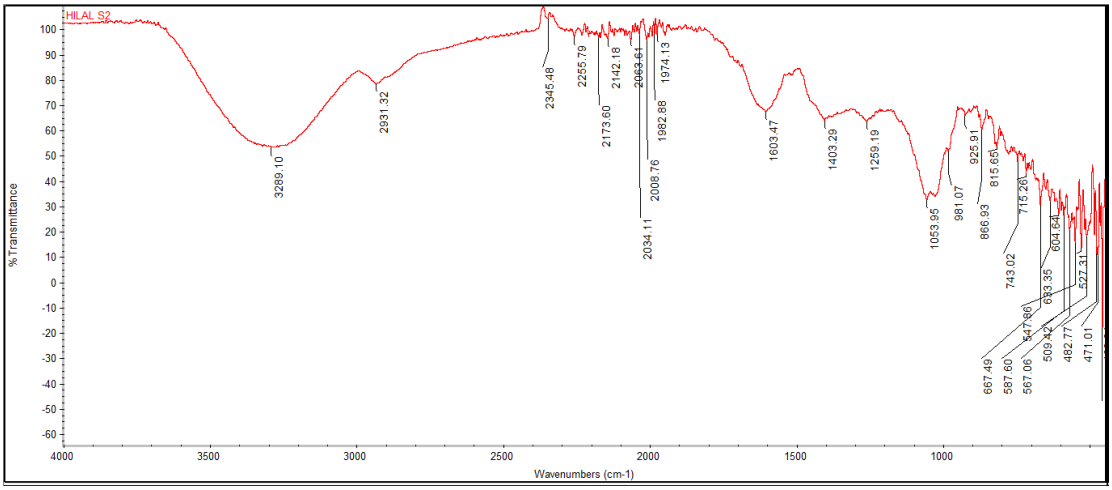


Figure 1: FTIR spectra before silver nanoparticles.

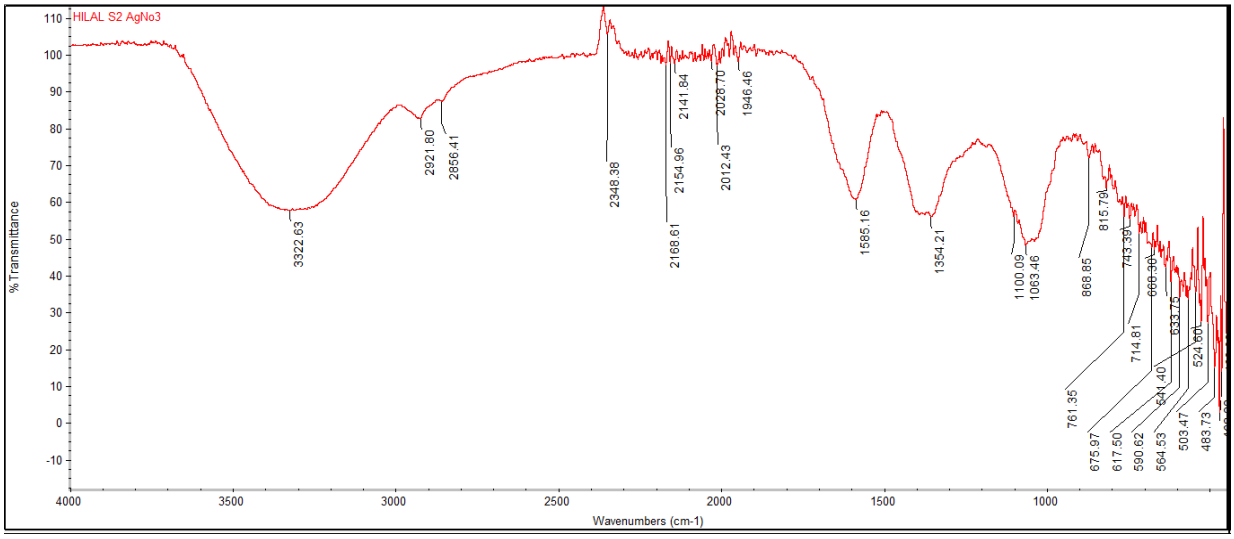


Figure 2: FTIR spectra after silver Nanoparticles formation.

