Research Article

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Green fabrication of silver nanoparticles using *Melia azedarach* ripened fruit extract, their characterization, and biological properties

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Abstract: In the current research work, an attempt was made to synthesize silver nanoparticles (MA-AgNPs) utilizing the ripened fruit extract of *Melia azedarach*. Various characterization techniques such as UV-visible spectroscopic analysis, thermal gravimetric analysis (TGA), and scanning electron microscopy (SEM) were used to confirm the AgNPs synthesis. The bioreduction and color changes were tracked by UV-visible spectroscopy while SEM confirmed AgNPs of size 2–60 nm. TGA revealed the stability of the synthesized AgNPs. The antibacterial potential of the *M. azedarach*-based AgNPs and the fruit extract was assessed in terms of zone of inhibition (ZI), minimum bactericidal concentration, and minimum inhibitory concentration against tested bacterial strains where higher activity was noted for NPs (*P. aeruginosa* ZI = 22). The 2,2-diphenyl-1-picrylhydrazyl (DPPH) and (2,2-azinobis-[3-ethylbenzthiazoline]-6-sulfonic acid) (ABTS) assays revealed that NPs have significant antioxidant activities. The IC_{50} values recorded for extract was 340 and 350 $\mu g \cdot mL^{-1}$ against DPPH and ABTS whereas the corresponding values obtained for AgNPs were 40 and 58 $\mu g \cdot mL^{-1}$, respectively. The study suggests that the engineered NPs have promising biological activities compared to the parental extract, and thus could be used in drug designing as antibacterial and antioxidant agents; however, there should be further *in vivo* exploration in this regard before extending their uses to biological systems.

Keywords: antibacterial activity, antioxidant activity, fruit extract, green synthesis, *Melia azedarach*

1 Introduction

As a result of rapid industrialization and urbanization, serious threats have been imposed on environment, which has now become a serious global issue. Large amount of hazardous and unnecessary chemicals, gases, and other hazardous substances are released into the environment among which pharmaceutical ingredients release have given rise to over whelming issue of drug resistance in microbes. Therefore, it is needed to learn about the secrets that are present in nature in the form of their products. The phenolic compounds by virtue of resonance effect can act as capping agents in fabrication of nanoparticles (NPs). Biological molecules have a wonderful fit-in application of nanotechnology due to their unique characteristics. The biological molecules have proven to be more astonishing capping agents in the synthesis of metal NPs, which have been shown to be reliable and beneficial in long run for the sustainable environment [1]. NPs are defined as the particles with a size between 1 and 100 nm that may be different from the bulk material due to their size. Currently, several metallic nanostructures are being fabricated using silver (Ag), copper, gold, zinc, titanium, alginate, and magnesium. NPs are employed for a wide range

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of applications, including medicinal treatments, energy storage in solar and oxide fuel batteries, and widespread inclusion into many common products including cosmetics and clothing [2]. Due to its prospective uses, the production and synthesis of metal and semiconductor nanoparticles is a broad field of research that have been included in the creation of breakthrough technologies [3]. Nanotechnology is one of the most recent subfields of study in the discipline of material science today. NPs have a number of completely new or improved characteristics, including the size, dispersion, and shape of the particles. New uses for NPs or nanomaterials are quickly emerging in a variety of disciplines [4]. Nearly all technological disciplines, including medicine, now use metal NPs as well as metal oxide NPs. These are utilized in medicine for the delivery of medicines, genes, and other biopolymers, as well as in tissue engineering, food packaging, and biosensors [5,6].

