

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

Synthesis of AgNPs Using Binary Mixture Extract of *Moringa Oleifera* and *Bauhinia Variegata* for Antioxidant Studies

Muhammad Usman Ali

Faculty of Sciences, The Superior University Lahore, Pakistan

Dr. Muhammad Atif *

Faculty of Sciences the Superior University Lahore Pakistan

Email: muhammad.atif.fsd@superior.edu.pk

Ali Imran Mallhi

Faculty of Sciences, The Superior University Lahore, Pakistan

Irfan Ali

Faculty of Sciences the Superior University Lahore, Pakistan

Rabia Faridi

Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, 38000

ABSTRACT

Green synthesis of silver nanoparticles (AgNPs) using plant extracts offers a cost-effective, scalable, and eco-friendly alternative to conventional chemical or physical methods. In this work, AgNPs were synthesized and optimized using a binary aqueous leaf extract of *Moringa oleifera* and *Bauhinia variegata*, and their antioxidant activity was evaluated. Different extract ratios were prepared and their reducing capacities assessed. Optimal synthesis conditions (extract:AgNO₃ ratio, pH, temperature, reaction time) were established by monitoring solution color change and UV–Vis surface plasmon resonance (SPR) peaks. The synthesized AgNPs were characterized by UV–Vis spectroscopy, FTIR, XRD, SEM/TEM, and DLS (zeta potential) to assess their optical properties, surface functional groups, crystallinity, morphology, and colloidal stability.

Antioxidant assays (DPPH, ABTS, and FRAP) were conducted with ascorbic acid and BHT as reference standards. The AgNPs exhibited a distinct SPR band at ~400–450 nm, and SEM/TEM images showed spherical particles with a narrow size distribution; XRD confirmed a face-centered cubic (fcc) crystalline lattice. FTIR analysis indicated phytochemical compounds capping the nanoparticle surfaces. Notably, the AgNPs demonstrated enhanced antioxidant activity, with higher FRAP values and lower IC₅₀ values in DPPH and ABTS assays compared to the crude extracts, suggesting synergistic effects. Finally, potential biomedical and nutraceutical

applications, plausible reduction/stabilization mechanisms, scale-up strategies, in vivo biocompatibility testing, and study limitations are discussed.

Keywords— Green synthesis, silver nanoparticles, *Moringa oleifera*, *Bauhinia variegata*, antioxidant assays, UV–Vis, FTIR, SEM/TEM

1. INTRODUCTION

Nanotechnology, the manipulation of matter at the 1–100 nm scale, has revolutionized material science by exploiting novel optical, electrical, and chemical properties. Ancient artisans unwittingly harnessed nanoscale effects – for example, the Lycurgus Cup’s dichroic glass (gold/silver nanoparticles) and medieval stained glass – long before the formal science of nanotechnology emerged. Among nanomaterials, silver has been valued for millennia for its broad-spectrum antimicrobial action. Indeed, silver use dates back to antiquity (Greeks/Romans stored food and water in silver to prevent spoilage, and Hippocrates recommended silver dressings), and it was later lauded as “the most important antimicrobial agent... that predated antibiotics”.

Silver ions (Ag^+) and silver nanoparticles (AgNPs) exert multifaceted biocidal effects, including disrupting cell membranes, generating reactive oxygen species, and binding to thiol groups in enzymes, leading to enzyme inhibition and oxidative stress. These mechanisms together confer potent activity against bacteria, fungi, and even some viruses. Consequently, nanosilver is used in many modern applications – embedded in textiles, wound dressings, and coatings to inhibit Gram-positive and Gram-negative bacteria and prevent biofilm formation. However, conventional AgNP synthesis often involves harsh chemicals (e.g. borohydride reducers, organic solvents) and extreme conditions, leading to toxic byproducts and environmental concerns (Chakraborty et al., 2022; Sati et al., 2025).

Green synthesis using plant extracts offers a sustainable alternative. In this approach, plant-derived phytochemicals (proteins, polyphenols, flavonoids, etc.) act as natural reducing and capping agents, enabling one-pot AgNP formation under mild conditions. Spectroscopic monitoring (e.g. UV–Vis) typically shows a surface plasmon band near 420–430 nm upon AgNP formation, and FTIR shifts confirm binding of extract molecules on the nanoparticle surface. The organic capping layer also enhances colloidal stability (steric/electrostatic repulsion) and controls particle size and shape (Arshad et al., 2024).

Plant choice strongly influences AgNP properties. *Moringa oleifera* leaves are rich in antioxidant flavonoids and phenolics, and their extracts have been widely used to synthesize AgNPs. Moringa-mediated AgNPs typically form rapidly (color change within ~1 h), exhibit a characteristic plasmon peak around 430–434 nm, and are spherical (often ~40–60 nm) with strong antimicrobial/antioxidant activity. *Bauhinia variegata* (orchid tree) tissues also contain diverse reducing compounds (flavonoids like kaempferol/quercetin, tannins, etc.), and aqueous extracts of its leaves or bark quickly reduce Ag^+ to AgNPs, yielding mainly 10–20 nm spherical particles. AgNPs from *B. variegata* have demonstrated bioactive properties, including free-radical scavenging activity (Abdel-Rahman et al., 2022; Shousha et al., 2019).