The SEM findings correlate well with UV-vis spectroscopic results, where a sharp surface plasmon resonance band at 430-450 nm suggested a predominantly spherical and well-dispersed nanoparticle population. Together with FTIR analysis, the SEM results confirm the successful green synthesis of stable, spherical, and uniformly dispersed silver nanoparticles, highlighting their suitability for potential biomedical, catalytic, and environmental applications.

In vitro Assay

Preliminary phytochemical analysis of *Farsetia jacquemontii* was performed to determine the presence of major bioactive constituents including alkaloids, flavonoids, steroids, and tennis.

The analysis confirmed the presence of alkaloids, terpenoids, flavonoids, glycosides, and anthraquinones in the extract, whereas steroids and tannins were not detected. The presence of these phytoconstituents suggests a strong potential for biological activity and supports their role in the reduction and stabilization of silver nanoparticles during green synthesis.

Antioxidant Activity (DPPH Radical Scavenging Assay)

The percentage of DPPH inhibition increased progressively with increasing AgNP concentration, reaching 95.29% at 250 µg/mL. Although this value was slightly lower than that of the reference standard ascorbic acid (96.75%), the difference was minimal, indicating a comparable antioxidant capacity. At lower concentrations, AgNPs demonstrated substantial radical scavenging activity, achieving 59.08% inhibition at 100 µg/mL and 76.92% at 150 µg/mL. The Half-Maximal Inhibitory Concentration (IC_{50}) for AgNPs was calculated as 149.53 µg/mL, compared with 91.82 µg/mL for ascorbic acid. These results suggest that the phytochemicals adsorbed onto the nanoparticle surface contribute significantly to the enhanced free radical scavenging ability of the AgNPs (Table 1).

Antibacterial Potential

The small particle size and high surface-to-volume ratio of the synthesized AgNPs likely enhanced their interaction with bacterial membranes, facilitating penetration and disruption of vital metabolic processes. Antibacterial activity increased with AgNP concentration, indicating a clear dose-dependent response. At both tested concentrations, 5 mg/mL (Table 2), and 10 mg/mL (Table 3), FJ-AgNPs produced zones of inhibition comparable to, and in some cases exceeding, those of the standard antibiotic gentamicin. In contrast, the negative control (DMSO) showed no inhibitory activity, confirming that the antibacterial effects were attributable solely to the nanoparticles.

In vivo antidiabetic activity

Effect of AgNPs on Body Weight

Body weight is an important physiological parameter for assessing overall health status and therapeutic efficacy in diabetic animal models. In the present study treatment with *Farsetia jacquemontii*-mediated AgNPs resulted in a dose-dependent improvement in body weight. Mice treated with AgNPs at 150 mg/kg showed gradual weight recovery over time, whereas those receiving the higher dose (300 mg/kg) demonstrated a more pronounced restoration of body weight, approaching values observed in the normal control group by day 15. The standard antidiabetic drug glibenclamide also produced moderate improvement but remained inferior to the higher AgNP dose (Table 3).

Effect of AgNPs on Blood Glucose Levels

Treatment with *Farsetia jacquemontii*-mediated Silver Nanoparticles (AgNPs) resulted in a significant, dose-dependent reduction in blood glucose levels over time. Mice treated with AgNPs at 150 mg/kg showed a progressive decline in glucose levels from 196 mg/dL on day 0 to 128 mg/dL by day 15, indicating substantial improvement in glycemic control. The higher dose

(300 mg/kg) also produced a significant antihyperglycemic effect, with glucose levels maintained at lower values throughout the study period and comparable to those observed in the standard drug-treated group.

The standard antidiabetic drug glibenclamide produced moderate reductions in blood glucose levels; however, the 150 mg/kg AgNP treatment demonstrated superior glycemic improvement by the end of the study (Table 4).