NPs can come from both natural and man-made sources [7–9]. Photochemical reactions, volcanic eruptions, forest fires, simple erosion, and the loss of skin and hair by animals are few examples of natural processes that produce NPs [10]. The green synthesis of NPs aims to build an environment friendly synthetic route by avoiding production of harmful byproducts and minimizing the pollution by decreasing waste production. For this reason, it is important to use green solvents and naturally occurring resources during such synthesis process. Moreover, to achieve this, different naturally occurring resources such as bacteria, fungi, yeast, and plant extracts have been employed. Simple and easy synthesis of metallic NPs has been achieved by using plant extracts among all green methods. All these plant extracts comprised phytochemicals such as terpenoids, flavones, aldehydes, ketones, carboxylic acids, ascorbic acids, amides, and phenols, which have the potential for synthesizing metal NPs by the reduction of metal salts [11,12]. The redox process used to create environmentally beneficial nanosized particles is continually involved in these primary and secondary metabolites. Numerous earlier studies have shown that biosynthesized NPs efficiently reduced alterations related to oxidative stress, genotoxicity, and apoptosis [13]. Ag metal has antimicrobial properties, and attempts have been made to prepare its NPs and investigate their clinical and other applications as well [14]. AgNPs have been used in the field of sensitive biomolecular detection, diagnosis and therapeutics, catalysis, and microelectronics. Moreover, Ag and AgNPs are used in skin cream and ointment for burns and open wounds [15].

Melia azedarach (*M. azedarach*) is a perennial tree found across sub-Himalayan belt, and belongs to the family Meliaceae which constitutes 45 genera and more than 750 species. Tropical and subtropical parts of the world are home to the deciduous trees like *M. azedarach*, which has a reddish-purple bark. Though the majority of the plants are approximately 9 m tall, it may grow up to a height of about 15 m [16]. Having an alternative orientation, the plant leaves are complex. In the spring, fragrant flowers bloom. It produces fruits with firm seeds that are mucilaginous and sticky. This plant's leaves are a cure for common fever in localities where it is found. Herpes simplex type 1 can be treated with meliacine, a substance found in the leaves of this tree [17]. *M. azedarach* is locally known as "Thora shandai" in different areas of Khyber Pakhtunkhwa, Pakistan and its other common names include Persian Lilac, Bakain, and China berry. Traditionally, *M. azedarach* is used to treat a range of ailments such as antimalarial, antibacterial, antiviral, anti-fertility, and anticancer. The phytochemicals triterpenoids, flavonoids, glycosides, steroids, and carbohydrates are known to be present in the bark extract. Additionally, polyphenolic chemicals that result in significant antioxidant activity have been reported [18,19]. The reports on successful synthesis of AgNPs using different plant extracts and their enhanced biological potentials make the topic interesting to be investigated further using more medicinally important plants to improve their biological potential as different plants have different phytochemical compositions.

The aim of the current research work was to synthesize AgNPs using *M. azedarach* ripened fruit extract. Various characterization techniques, including UV-visible (UV-Vis) spectroscopy and scanning electron microscopy (SEM), were used to examine the synthesized NPs (AgNPs). The anti 2,2-diphenyl-1-picrylhydrazyl (DPPH) and (2,2-azinobis-[3-ethylbenzthiazoline]-6-sulfonic acid) (ABTS) activity of the fabricated AgNPs and fruit extract were also assessed. Additionally, the antibacterial activities of the synthesized NPs were also determined and compared with that of crude ripened fruit extract.

2 Materials and methods

2.1 Preparation of the plant extracts

M. azedarach ripened fruits were collected from several locations in the Tehsil Adenzai District of Dir Lower, Khyber Pakhtunkhwa, Pakistan. Following collecting, the plant material was then identified and authenticated by botanist Dr. Muhammad Nisar, Botany Department, University of Malakand, Pakistan. The plant fruits were

cleaned with distilled water, dried in a shaded area and then grinded to powder form using a mortar and pistil. About 10 g plant materials were weighed and mixed with 200 mL of distilled water, heated for 30 min while being constantly stirred in a clean, sterilized conical flask. The mixture solution was filtered using Whatman filter paper No. 1 to get the plant extract. The filtered extract obtained was refrigerated in closed vessel till further use.