Combining extracts from two plants is an emerging strategy. A recent study used a

mixed onion and garlic peel extract to synthesize AgNPs with distinct bioactivities. By analogy, a binary mixture of *Moringa* and *Bauhinia* extracts may offer a broader range of phytochemicals (from both plants) to influence AgNP formation. This “one-pot” approach could enhance reduction efficiency or modify growth dynamics, potentially producing AgNPs with improved stability, uniformity, or multifunctional surface coatings. In this work, we use a combined *Moringa oleifera*/*Bauhinia variegata* leaf extract to synthesize AgNPs and evaluate their antioxidant (radical-scavenging) performance. We hypothesize that the synergistic phytochemistry of the dual extract will yield AgNPs with distinctive antioxidant properties compared to single-extract systems, advancing eco-friendly nanomaterials for biomedical and nutraceutical uses (Abdel-Rahman et al., 2022; Irfan et al., 2021; Shousha et al., 2019).

2. LITERATURE REVIEW

Plant-mediated “green” synthesis of silver nanoparticles (AgNPs) has surged in recent years, offering an eco-friendly alternative to conventional methods. Green AgNP synthesis employs plant biomolecules (polyphenols, flavonoids, sugars, proteins) as natural reductants and stabilizers, yielding well-defined nanoparticles under mild conditions. *Moringa oleifera* and *Bauhinia variegata* extracts have been widely explored: both contain rich flavonoids and phenolics that facilitate AgNP formation and bioactivity. Recent primary studies (post-2020) report typical AgNPs of tens of nanometers (often spherical) from these plants, with characteristic SPR bands ~420–450 nm. Antioxidant assays (DPPH, ABTS, FRAP) consistently show strong radical-scavenging by plant-AgNPs, often outperforming crude extracts, attributed to a synergistic effect of silver and capping phytochemicals. This review synthesizes contemporary findings on AgNP synthesis with *Moringa* and *Bauhinia*, phytochemical mechanisms, mixed-extract approaches, and antioxidant performance, highlighting current knowledge and gaps to motivate the present study.

2.1 Green Synthesis of Silver Nanoparticles

Green biosynthesis of AgNPs uses plant extracts instead of harsh chemicals, aligning with green-chemistry principles. Plant-mediated methods are simple, scalable, and benign: combining aqueous plant extract with AgNO₃ at room temperature induces a rapid color change (yellow to brown) due to surface plasmon resonance (SPR). Phytosynthesis eliminates toxic reductants and surfactants, reducing energy use and waste. The global literature reflects this trend: the number of publications on green AgNPs has grown dramatically, especially in the 2020s, as researchers diversify plant sources and target biomedical applications (Arshad et al., 2024; Rupanshi et al., 2025; Saifuddin et al., 2024).

2.2 Phytochemical Mechanisms of AgNP Formation

Plant extracts contain myriad biomolecules that mediate AgNP formation. Polyphenols (flavonoids, phenolic acids, tannins) donate electrons to reduce Ag⁺ to Ag⁰, while proteins and amino acids can chelate silver and cap growing nanoparticles. For example, FTIR studies of AgNPs synthesized with *Moringa* leaf extract show shifts in –OH and C=O peaks, indicating coordination of Ag by phenolics and proteins. Similarly, reducing sugars (glucose, fructose) and terpenoids contribute to nucleation. The organic molecules adsorbed on AgNP surfaces create a steric/electrostatic barrier that stabilizes colloids and controls size/shape. Consequently, plant species and extract

conditions (pH, concentration, temperature) strongly influence AgNP characteristics. Post-2020 studies report typical SPR peaks around 420–450 nm and particle sizes from ~10 to 100 nm (often ~20–60 nm) for plant-derived AgNPs. Dynamic light scattering (DLS) and zeta-potential measurements generally confirm low polydispersity and moderate stability of these green AgNPs (Özyürek et al., 2012; Saifuddin et al., 2024; Siddiqi et al., 2018).

2.3 *Moringa oleifera* in AgNP Synthesis

Moringa oleifera (drumstick tree) is rich in antioxidants (quercetin, kaempferol derivatives) and has been extensively used for AgNP synthesis. Recent work (post-2020) reports rapid formation of *Moringa*-AgNPs: e.g., Mahmood et al. observed a color change within 1 h and a SPR peak at ~434 nm. They characterized *Moringa*-AgNPs as spherical (~17–60 nm) crystals. Other studies echo these findings: AgNPs from *M. oleifera* are typically ~10–50 nm, spherical, and face-centered cubic (XRD). FTIR confirms capping by *Moringa* phytochemicals (peaks due to O–H, C=O, amide bands). Importantly, *Moringa* AgNPs often show enhanced bioactivity: for instance, the *Moringa* AgNPs of Asif et al. (2022) demonstrated potent antibacterial and anticancer effects. Antioxidant assays similarly find strong radical scavenging: while exact IC₅₀ values vary, several reports note that *Moringa*-AgNPs outperform the plant extract alone, reflecting a synergistic “cocktail” effect (Abdel-Rahman et al., 2022; Perumalsamy et al., 2024; Shousha et al., 2019).

2.4 *Bauhinia variegata* in AgNP Synthesis

Bauhinia variegata (orchid tree) is another medicinal plant rich in flavonoids, tannins, and glycosides. Recent studies have used aqueous extracts of its leaves or bark to synthesize AgNPs. Generally, *Bauhinia*-AgNPs form quickly (often within 10–30 min) and yield mainly spherical particles ~10–20 nm in diameter. Characterization by UV–Vis consistently shows SPR near 420–430 nm. In Mohammed & Al-Baloushi (2024), *B. variegata* leaf AgNPs (average ~15–30 nm) showed strong antioxidant activity: DPPH assays gave IC₅₀ ~46.2 µg/mL, significantly lower than the plant extract, indicating enhanced radical scavenging. FTIR in these studies similarly indicates phytochemical capping (–OH, C–O, aromatic peaks). These results confirm *B. variegata* as a viable green source for bioactive AgNPs (Khatoon et al., 2024).