Effect of AgNPs on Liver and renal Function

In the present study, diabetic control mice exhibited significant elevations in liver function markers, including Alanine Aminotransferase (ALT), bilirubin, and Alkaline Phosphatase (ALP), reflecting hepatic dysfunction and impaired metabolic capacity. Specifically, ALT levels increased from normal values (28 U/L) to 49 U/L, bilirubin rose to 1.82 mg/dL, and ALP reached 204 U/L, confirming diabetes-associated liver damage.

Treatment with *Farsetia jacquemontii*-mediated Silver Nanoparticles (AgNPs) resulted in a marked, dose-dependent improvement in liver function parameters. Mice treated with AgNPs at 150 mg/kg exhibited significant reductions in ALT (35 U/L), bilirubin (0.89 mg/dL), and ALP (173 U/L). Notably, the higher AgNP dose (300 mg/kg) produced near-normalization of hepatic markers, with ALT reduced to 29.5 U/L, bilirubin to 0.83 mg/dL, and ALP to 142 U/L.

Similarly, administration of *Farsetia jacquemontii*-mediated Silver Nanoparticles (AgNPs) resulted in a significant, dose-dependent improvement in renal function markers. Mice treated with AgNPs at 150 mg/kg demonstrated marked reductions in urea (85 mg/dL) and creatinine (0.94 mg/dL), indicating partial restoration of renal function. Notably, treatment with the higher dose (300 mg/kg) produced further improvement, with urea (78 mg/dL) and creatinine (0.81 mg/dL) levels approaching those of normal controls. In parallel, total serum protein levels were normalized, reflecting improved renal protein handling and reduced protein loss (Table 5).

Effect of AgNPs on Lipid Profile

Treatment with *Farsetia jacquemontii*-mediated Silver Nanoparticles (AgNPs) produced significant, dose-dependent improvements in lipid parameters. Mice receiving AgNPs at 150 mg/kg exhibited substantial reductions in total cholesterol (144 mg/dL) and LDL (98 mg/dL), accompanied by an increase in HDL levels (33 mg/dL). Notably, administration of the higher AgNP dose (300 mg/kg) resulted in a more pronounced hypolipidemic effect, with further reductions in total cholesterol (129 mg/dL) and LDL (78 mg/dL), and a marked elevation in HDL (38 mg/dL). Triglyceride levels were also significantly reduced in AgNP-treated groups compared with diabetic controls (Table 6).

DISCUSSION

Phytochemical analysis plays a crucial role in activity of plant extract. In the recent experiment preliminary phytochemical analysis of *Farsetia jacquemontii* was performed to determine the presence of major bioactive constituents including alkaloids, flavonoids, steroids, and tennis.

Table 1: Antioxidant activity of *Farsetia jacqmontii* derived AgNPs.

Concentration	DPPH free radicals % inhibition	
	AgNPs	Ascorbic acid
100 µg/mL	59.08±0.92^{c}	77.67±1.61^{c}
150 µg/mL	76.92±0.29^{b}	91.25±3.51^{b}
200 µg/mL	92.17±2.09^{a}	95.37±1.36^{a}
250 µg/mL	95.29±0.94^{a}	96.75±0.51^{a}
IC_{50}	149.53 µg/mL	91.82 µg/mL

± indicates value of standard error. Means with different English letters are statistically significant at $p<0.05$. the number of replicas per treatment is 3 ($n=3$).