2.2 Chemicals and other materials

All the chemicals and reagents including silver nitrate ($AgNO_3$), distilled water, nutrient agar, nutrient broth, and ascorbic acid were obtained from Sigma Aldrich, Germany. All these chemicals and reagents were of analytical grade and of high purity.

2.3 Biosynthesis of AgNPs mediated by *M. azedarach* fruit extract

AgNPs were greenly synthesis employing a standard method [20]. About 1 mM solution of $AgNO_3$ was prepared by dissolving 1.17 g $AgNO_3$ in 100 mL of distilled water. The $AgNO_3$ solution was initially agitated for 10 min at room temperature, before *M. azedarach* fruit extract was added. The reaction mixture was shaken for 5 h. The color of the solution instantly changed from colorless to yellowish brown after the addition of fruit extract. The color changes indicated that AgNPs have been formed. After that, the samples were centrifuged for 40 min at 14,000 rpm while keeping the temperature at 37°C. The residue collected from the solution with centrifugation was air dried at room temperature and subsequently subjected to characterization and biological evaluation.

2.4 Characterization of the synthesized AgNPs

2.4.1 UV-Vis spectroscopy

UV-Vis spectroscopy was used to confirm that the ripened fruit extract of *M. azedarach* caused the synthesis of AgNPs. *M. azadarch* fruit extract and different concentrations of Ag solution were mixed in order to get maximum yield. For recording the absorbance, small aliquots were placed in a quartz cuvette and monitored for absorbance between 200 and 500 nm using a spectrophotometer. Perkin Elmer Lambda 950 UV/Vis spectrometer was used for UV-Vis spectroscopy.

2.4.2 SEM analysis

By employing a Hitachi S-4500 SEM, the surface morphology of the fabricated NPs was visualized. The sample of optimized ratio was centrifuged at 14,000 rpm for 10 min. The pellet of NPs obtained was mixed with deionized water and recentrifuged. After repeating the procedures three times, an acetone wash was applied. To get a clear and homogenous suspension, the cleaned AgNPs were subjected to sonication for 30 min. The sample was then dried. A very little quantity of the sample was dropped onto the SEM grid to create thin film, which were then coated in gold using a sputter coater. The SEM grid's film was then dried by placing it under a mercury lamp for 10 min (after extra solutions were removed using blotting paper) and photographs were then taken at various magnifications.

2.4.3 Thermal gravimetric analysis (TGA)

Aluminum oxide (Al_2O_3) was used as a reference crystalline sample. TGA were performed using Pyris Diamond Series TG/DTA Perkin Elmer, USA (temperature range: 1,300°C). The weight loss of the sample was calculated using a heating rate of 10°C up to 1,120°C under inert gas to nitrogen at a rate of 20 mL·min^{-1}. The initial mass taken was 13.09 mg (starting sample weight).

2.5 Antibacterial activities of extract and AgNPs

The zone of inhibition (ZI), minimum inhibitory concentration (MIC), and minimum bactericidal concentration (MBC) approaches were used to assess the antibacterial activities of the fruit extract and NPs against the selected bacterial strains. The strain of selected bacteria were inoculated onto sterilized agar culture dishes, and 2 mm holes were made in the medium at a distance of 4 cm from each other and from the reference standard antibiotic (amoxicillin). Using a micropipette, the solution of the extract and NPs were inserted into the holes. The bacterial culture plates were incubated at 37°C for 24 h. Each inhibition around each hole was measured as zone of inhibition. The entire process was completed in laminar flow to avoid any contamination during the experiment.

2.5.1 MIC and MBC assays

The MIC was calculated using the macro broth dilution technique [21]. In the Mueller Hinton broth medium, solutions of the standard (amoxicillin), AgNPs, and fruit extract were prepared and inoculated with a bacterial strain (0.04–10 mg·mL^{-1}) used in this study. A single tube containing just medium broth served as the control. The tubes placed in an incubator for 12 h at 37°C. The tubes were visually examined for turbidity, and the first tube in the series without noticeable changes in turbidity was chosen as the MIC. The tube with no growths were further subjected to incubation for additional 3 days (4 days total). The tube with no bacterial growth after 96 h was chosen as MBC.