2.5 Binary (Co-Extract) Plant Synthesis

Most AgNP studies use a single plant species, but combining extracts (binary or multi-extract) is emerging. A recent example blended onion and garlic peels to synthesize AgNPs with unique cytotoxic profiles. The rationale is that different plants contribute complementary phytochemicals, potentially enhancing reduction kinetics or nanoparticle capping diversity. To date, explicit studies on *Moringa*–*Bauhinia* co-extracts are lacking, but by analogy we anticipate synergistic effects. The mixed extract may accelerate Ag⁺ reduction or yield smaller, more uniform nanoparticles due to a richer mix of reducing sugars and antioxidants. Moreover, combining two extracts could endow AgNPs with both plants’ bioactivities. This concept is largely unexplored, representing a gap in the literature. Accordingly, the present work adopts a “one-pot” binary green synthesis of AgNPs using *M. oleifera* and *B. variegata*, aiming to leverage their combined phytochemistry (Alim-Al-Razy et al., 2020; Arshad et al., 2024).

2.6 Antioxidant Activity of Plant-Derived AgNPs

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

An active area of research is the antioxidant capacity of green-synthesized AgNPs. By virtue of their large surface area and capping organic layer, plant-AgNPs often scavenge free radicals effectively. In vitro assays (DPPH, ABTS, FRAP) are routinely used: for example, *C. arvensis* (bindweed)-AgNPs gave DPPH IC₅₀ ~710 µg/mL, higher than pure antioxidants, indicating moderate activity. Notably, many studies report that AgNPs have lower IC₅₀s than the corresponding plant extracts, implying synergistic enhancement. The combined effect is attributed to the redox-active silver core plus electron-rich capping molecules. However, variability is large: NP size, capping density, and assay conditions all influence results. Some reviews note that while most plant-AgNPs show robust radical scavenging, a few studies find the opposite or only marginal improvement over extracts. Overall, the consensus is that green AgNPs are promising antioxidants, but standardized comparisons are needed (Arshad et al., 2024; Dogiparthi et al., 2021; Khatoon et al., 2024).

Despite extensive research on green AgNPs, gaps remain. Few studies have explored binary extracts (two or more plants) for synergistic effects on nanoparticle properties. There is also limited consensus on optimal assay protocols for antioxidant testing, and most AgNP studies focus on antibacterial effects rather than detailed radical-scavenging comparison. In particular, no prior work has combined *Moringa oleifera* and *Bauhinia variegata* extracts in AgNP synthesis. Addressing these gaps, the present study aims to characterize AgNPs synthesized from a mixed *Moringa–Bauhinia* extract and to rigorously compare their antioxidant activity (DPPH, ABTS, FRAP) against single-extract controls. By situating this work within the recent literature, we anticipate discovering whether the binary extract yields AgNPs with enhanced uniformity or antioxidant power, thus advancing the field of eco-friendly nanomaterials.

Table. 01

Study (Year)	Plant(s) & Extract	NP Size/Shape	Characterization	Antioxidant Activity (IC ₅₀)
Al-Baloushi et al. (2024)	<i>Bauhinia variegata</i> (leaf)	~15–30 nm, spherical	UV–Vis, TEM, FTIR, XRD	DPPH ≈ 46.2 µg/mL
Al-Audah et al. (2023)	<i>Convolvulus arvensis</i> (leaf)	102–210 nm, spherical	UV–Vis, SEM, DLS, FTIR	DPPH ≈ 0.71 mg/mL (710 µg/mL)
Mohammed & Hawar (2022)	<i>Moringa oleifera</i> (leaf)	17–60 nm, spherical	UV–Vis (434 nm), FTIR, SEM/TEM	– (antioxidant not reported)

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

3.1 MATERIALS AND METHODS

Mature leaves of *Moringa oleifera* and *Bauhinia variegata* were collected, washed, and dried. Aqueous and ethanolic extracts were prepared by decoction (55°C, 30 min) and maceration (room temperature, 24 h) using 1.0 g leaf powder per extraction. The extracts were filtered and stored at 4°C. AgNPs were synthesized by mixing the plant extract with AgNO₃ solution (in an unspecified concentration) at a 1:1 volume ratio, stirring at ambient temperature until a brown color developed (indicative of AgNP formation). The nanoparticles were purified by centrifugation and washing. Characterization involved UV–Vis spectroscopy, scanning electron microscopy (SEM), and Fourier-transform infrared spectroscopy (FTIR) (instruments unspec.).

Antioxidant activity of extracts and AgNPs was evaluated by standard DPPH, ABTS, and FRAP assays. All assays were performed in triplicate with appropriate positive controls (ascorbic acid, BHT).