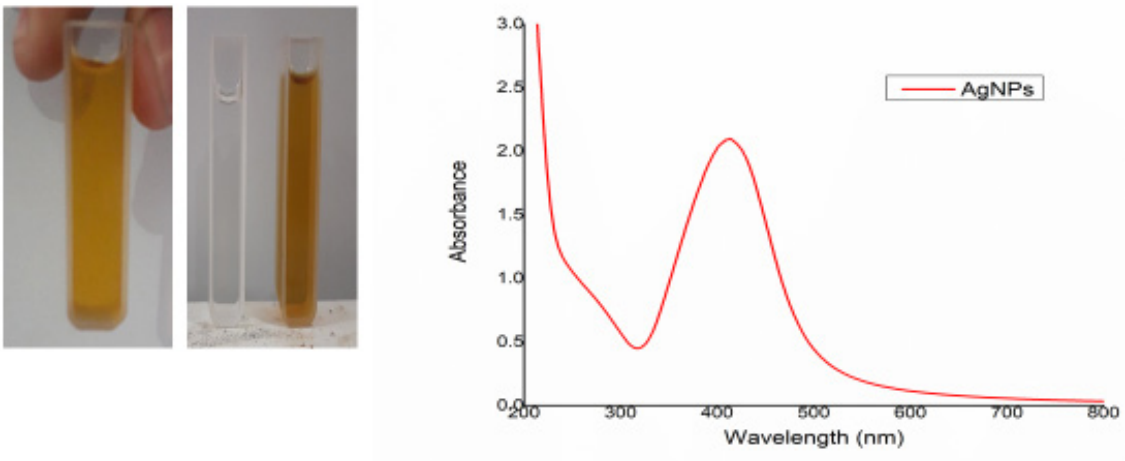


Figure 3: Visual color change and UV-vis characterization of green-synthesized AgNPs, showing a distinct surface plasmon resonance peak at ~430-450 nm, confirming successful nanoparticle formation and stability.

Table 2: Antibacterial activity of *Farsetia jacquemontii*-derived AgNPs (5 mg/mL).

Effects of 5 mg/mL AgNPs on zone of inhibition				Effects of 5 mg/mL AgNPs on zone of inhibition		
	Staphylococcus aureus	*Klebsilla pneumonia*	*E. coli*	*Staphylococcus aureus*	*Klebsilla pneumonia*	*E. coli*
AgNPs	24.1±0.05[b]	23.3±0.09[b]	22.5±0.07[a]	25.2±0.06[b]	22.4±0.04[a]	24.5±0.05[a]
Gentamycin	21.9±0.07[b]	22.5±0.2[a]	21.1±0.1[a]	24.1±0.21[a]	24.9±0.08[b]	25.1±0.03[a]
DMSO	0	0	0	0	0	0

Table 3: Effect of *Farsetia jacquemontii*-derived AgNPs on body weight of diabetic mice.

Groups	Dose (mg/kg)	0th day	5th day	10th day	15th day
Normal control	----------	190±0.67[a]	194±0.37[a]	197±0.43[a]	197±0.29[a]
Diabetic control	----------	190±0.33[a]	194±0.69[a]	196±0.33[a]	197±0.48[a]
Glabinclamide	10	179±0.58[b]	180±0.72[c]	187±0.58[c]	188±0.61[c]
AgNPs	150	180±0.53[b]	186±0.84[b]	188±0.62[c]	189±0.58[c]
AgNPs	300	190±0.59[a]	194±0.92[a]	194±0.55[b]	195±0.52[b]
LSD		1.757	2.203	1.557	1.693

Values are expressed as mean±standard error (n=3). Means within the same column sharing different superscript letters are significantly different at p<0.05.

Table 4: Effect of *Farsetia jacquemontii*-derived AgNPs on blood glucose levels (mg/dL).

Groups	Dose (mg/kg)	0th day	5th day	10th day	15th day
Normal control	----------	111±0.88[e]	123±0.57[e]	126±0.37[d]	111±0.45[d]
Diabetic control	----------	249±0.38[a]	239±0.43[b]	206±0.33[a]	193±0.67[a]
Glabinclamide	10	247±0.75[b]	340±0.71[a]	209±0.1.45[a]	194±0.56[a]
AgNPs	150	196±0.33[c]	177±0.52[c]	148±0.65[c]	128±0.37[c]
AgNPs	300	177±0.35[d]	173±0.57[d]	174±0.44[b]	174±0.39[b]
LSD		1.936	1.693	2.252	1.242

Values are expressed as Mean±Standard error (n=3). Means within the same column sharing different superscript letters are significantly different at p<0.05.