2.6 Antioxidant activity

2.6.1 Determination of free radical scavenging activity by DPPH assay

To determine the percent scavenging potentials of fruit extract and AgNPs, DPPH was used as synthetic free radical [22]. About 20 mg DPPH was dissolved in 100 mL of methanol to prepare the DPPH solution (stock). Approximately, 3 mL from this solution was collected in a covet, and its absorbance was adjusted to 0.75 at 515 nm and was used as the control solution. The production of free radicals was then furnished by keeping the stock solution covered with aluminum foil in dark for 24 h. The extract and NPs stock solutions were then produced (5 mg·mL^{-1}) in methanol, from which various dilutions between 1,000 and 62.5 g·mL^{-1} were prepared.

2 mL each of dilution and DPPH stock solutions were incubated for at least 30 min. The absorbance after incubation was noted using a spectrophotometer. The ascorbic acid solution was used as the standard. To calculate percent inhibition, the following formula was used:

$$\%\text{DPPH free radical scavenging activity} = \frac{A - B}{A} \times 100 \quad (1)$$

where B is the absorbance of the sample that was measured after 25 min of the reaction with DPPH, and A is the absorbance of pure DPPH in its oxidized state. Each of the experiment was run in triplicates and the mean values were considered.

2.6.2 ABTS assay

The ABTS assay was also used to enumerate the antioxidant potential of NPs and extract, as per reported standard protocol [23]. Same dilutions as constituted for DPPH assay were added to the ABTS stock solution (3 mL each), incubated for 20 min and the resultant solution's absorbance was measured using a Perkin Elmer Lambda 950 UV-Vis spectrophotometer at 745 nm. The same procedures were used to prepare ascorbic acid in various dilutions (positive control) and mixed with ABTS solution as described above, in order to compare the scavenging of NPs and extract with standard and enumerate the IC_{50} values. The results were recorded in triplicates whereas percent activity was calculated using Eq. 1.

3 Result and discussion

Due to the use of expensive equipment and toxic components like solvents, reducing agents, and precursors, most physical, chemical, and hybrid techniques are generally expensive and dangerous in nature [24]. Using green ways to prepare NPs is more affordable, environmentally friendly, and simple to implement. As a result, these methods are more widely used for the synthesis of metallic of NPs. A range of natural resources, including microbes, biomolecules, plant extracts, etc., have been used in the attempts at green synthesis of NPs so far [25]. Plant extracts are preferred over other natural resources, despite the fact that a sizable number of research works have been published in the literature on the green synthesis of NPs employing biomolecules, microbes, and plant extracts, as plant extract-based methods are affordable, effective, and do not require a laborious procedure for isolating and keeping microbiological cultures [26]. The green synthesis of NPs is effectively carried out using extracts from several plant species, their organs, and isolated chemicals. In addition to being environmentally beneficial, the synthesis of nanomaterials may be made more sustainable by utilizing industrial and agricultural waste [27].

3.1 AgNPs synthesis and its confirmation by UV/Vis spectroscopy

Plant extracts are made up of a variety of chemicals, some of which may have stabilizing or lowering effects. The oxidization status of metal ions can also be altered by such substances. To determine the optimal ratio for NPs production, a fixed volume of extract was combined with different concentrations of $AgNO_3$. The fruit extract's color began to alter when it was combined with the

$AgNO_3$ solution. It has long been known that AgNPs in water have a dark brown color. As the AgNPs formed, a change in color was observed that was an indication towards its synthesis.