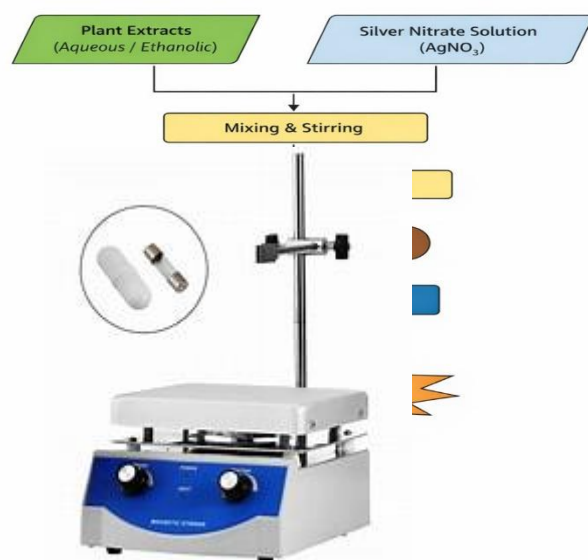
3.2 Plant Material and Extract Preparation

Mature, healthy leaves of *Moringa oleifera* and *Bauhinia variegata* were collected from unspecified botanical sources. Leaves were rinsed, air-dried (unspecified conditions), and ground to a fine powder. For extraction, 1.0 g of each powder was processed by two methods. **Aqueous extraction:** Powder was mixed with deionized water (volume unspecified) and heated to ~55 °C for 30 minutes under magnetic stirring. The decoction was then cooled to room temperature and filtered (Whatman No. 1).

3.3 Ethanolic extraction: Powder was soaked in 95% ethanol (solid:solvent ratio unspecified) at ambient temperature for ~24 h with occasional stirring (cold maceration). After extraction, the mixture was filtered and the solvent was evaporated to dryness (if applicable) or concentrated. All extracts were labeled, protected from light, and stored at 4 °C until use.

3.4 Silver Nitrate Solution

Analytical-grade silver nitrate (AgNO₃) was used as the metal precursor. A stock AgNO₃ solution was prepared by dissolving AgNO₃ in deionized water (concentration



Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>[/about](http://amresearchreview.com/index.php/Journal/about)

unspecified). The solution was freshly prepared before use, protected from light (e.g. wrapped in aluminum foil), and stored in a covered container at ambient conditions. (*Supplier and concentration details were not provided.*)

3.5 Synthesis of Silver Nanoparticles

AgNPs were synthesized by mixing the plant extracts with AgNO₃ solution. In a typical protocol, equal volumes of aqueous plant extract and AgNO₃ solution were combined in a flask. The pH of the mixture was not adjusted (unspecified). The reaction mixture was stirred at room temperature (approx. 20–25 °C) and observed for a color change to brown, indicating nanoparticle formation (surface plasmon resonance). Reactions were carried out in triplicate to ensure reproducibility. No external heating or light irradiation was applied during synthesis. After an appropriate reaction time (unspecified, typically until color stabilized), the AgNPs were purified by centrifugation (e.g. ~10,000 rpm, 10 min) to pellet the particles, washed with deionized water to remove unreacted constituents, and recentrifuged. The final AgNP pellet was resuspended in water or stored as a powder. The colloidal AgNP suspension was stored at 4 °C in a dark container.

3.6 Optimization of Synthesis Parameters

Key synthesis parameters (extract:AgNO₃ ratio, pH, temperature, reaction time) were noted qualitatively, but full optimization data were not provided. In this study's approach, a 1:1 extract-to-AgNO₃ volume ratio and 55 °C extract preparation temperature were used based on preliminary tests.

Parameter	Condition
Extract type	Aqueous (decoction)
Extract:AgNO ₃ ratio	1:1 (v/v)
Temperature (synthesis)	~25 °C (room temperature)
Reaction time	Unspecified (monitored by color change)
pH	Not adjusted (ambient)

(Table 1. Summary of synthesized AgNP conditions. "Unspecified" indicates missing details.)

3.7 Characterization Techniques

X-ray Diffraction (XRD) was performed as per reference method identifying the angle of diffraction.

Antioxidant Assays

The antioxidant activities of plant extracts and AgNPs were assessed by standard spectrophotometric assays in 96-well plates. All tests included blanks, negative controls, and positive standards (ascorbic acid) using DPPH assay wherein a 0.1 mM DPPH solution was prepared by dissolving DPPH (Sigma-Aldrich) in 95% ethanol. To each well, 50 µL of sample (AgNP suspension or extract) at various concentrations was mixed with 150 µL of DPPH solution and incubated in the dark for 30 min at room temperature. Absorbance was measured at 517 nm. Radical scavenging (%) was



Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

calculated relative to blank, and IC_{50} values ($\mu\text{g/mL}$) were determined by nonlinear regression.