The analysis confirmed the presence of alkaloids, terpenoids, flavonoids, glycosides, and anthraquinones in the extract, whereas steroids and tannins were not detected. The presence of these phytoconstituents suggests a strong potential for biological activity and supports their role in the reduction and stabilization of silver nanoparticles during green synthesis. Similar analysis was obtained by other scientists (Salehi *et al.*, 2019).

Oxidative stress is a key contributor to the development of antioxidant potential and evaluating therapeutic efficacy. In this study, *Farsetia jacquemontii*-derived Silver Nanoparticles (AgNPs) exhibited strong, concentration-dependent antioxidant activity as determined by the 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) radical scavenging assay. The potent antioxidant activity observed indicates an effective capacity to neutralize Reactive Oxygen Species (ROS), which may protect pancreatic β-cells as well as hepatic, renal, and vascular tissues from oxidative injury. Similar reports were obtained by other studies (Dayana *et al.*, 2026).

Plant-mediated silver nanoparticles synthesized using *Farsetia jacquemontii* (FJ-AgNPs) demonstrated pronounced antibacterial activity against multiple pathogenic bacterial strains, including *Staphylococcus aureus, Klebsiella pneumonia*, and *Escherichia coli*. The observed broad-spectrum efficacy is consistent with the well-documented multimodal antibacterial mechanisms of silver nanoparticles, which include disruption of bacterial cell membranes, generation of Reactive Oxygen Species (ROS), interference with DNA replication, and interaction with thiol groups of essential enzymes, ultimately leading to bacterial cell death. These findings highlight the potential of *F. jacquemontii*-derived AgNPs as effective alternative antimicrobial agents, particularly in the context of rising Multidrug-Resistant (MDR) bacterial infections as was obtained by other investigations (Dunah *et al.*, 2026).

Body weight is an important physiological parameter for assessing overall health status and therapeutic efficacy in diabetic animal models. In the present study, diabetic mice exhibited impaired weight gain compared with normal controls over the experimental period, reflecting classical diabetic manifestations such as enhanced protein catabolism, muscle wasting, and reduced glucose utilization. The diabetic control group showed only a marginal increase in body weight during the study period,

indicating persistent metabolic dysregulation (Ul Haq *et al.*, 2022).

Treatment with *Farsetia jacquemontii*-mediated AgNPs resulted in a dose-dependent improvement in body weight. Mice treated with AgNPs at 150 mg/kg showed gradual weight recovery over time, whereas those receiving the higher dose (300 mg/kg) demonstrated a more pronounced restoration of body weight, approaching values observed in the normal control group by day 15. The standard antidiabetic drug glibenclamide also produced moderate improvement but remained inferior to the higher AgNP dose.The observed recovery in body weight following AgNP treatment suggests improved glycemic control, enhanced nutrient utilization, and reduced proteolysis. These effects are likely mediated through improved metabolic efficiency and attenuation of diabetes-associated oxidative stress. Restoration of body weight indicates improved systemic health and metabolic balance, supporting the antidiabetic efficacy of *F. jacquemontii*-derived AgNPs, which are in coherence of other investigation (Tahir *et al.*, 2025).

Blood glucose regulation is the primary indicator for assessing antidiabetic efficacy. In the present study, untreated diabetic mice exhibited persistently elevated blood glucose levels throughout the experimental period, confirming sustained hyperglycemia and poor glycemic control. Blood glucose levels in the diabetic control group remained markedly high from day 0 through day 15, reflecting impaired insulin action and metabolic dysfunction. In contrast, treatment with *Farsetia jacquemontii*-mediated Silver Nanoparticles (AgNPs) resulted in a significant, dose-dependent reduction in blood glucose levels over time. The standard antidiabetic drug glibenclamide produced moderate reductions in blood glucose levels; however, the 150 mg/kg AgNP treatment demonstrated superior glycemic improvement by the end of the study. The observed antihyperglycemic effect of AgNPs may be attributed to enhanced insulin secretion, improved peripheral glucose uptake, and/or inhibition of carbohydrate-hydrolyzing enzymes by bioactive phytochemicals adsorbed on the nanoparticle surface. Additionally, the antioxidant properties of AgNPs may protect pancreatic β-cells from oxidative stress, thereby supporting improved insulin function (Elmehalawy *et al.*, 2025).