Utilizing UV-Vis spectroscopy, more validation was achieved as shown in Figure 1. Reactions with various concentrations of $AgNO_3$ and extract were performed in order to determine the optimal ratio of $AgNO_3$ and *M. azedarach* fruit extract (reducing agent) solutions. In a quartz cuvette, a little aliquot of various layers of the reaction mixture was obtained in order to study the absorption spectra. The layer that produced the greatest results and had the sharpest absorption peak was chosen as the ideal ratio. The high intensity absorption peak was observed at 400 nm. The biosynthesized AgNPs of *M. azedarach* fruits were further character ized by SEM and TGA analysis as described below.

3.2 SEM analysis of AgNPs

SEM examination was used to better analyze the *M. azedarach* fruit mediated AgNPs for their surface morphology and sizes. It was found that the particles are spherical in form. The captured picture is displayed in Figures 2 and 3. The white spots in the photograph proved that Ag-NPs were synthesized. There were other particles that were not spherical in form. The size of the particles was in the nanomer range. The different sizes of NPs may be correlated with the variable shapes. Our results are in close resemblance with a study published in the literature [28]. The diameter of the particles was from 2 to 60 nm. The bigger AgNPs observed during SEM studies may be the result of the smaller NPs aggregation due to presence of moisture contents that have resulted in lump formation [29].

3.3 TGA

We can see the results of the thermal gravimetric study in Figure 4, which tells us how much weight AgNPs have loosed as the temperature rises. The AgNPs were heated at a rate of 10°C·min^{-1} up to 1,120°C. The sample initially weighed 13.09 mg, but when the temperature was raised to 490°C, the weight gradually fell to 6 mg as moisture was removed from the NPs due to heat (evaporation). The sample size then abruptly decreased until it reached 0.0766 mg at 610°C, after which there was no additional weight loss and the sample size remained steady.

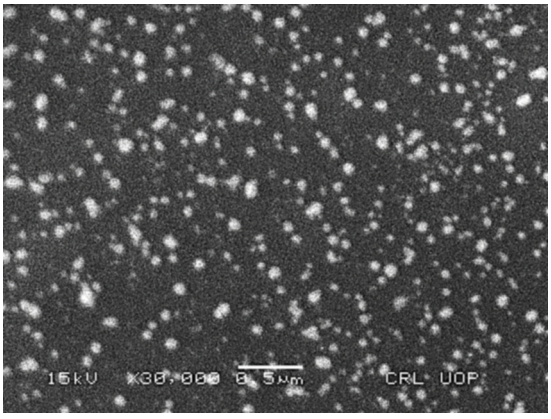

Figure 2: SEM photograph of AgNPs at 0.5 micron.

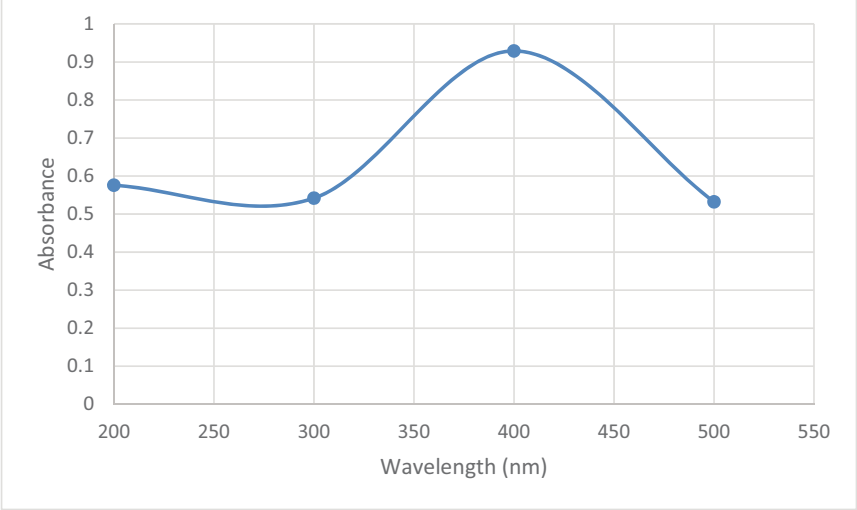

Figure 1: UV-Vis spectra of the synthesized AgNPs.