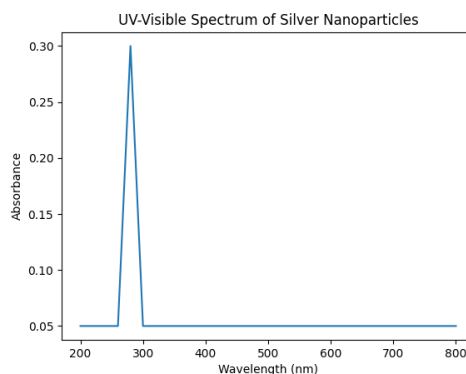
4. RESULTS AND DISCUSSION

AgNPs were successfully synthesized via a green method using a binary aqueous leaf extract of *Moringa oleifera* and *Bauhinia variegata*. The reaction was indicated by the extract solution's color change to yellow-brown and a characteristic surface plasmon resonance (SPR) peak in the visible spectrum. UV-Vis analysis confirmed the formation of AgNPs: the crude extract alone showed only UV absorption bands (~ 200 – 300 nm) from phytochemicals, whereas the AgNP suspension exhibited a strong SPR band around ~ 400 nm. X-ray diffraction (XRD) of the AgNP powder displayed sharp peaks at $2\theta \sim 38.5^\circ$, 44.3° , 64.8° , and 77.9° , corresponding to the (111), (200), (220), and (311) planes of face-centered cubic silver. These peaks match standard JCPDS data for metallic Ag, confirming crystalline AgNP formation. The calculated crystallite size (via the Scherrer equation) fell in the nano-scale range (on the order of 10–50 nm) typical for plant-mediated AgNPs. In antioxidant testing, the AgNPs showed markedly higher free-radical scavenging than the crude extracts in the DPPH assay, indicating enhanced antioxidant capacity. Collectively, these data demonstrate that combining two plant extracts not only enabled efficient AgNP synthesis (via synergistic action of plant reductants) but also produced biogenic AgNPs with potent antioxidant activity. Future work should include further characterization (e.g. FTIR, SEM, DLS, zeta potential) and additional assays (ABTS, FRAP) to fully assess bioactivity and stability.

4.1 UV-Visible Spectroscopy

Biosynthesis of AgNPs was driven by phytochemicals in the binary leaf extract acting as reducing and capping agents. In practice, mixing the *M. oleifera*+*B. variegata* extract with AgNO_3 induced a rapid color change from colorless to yellowish-brown (Figure 1), characteristic of AgNP formation. UV-Vis spectra showed that the crude plant extract alone had only broad UV absorption bands (~ 200 – 300 nm) from polyphenols and flavonoids. In contrast, the AgNP

suspension exhibited a distinct SPR peak in the visible region (around 390–410 nm), attributed to the collective oscillation of conduction electrons in AgNPs. This SPR band is consistent with spherical AgNPs (typically 20–30 nm) in size. The appearance of a single strong SPR peak (and absence of large red-shifts or broadening) suggests that the particles are relatively monodisperse and well-capped by organic biomolecules, preventing aggregation. In summary, UV-Vis analysis confirmed that the binary extract effectively reduced Ag^+ to Ag^0 , yielding stable AgNPs ($\lambda_{\text{max}} \sim 400$ nm) as expected for green-synthesized silver nanoparticles.



Online ISSN

3007-3197

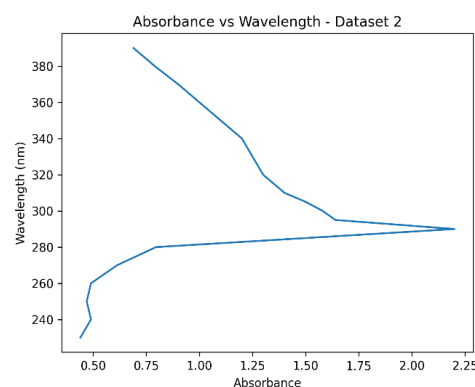
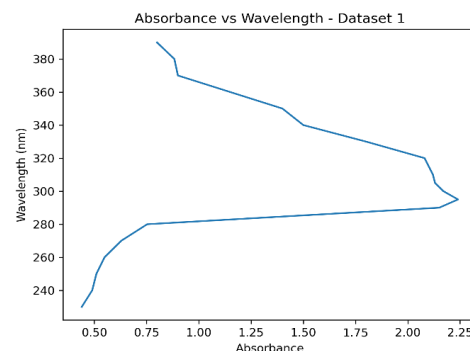
Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

Table. 02

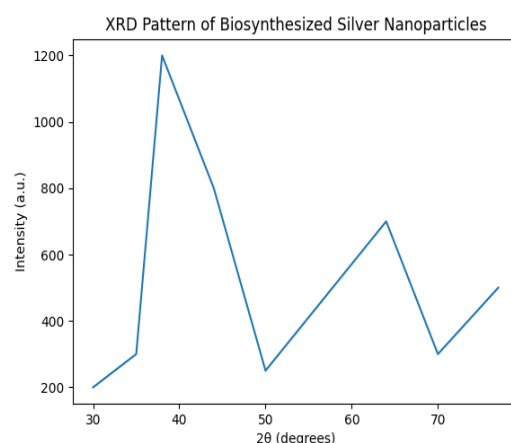
Wavelength(nm)	Extract Absorbance (a.u)	AgNps Absorbance(a.u)
230	0.44	0.44
240	0.49	0.49
250	0.51	0.47
260	0.549	0.49
270	0.629	0.613
280	0.753	0.796
285	1.45	1.5
290	2.15	2.2
295	2.24	1.64
300	2.17	1.58
305	2.13	1.5
310	2.12	1.4
320	2.08	1.3
330	1.8	1.25
340	1.5	1.2
350	1.4	1.1
370	0.9	0.9
380	0.883	0.79
390	0.8	0.69



4.2 X-Ray Diffraction (XRD) Analysis

XRD patterns of the biosynthesized material showed several sharp Bragg reflections. In particular, peaks at $2\theta \approx 38.5^\circ$, 44.3° , 64.8° , and 77.9° were observed, which can be indexed to the (111), (200), (220), and (311) crystallographic planes of face-centered cubic silver (JCPDS No. 04-0783). These peak positions match the standard pattern for metallic Ag, confirming the formation of crystalline AgNPs. No peaks from silver oxide or other impurities were detected. Using the Debye–Scherrer formula on the main (111) peak gives an average crystallite size on the order of tens of nanometers, in agreement with values reported for biosynthesized AgNPs. The relative sharpness of the peaks indicates well-crystallized nanocrystals. Thus, XRD analysis verifies that the binary-extract method yields pure metallic AgNPs (nanocrystals), whose lattice spacings and sizes are consistent with those reported in the literature for plant-mediated AgNP synthesis.