Liver function parameters are critical indicators of hepatic integrity, particularly under diabetic conditions where oxidative stress and metabolic imbalance often lead to hepatocellular injury. In the present study, diabetic control mice exhibited significant elevations in liver function markers, including alanine Aminotransferase (ALT), bilirubin, and Alkaline Phosphatase (ALP), reflecting hepatic dysfunction, renal profile and impaired metabolic capacity. The restoration of liver enzyme and renal profile suggests a pronounced hepatoprotective effect of AgNPs, likely mediated through their antioxidant activity, stabilization of

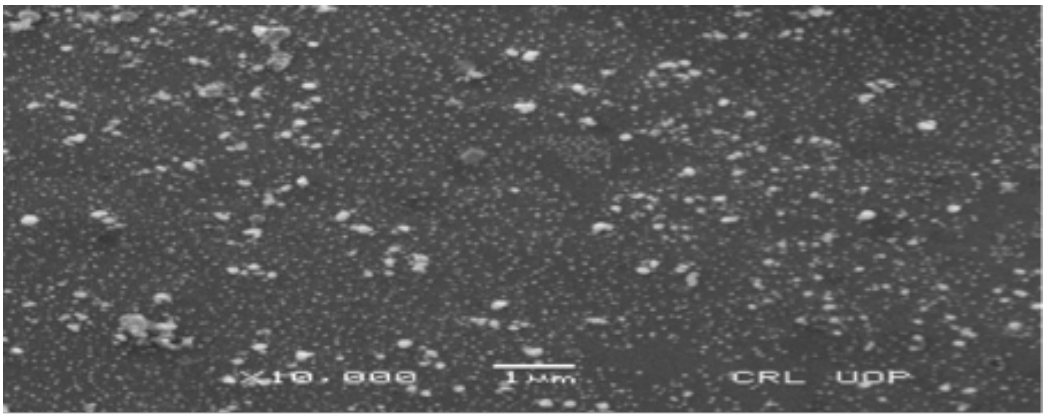


Figure 4: SEM micrograph of green-synthesized AgNPs showing predominantly spherical morphology with uniform dispersion at 10,000× magnification (scale bar = 1 µm).

Table 5: Effect of *Farsetia jacquemontii*-derived AgNPs on liver function parameters.

Treatment	Dose	ALT	Bilirubin	ALP	Urea mg/dL	Creatinine	T. protein
Normal control	--------	28±0.34^{e}	0.8±0.03^{c}	119±0.46^{d}	50±0.88^{e}	0.58±0.05^{e}	8.5±0.07^{b}
Diabetic control	--------	49±0.45^{a}	1.82±0.11^{a}	204±0.37^{a}	27±0.75^{a}	2.19±0.03^{a}	9.1±0.05a
Glibenclimide	10 mg	38±0.49^{b}	0.89±0.06^{b}	173±0.33^{b}	93±0.45^{b}	0.88±0.01^{c}	6.4±0.11^{cd}
Dose-1 AgNPs	150 mg	35±0.17^{c}	0.89±0.05^{b}	173±0.35^{b}	85±.37^{c}	0.94±0.07^{b}	6.4±0.07^{d}
Dose-2 AgNPs	300 mg	29.5±0.28^{d}	0.83±0.01^{b}	142±0.67^{c}	78±0.32^{d}	0.81±0.01^{d}	6.5±0.03^{c}
LSD		0.9395	0.0504	1.328	1.557	0.011	0.168

Values are expressed as Mean±Standard error (n=3). Means within the same column sharing different superscript letters are significantly different at p<0.05.