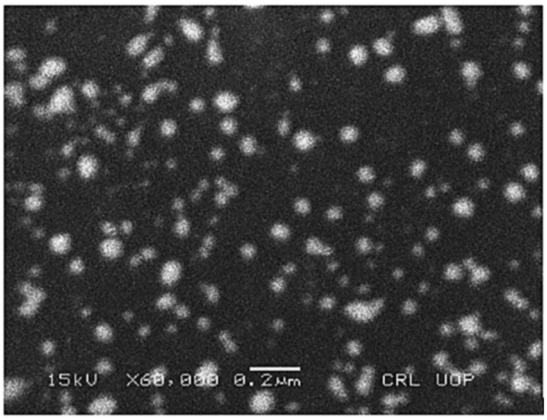

Figure 3: SEM photograph of AgNPs at 0.2 micron.

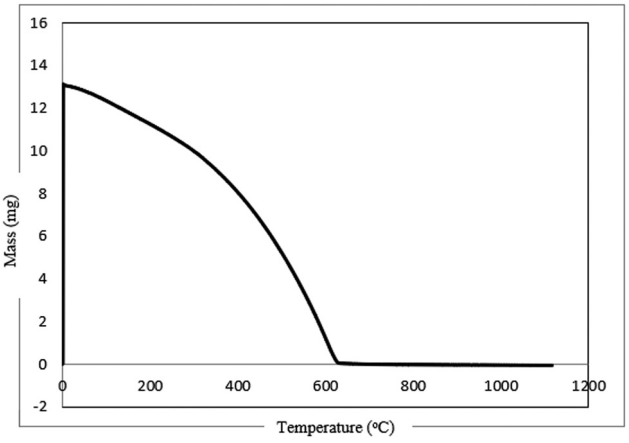

Figure 4: TGA of synthesized AgNPs.

3.4 Antibacterial activities of *M. azedarach* fruit extract and AgNPs

Secondary metabolites in plants frequently serve as capping in greenly synthesized nanoparticles (GNPs). These substances may increase their bioactivities in addition to stabilizing them as capping agents or stabilizers [29]. Antibiotic resistance has been observed in numerous human harmful microorganisms/pathogens. To address this issue, new antibiotics must be developed. Since AgNPs have significant antibacterial characteristics, they may be an option against many human harmful microorganisms [30].

Agar well diffusion was used to test the antibacterial potential of AgNPs made from *M. azedarach* fruit extract against *Bacillus cereus*, *Escherichia coli*, *K. pneumonia*, and *P. aeruginosa* [31]. The cultures were inoculated via spread plate inoculation. The antibacterial activity of AgNPs and *M. azedarach* fruit extract was assessed in order to compare their biological potentials against selected strains. In Tables 1 and 2, results of the antibacterial activities of *M. azedarach* fruit based AgNPs and aqueous extracts in term of ZI, MIC, and minimum bactericidal inhibition are presented.

3.4.1 Determination of Zi

Table 1 displays the outcome of ZI approach. The plant's fruit extract had a smaller inhibitory zone than the AgNPs. AgNPs displayed 18 mm ZI against *B. cereus*, whereas fruit extract only had 11 mm ZI. The fruit extract generated a ZI of around 10 mm whereas the NPs created a 17 mm ZI against *E. coli*. AgNPs had a ZI of 19 mm against *K. pneumonia* compared to 12 mm by the extract. Similarly, for *P. aeruginosa*, the extract only produced ZI of around 9 mm, while the NPs produced 16 mm ZI. A positive control used was amoxicillin. In another literature report, AgNPs have demonstrated a greater ZI than their parental extract, tested against human pathogenic gram-positive *B. cereus* (34 mm) and gram-negative *E. coli* (37 mm) bacteria, demonstrating their stronger antibacterial efficacy [32]. According to reports, the smaller sized particles encountered less resistance to microbes rather than coarse sized particles. The antibacterial capabilities of a NP have been altered by its spherical form as seen in SEM analysis [33]. According to literature reports, it is unclear exactly how AgNPs stop bacterial development. Sondi and Sondi, however, demonstrated that the antibacterial activity of AgNPs against gram-negative