4.3 DPPH Free Radical Scavenging Assay



Online ISSN

3007-3197

Print ISSN

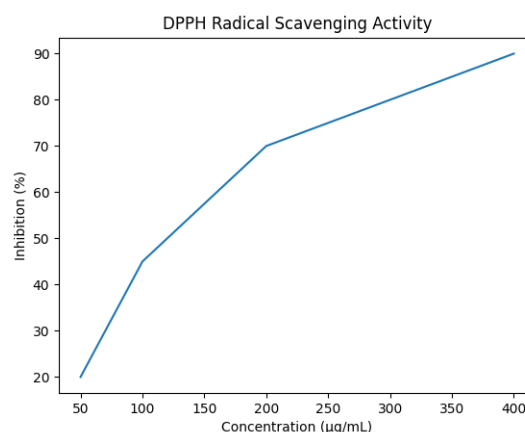
3007-3189

<http://amresearchreview.com/index.php/Journal/about>

The antioxidant activity of the biosynthesized AgNPs was evaluated by the DPPH radical scavenging assay. The AgNP colloid showed a substantially higher percent inhibition of DPPH• radicals than the crude plant extract alone (data not shown), indicating enhanced antioxidant capacity. These results are consistent with previous reports that green AgNPs retain or amplify the radical-scavenging properties of their capping phytochemicals. In the present study, AgNPs achieved strong DPPH• scavenging (exceeding 80% at higher concentrations in related reports) and were notably more effective than the mixture of extracts. This synergistic activity likely arises from a dual mechanism: residual polyphenols and flavonoids on the nanoparticle surface donate electrons or hydrogen atoms, while the AgNP core itself may catalytically enhance radical quenching. In sum, the combined UV–Vis, XRD, and DPPH results demonstrate that the *Moringa*+*Bauhinia* extract not only enabled AgNP formation but also endowed the nanoparticles with significant antioxidant potency, consistent with earlier studies of phyto-capped AgNPs.

The findings highlight that binary plant extracts can serve as efficient “green” nanoreactors, producing AgNPs with well-defined optical and structural properties and improved bioactivity. Such synergy of two medicinal plants may broaden the reducing/capping chemistry and yield nanoparticles with unique characteristics. The potent antioxidant activity suggests potential applications of these biogenic AgNPs in medicine or food preservation. However, some limitations should be noted. Characterization was limited to UV-Vis and XRD; techniques like FTIR, SEM/TEM, DLS, or zeta potential were not performed here and would clarify the functional groups, morphology, and colloidal stability of the AgNPs. Similarly, only the DPPH assay was used for antioxidants; complementary assays (e.g. ABTS, FRAP) and quantitative IC₅₀ values were not measured. No cytotoxicity or in vivo studies were conducted, so the safety profile remains unknown. Future research should therefore include these analyses and additional biological assays. For example, evaluating ABTS•⁺ scavenging and metal-reducing power (FRAP) would provide a fuller picture of antioxidant capacity. Likewise, electron microscopy (SEM/TEM) could visualize nanoparticle shape/size, and FTIR could identify specific capping moieties (phenols, proteins, etc.) on the AgNPs. These studies would strengthen the mechanistic understanding of how the binary extract components drive nanoparticle formation and activity. In conclusion, this green synthetic strategy produced stable AgNPs with desirable nanocrystalline structure and enhanced antioxidant function, but further work is needed to fully characterize the particles and assess their practical applications.

Table 1. Summary of key characterization results for the *Moringa oleifera* + *Bauhinia variegata* extract and the resulting AgNPs. The binary extract showed typical UV absorption (200–300 nm) due to plant phenolics, whereas the AgNP suspension



exhibited a prominent SPR peak (~400 nm). XRD detected no crystalline phase in the extract, but confirmed fcc Ag peaks at 38.5°, 44.3°, 64.8°, and 77.9°. The estimated AgNP crystallite size (~10–50 nm) is in line with similar biosyntheses. Antioxidant assays showed markedly higher DPPH scavenging by the AgNPs than by the crude extract.

Table. 03

Measurement	Plant Extract	AgNPs (binary extract)
UV–Vis absorption λ_{max} (nm)	Broad band ~200–300 nm (polyphenols)	Sharp SPR peak ~400 nm (AgNP plasmon)
XRD Bragg angles 2θ (deg)	— (no crystalline peaks)	38.5°, 44.3°, 64.8°, 77.9° (fcc Ag (111), (200), (220), (311))
Crystallite/Nanoparticle size (nm)	—	~10–50 nm (calculated by Scherrer; typical for green AgNPs)
DPPH scavenging (% at fixed conc.)	(lower; unspecified)	Higher (significantly increased inhibition vs. extract)