Table 6: Effect of *Farsetia jacquemontii*-derived AgNPs on lipid profile.

Group	Dose mg/dl	Total.CH mg/dl	HDL mg/dl	LDL mg/dl	TG mg/dl
Normal control	-------	133±.33[d]	45±.36[a]	109±.34[b]	149±.33[d]
Diabetic control	-------	208±.39[a]	24±.37[d]	149±.41[a]	197±.45[a]
Glibenclimide	10 mg	156±.88[b]	33±.45[c]	98±39[c]	173±.39[b]
Dose-1 AgNPs	150 mg	144±.66[c]	33±.33[c]	98±31[c]	173±.41[b]
Dose-2 AgNPs	300 mg	129±.34e	38±.39[b]	78±.34[d]	170±45[c]
LSD		1.757	1.051	1.051	1.242

hepatocellular membranes, and reduction of lipid peroxidation. Improved hepatic enzyme profiles also indicate enhanced detoxification capacity and promotion of hepatic recovery. Similar hepatoprotective effects have been reported for other plant-derived nanoparticle systems, further supporting the therapeutic potential of green-synthesized AgNPs in mitigating liver-related complications associated with diabetes (Barabadi *et al*., 2025).

Dyslipidemia is a common metabolic abnormality associated with diabetes mellitus and represents a major contributor to cardiovascular morbidity. In the present study treatment with *Farsetia jacquemontii*-mediated Silver Nanoparticles (AgNPs) produced significant, dose-dependent improvements in lipid parameters. The observed improvement in lipid profile may be attributed to enhanced insulin sensitivity, improved hepatic lipid metabolism, and antioxidant-mediated suppression of lipid peroxidation. By restoring lipid homeostasis, *F. jacquemontii*-derived AgNPs not only contribute to improved metabolic control but also reduce cardiovascular risk associated with diabetes. These findings underscore the multifunctional therapeutic potential of plant-mediated AgNPs in the management of diabetes-related dyslipidemia (Paul *et al*., 2024).

CONCLUSION

This study successfully demonstrates the green synthesis of silver nanoparticles using *Farsetia jacquemontii* extract and provides comprehensive physicochemical and biological validation of their therapeutic potential. Nanoparticle formation and stability were confirmed through UV-vis spectroscopy, FTIR, and SEM analyses, which collectively revealed characteristic surface plasmon resonance, spherical morphology, nanoscale dimensions, and effective biomolecular capping. FTIR spectra confirmed the involvement of plant-derived phenolics, proteins, and carbohydrates in the reduction and stabilization of Ag^+ ions, underscoring the role of phytochemicals in producing stable and biocompatible nanoparticles.

Biological evaluation revealed that *F. jacquemontii*-mediated AgNPs exerted robust antioxidant activity, effectively scavenging free radicals and mitigating oxidative stress-a central driver of diabetic pathology.

ACKNOWLEDGEMENT

The authors are thankful to Department of Biotechnology UST Bannu for provision of essential help.

ABBREVIATIONS

AgNPs: Silver Nanoparticles; **FTIR:** Fourier Transform Infrared Spectroscopy; **SEM:** Scanning Electron Microscopy; **UV-vis:** Ultraviolet-visible Spectroscopy; **SPR:** Surface Plasmon Resonance; **DPPH:** 2,2-Diphenyl-1-picrylhydrazyl; **ALT:** Alanine Aminotransferase; **ALP:** Alkaline Phosphatase; **HDL:** High-Density Lipoprotein; **LDL:** Low-Density Lipoprotein.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Cite this article: Ullah A, Jan S, Rizvi SA, Khan YM, Khan MU, Hussain M, *et al*. Green Synthesis and Pharmacological Assessment of Silver Nanoparticles using Medicinal Plant Extract of *Farsetia jacquemontii*. Pharmacog Res. 2027;19(1):605-14.