Table 1: ZI of AgNPs and leaf extract against different bacterial strains

Bacterial strain	ZI (mm): mean value ± SEM		
	Aqueous extract	AgNPs	Amoxicillin
B. cereus	19.00 ± 1.30***	21.00 ± 0.30***	23.00 ± 0.50
E. coli	18.00 ± 0.96***	19.00 ± 1.13 ns	22.00 ± 0.22
K. pneumonia	16.00 ± 1.27***	20.00 ± 1.10***	26.00 ± 0.33
P. aeruginosa	17.00 ± 0.21***	22..00 ± 0.17***	25.00 ± 1.20

***$P < 0.001$ and $^{ns}P > 0.05$ as compared to the standard amoxicillin

Table 2: MIC and MBC of leaf extract, AgNPs, and standard in $\mu g \cdot mL^{-1}$

Bacteria	Aqueous extract		AgNPs		Standard	
	MIC	MBC	MIC	MBC	MIC	MBC
B. cereus	$130.00 \pm 2.15^{***}$	$235.00 \pm 1.75^{***}$	$70.00 \pm 1.95^{***}$	$80.00 \pm 2.10^{***}$	55.00 ± 1.14	75.00 ± 1.40
E. coli	$210.00 \pm 1.10^{***}$	$450.00 \pm 1.33^{***}$	$85.00 \pm 1.05^{***}$	$160.00 \pm 1.20^{***}$	60.00 ± 1.21	70.00 ± 1.50
K. pneumonia	$180.00 \pm 1.20^{***}$	$360.00 \pm 0.70^{***}$	$60.00 \pm 1.00^{***}$	$120.00 \pm 1.30^{***}$	50.00 ± 1.26	80.00 ± 1.11
P. aeruginosa	$260.00 \pm 1.20^{***}$	$440.00 \pm 1.30^{***}$	$75.00 \pm 0.32^{***}$	$160.00 \pm 1.25^{***}$	65.00 ± 1.37	65.00 ± 0.20

MIC and MBC values where $^{***}P < 0.001$ are compared to the standard (amoxicillin).

bacteria depended on the AgNPs concentration and was directly connected to the formation of pits in bacterial cell walls [34]. Our results are closely comparable to other studies in literature where it was shown that AgNPs have significant antibacterial activities against the tested bacterial strains [35]. In Table 1, ZI (mm) created by *M. azedarach* fruit aqueous extract, AgNPs, and standard drug (amoxicillin) against different bacterial strains have been shown where clear differences of the activities are evident among the two.

3.4.2 MIC and minimum bactericidal inhibitions of the synthesized AgNPs and extract

The MIC and MBC values for synthesized AgNPs and fruit extract of *M. azedarach* are shown in Table 2. The findings in the table demonstrate that the values of MIC and MBC are comparable to those of the standard for AgNPs as compared to plant extract. The greatest activity against *B. cereus* was shown by the aqueous extract and AgNPs, with MIC values of 130 and 70 $g \cdot mL^{-1}$ and MBC values of 235 and 80 $g \cdot mL^{-1}$, respectively.