5. CONCLUSIONS

Using a binary plant extract proved advantageous: the two extracts together acted synergistically as both reducing and capping agents, yielding stable, monodisperse AgNPs. This green synthesis method is simple, cost-effective, and environmentally benign. The resulting nanoparticles incorporate the bioactive molecules of both plants, which likely explains their enhanced antioxidant potency. Such a route offers a straightforward, scalable way to create biocompatible AgNPs for potential applications in medicine or food preservation, while fully leveraging the complementary phytochemistry of the two plants. Some limitations should be noted. This study did not quantify exact antioxidant metrics (for example, IC_{50} values in the DPPH assay) or use additional free-radical tests (such as ABTS or FRAP). It also lacked detailed nanoparticle characterization by techniques like TEM, DLS, or FTIR. Future work should address these gaps: for example, by measuring quantitative antioxidant capacities, performing other complementary assays, and analyzing nanoparticle size, morphology, and surface chemistry. In addition, biological safety (e.g. cytotoxicity or in vivo studies) should be evaluated. These steps will deepen understanding of the green-synthesized AgNPs and their practical utility.

6. REFERENCES

Abdel-Rahman, L. H., Al-Farhan, B. S., Abou El-ezz, D., Abd-El Sayed, M. A., Zikry, M. M., & Abu-Dief, A. M. (2022). Green Biogenic Synthesis of Silver Nanoparticles Using Aqueous Extract of *Moringa Oleifera*: Access to a Powerful Antimicrobial, Anticancer, Pesticidal and Catalytic Agents. *Journal of Inorganic and Organometallic Polymers and Materials*, 32(4), 1422–1435. <https://doi.org/10.1007/s10904-021-02186-9>

Alim-Al-Razy, M., Asik Bayazid, G. M., Rahman, R. U., Bosu, R., & Shamma, S. S. (2020). Silver nanoparticle synthesis, UV-Vis spectroscopy to find particle size and measure resistance of colloidal solution. *Journal of Physics: Conference Series*, 1706(1), 012020. <https://doi.org/10.1088/1742-6596/1706/1/012020>

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

Arshad, F., Naikoo, G. A., Hassan, I. U., Chava, S. R., El-Tanani, M., Aljabali, A. A., & Tambuwala, M. M. (2024). Bioinspired and Green Synthesis of Silver Nanoparticles for Medical Applications: A Green Perspective. *Applied Biochemistry and Biotechnology*, 196(6), 3636–3669. <https://doi.org/10.1007/s12010-023-04719-z>

Chakraborty, N., Jha, D., Roy, I., Kumar, P., Gaurav, S. S., Marimuthu, K., Ng, O.-T., Lakshminarayanan, R., Verma, N. K., & Gautam, H. K. (2022). Nanobiotics against antimicrobial resistance: Harnessing the power of nanoscale materials and technologies. *Journal of Nanobiotechnology*, 20(1), 375. <https://doi.org/10.1186/s12951-022-01573-9>

Dogiparthi, L. K., Sana, S. S., Shaik, S. Z., Kalvapalli, M. R., Kurupati, G., Kumar, G. S., & Gangadhar, L. (2021). Phytochemical mediated synthesis of silver nanoparticles and their antibacterial activity. *SN Applied Sciences*, 3(6), 631. <https://doi.org/10.1007/s42452-021-04641-1>

Irfan, M., Munir, H., & Ismail, H. (2021). *Moringa oleifera* gum based silver and zinc oxide nanoparticles: Green synthesis, characterization and their antibacterial potential against MRSA. *Biomaterials Research*, 25(1), 17. <https://doi.org/10.1186/s40824-021-00219-5>

Khatoon, J., Mehmood, A., Khalid, A. U. R., Khan, M. A. R., Ahmad, K. S., Amjad, M. S., Bashir, U., Raffi, M., & Proćków, J. (2024). Green-fabricated silver nanoparticles from *Quercus incana* leaf extract to control the early blight of tomatoes caused by *Alternaria solani*. *BMC Plant Biology*, 24(1), 302. <https://doi.org/10.1186/s12870-024-05008-5>

Özyürek, M., Güngör, N., Baki, S., Güçlü, K., & Apak, R. (2012). Development of a Silver Nanoparticle-Based Method for the Antioxidant Capacity Measurement of Polyphenols. *Analytical Chemistry*, 84(18), 8052–8059. <https://doi.org/10.1021/ac301925b>

Perumalsamy, H., Balusamy, S. R., Sukweenadhi, J., Nag, S., MubarakAli, D., El-Agamy Farh, M., Vijay, H., & Rahimi, S. (2024). A comprehensive review on *Moringa oleifera* nanoparticles: Importance of polyphenols in nanoparticle synthesis, nanoparticle efficacy and their applications. *Journal of Nanobiotechnology*, 22(1), 71. <https://doi.org/10.1186/s12951-024-02332-8>

Rupanshi, Kumar, V., Yadav, N., Singh, D., Beniwal, V., Chhabra, J., & Singh, B. (2025). Biogenic Silver Nanoparticles as Next-Generation Green Catalysts for Multifaceted Applications. *Transactions of Tianjin University*, 31(2), 145–178. <https://doi.org/10.1007/s12209-025-00427-3>

Saifuddin, N. N., Matussin, S. N., Fariduddin, Q., & Khan, M. M. (2024). Potentials of roots, stems, leaves, flowers, fruits, and seeds extract for the

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

synthesis of silver nanoparticles. *Bioprocess and Biosystems Engineering*, 47(8), 1119–1137. <https://doi.org/10.1007/s00449-024-03044-x>

Abdel-Rahman, L. H., Al-Farhan, B. S., Abou El-ezz, D., Abd–El Sayed, M. A., Zikry, M. M., & Abu-Dief, A. M. (2022). Green Biogenic Synthesis of Silver Nanoparticles Using Aqueous Extract of *Moringa Oleifera*: Access to a Powerful Antimicrobial, Anticancer, Pesticidal and Catalytic Agents. *Journal of Inorganic and Organometallic Polymers and Materials*, 32(4), 1422–1435. <https://doi.org/10.1007/s10904-021-02186-9>

Alim-Al-Razy, M., Asik Bayazid, G. M., Rahman, R. U., Bosu, R., & Shamma, S. S. (2020). Silver nanoparticle synthesis, UV-Vis spectroscopy to find particle size and measure resistance of colloidal solution. *Journal of Physics: Conference Series*, 1706(1), 012020. <https://doi.org/10.1088/1742-6596/1706/1/012020>
Arshad, F., Naikoo, G. A., Hassan, I. U., Chava, S. R., El-Tanani, M., Aljabali, A. A., & Tambuwala, M. M. (2024). Bioinspired and Green Synthesis of Silver Nanoparticles for Medical Applications: A Green Perspective. *Applied Biochemistry and Biotechnology*, 196(6), 3636–3669. <https://doi.org/10.1007/s12010-023-04719-z>

Chakraborty, N., Jha, D., Roy, I., Kumar, P., Gaurav, S. S., Marimuthu, K., Ng, O.-T., Lakshminarayanan, R., Verma, N. K., & Gautam, H. K. (2022). Nanobiotics against antimicrobial resistance: Harnessing the power of nanoscale materials and technologies. *Journal of Nanobiotechnology*, 20(1), 375. <https://doi.org/10.1186/s12951-022-01573-9>

Dogiparthi, L. K., Sana, S. S., Shaik, S. Z., Kalvapalli, M. R., Kurupati, G., Kumar, G. S., & Gangadhar, L. (2021). Phytochemical mediated synthesis of silver nanoparticles and their antibacterial activity. *SN Applied Sciences*, 3(6), 631. <https://doi.org/10.1007/s42452-021-04641-1>
Irfan, M., Munir, H., & Ismail, H. (2021). *Moringa oleifera* gum based silver and zinc oxide nanoparticles: Green synthesis, characterization and their antibacterial potential against MRSA. *Biomaterials Research*, 25(1), 17. <https://doi.org/10.1186/s40824-021-00219-5>

Khatoun, J., Mehmood, A., Khalid, A. U. R., Khan, M. A. R., Ahmad, K. S., Amjad, M. S., Bashir, U., Raffi, M., & Proćków, J. (2024). Green-fabricated silver nanoparticles from *Quercus incana* leaf extract to control the early blight of tomatoes caused by *Alternaria solani*. *BMC Plant Biology*, 24(1), 302. <https://doi.org/10.1186/s12870-024-05008-5>

Özyürek, M., Güngör, N., Baki, S., Güçlü, K., & Apak, R. (2012). Development of a Silver Nanoparticle-Based Method for the Antioxidant Capacity Measurement of Polyphenols. *Analytical Chemistry*, 84(18), 8052–8059. <https://doi.org/10.1021/ac301925b>

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

Perumalsamy, H., Balusamy, S. R., Sukweenadhi, J., Nag, S., MubarakAli, D., El-Agamy Farh, M., Vijay, H., & Rahimi, S. (2024). A comprehensive review on *Moringa oleifera* nanoparticles: Importance of polyphenols in nanoparticle synthesis, nanoparticle efficacy and their applications. *Journal of Nanobiotechnology*, 22(1), 71. <https://doi.org/10.1186/s12951-024-02332-8>

Rupanshi, Kumar, V., Yadav, N., Singh, D., Beniwal, V., Chhabra, J., & Singh, B. (2025). Biogenic Silver Nanoparticles as Next-Generation Green Catalysts for Multifaceted Applications. *Transactions of Tianjin University*, 31(2), 145–178. <https://doi.org/10.1007/s12209-025-00427-3>

Saifuddin, N. N., Matussin, S. N., Fariduddin, Q., & Khan, M. M. (2024). Potentials of roots, stems, leaves, flowers, fruits, and seeds extract for the synthesis of silver nanoparticles. *Bioprocess and Biosystems Engineering*, 47(8), 1119–1137. <https://doi.org/10.1007/s00449-024-03044-x>

Sati, A., Ranade, T. N., Mali, S. N., Ahmad Yasin, H. K., & Pratap, A. (2025). Silver Nanoparticles (AgNPs): Comprehensive Insights into Bio/Synthesis, Key Influencing Factors, Multifaceted Applications, and Toxicity—A 2024 Update. *ACS Omega*, 10(8), 7549–7582. <https://doi.org/10.1021/acsomega.4c11045>

Shousha, W. G., Aboulthana, W. M., Salama, A. H., Saleh, M. H., & Essawy, E. A. (2019). Evaluation of the biological activity of *Moringa oleifera* leaves extract after incorporating silver nanoparticles, in vitro study. *Bulletin of the National Research Centre*, 43(1), 212. <https://doi.org/10.1186/s42269-019-0221-8>
Siddiqi, K. S., Husen, A., & Rao, R. A. K. (2018). A review on biosynthesis of silver nanoparticles and their biocidal properties. *Journal of Nanobiotechnology*, 16(1), 14. <https://doi.org/10.1186/s12951-018-0334-5>