3.5 Antioxidant activities

Aqueous extract of *M. azedarach* fruit and fabricated NPs demonstrated antioxidant properties. Table 3 displays the extract's and AgNPs' free radical scavenging capacities and their IC_{50} values as determined by DPPH and ABTS tests. AgNPs showed increased and promising antioxidant activity as compared to the aqueous extract indicating their strong antioxidant activity against DPPH and ABTS radicals at concentrations of 1,000, 500, 250, 125, and 62.5 $g \cdot mL^{-1}$. The activity seen was also concentration-dependent. The plots of the percentage activities against DPPH and ABTS vs concentrations of the extract/NPs was used to get the IC_{50} value, which is defined as the concentration of substrate that results in a 50% scavenging of

Table 3: Percent DPPH and ABTS scavenging potential and IC_{50} values of fruit extract of *Melia azedarach* and AgNPs

Sample	Dilutions ($\mu g \cdot mL^{-1}$)	% DPPH scavenging mean value ± SEM	IC_{50} ($\mu g \cdot mL^{-1}$)	% ABTS scavenging mean value ± SEM	IC_{50} ($\mu g \cdot mL^{-1}$)
Aqueous extract	1,000	63 ± 0.62	340	61 ± 0.87	350
	500	59 ± 0.31		54 ± 1.08	
	250	43 ± 0.41		45 ± 1.00	
	125	36 ± 0.25		36 ± 0.52	
	62.5	30 ± 1.31		29 ± 0.88	
AgNPs	1,000	80 ± 1.03	40	87 ± 0.28	58
	500	77 ± 0.95		80 ± 0.81	
	250	75 ± 0.85		76 ± 0.72	
	125	70 ± 1.10		67 ± 0.76	
	62.5	66 ± 0.17		56 ± 0.98	
Ascorbic acid	1,000	95 ± 0.23	35	90 ± 0.55	38
	500	82 ± 0.30		84 ± 0.67	
	250	77 ± 0.42		75 ± 0.84	
	125	65 ± 0.16		62 ± 0.67	
	62.5	55 ± 0.11		51 ± 0.54	

DPPH activity. Against DPPH, the IC_{50} values of 340, 40, and 35 $\mu g \cdot mL^{-1}$ of aqueous extract, synthesized AgNPs, and ascorbic acid as shown in Table 3, respectively, clearly indicate the enhancing effect of Ag on biological potential of the extract. Comparable IC_{50} values were also recorded against ABTS radicals.

It can be assumed that the existence of bioactive substances in extracts, such as phenolic compounds are responsible for the DPPH free radical scavenging effects [36]. They demonstrate antioxidant action by neutralizing free radicals or stopping the conversion of hydroperoxides into free radicals. Among the phytochemicals with antioxidant action, polyphenols are very important. Antioxidant activity of phenolic compounds is expected to be significantly influenced by the number of –OH groups [37–39]. The antioxidant activity of phenolic compounds is reported to be mainly due to their redox potentials [40].

4 Conclusion

Recently, a lot of research has been done on the biosynthesis of NPs utilizing plant extracts. The eco-friendly synthesis of NPs is induced by plant metabolites. The NPs produced by plants have been used in a number of clinical and industrial applications. In the current work, AgNPs were produced biologically using ripened fruit of *M. azedarach* fruit extract as capping agent being a sustainable and environmentally friendly method and is a competitive alternative to other traditional techniques used. *M. azedarach* fruit based AgNPs and fruit extract were evaluated for their antioxidant and antibacterial properties as well. The aqueous fruit extract of *M. azedarach* was shown to be inferior to the AgNPs in terms of antibacterial and antioxidant capabilities. The given plant extracts and AgNPs were also examined for their MIC and MBC. Both the AgNPs and the aqueous fruit extract had shown potential antioxidant activities as measured against the DPPH and ABTS radicals. Each time, the fabricated AgNPs were superior than the *M. azedarach* fruit extract being based on biological tests performed. It was concluded from the current research work that *M. azedarach* fruit based NPs should be utilized as alternative medicines due to their antibacterial and antioxidant properties. However, further *in vivo* evaluation will be needed to extend their uses to biological systems.

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