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ANTIBACTERIAL POTENTIAL OF *MELIA AZEDARACH* LEAVES AND FRUITS EXTRACTS AGAINST BACTERIAL SPECIES PRODUCING FOOD POISONING DISEASES

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Abstract *The current study was conducted for the evaluation of antimicrobial activities of Melia azedarach fruit and leaf extracts using aqueous and ethanol solvents against 5 bacterial strains: Pseudomonas aeruginosa, Salmonella typhi, Staphylococcus aureus, Escherichia coli, and Bacillus cereus. Antibacterial activities were evaluated by the disc diffusion method, whereas the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were measured applying standards bacteriological techniques. Outcomes of the disc diffusion technique assay showed that ethanol extracts displayed significant antibacterial potential as compared with water extracts, with a zone of inhibition spectrum of 15 to 22 mm for fruits and leaves, matched to 10 to 14 mm for water extracts at 100 mg/mL. The maximum vulnerability was shown against Bacillus cereus, while Pseudomonas aeruginosa showed the smallest sensitivity. The MIC degree additionally verified strong efficiency of ethanol leaf extracts, ranging from 25 to 125mg/mL, whereas fruit extracts (aqueous) showed the maximum MIC degrees (up to 200mg/mL). Likewise, MBC results showed that ethanol leaf extracts had the strongest bactericidal efficiency (50–225 mg/mL), while fruit water extracts displayed the weakest activities (200–250 mg/mL). Generally, the results indicate that Melia azedarach exhibits strong antibacterial activities, predominantly in ethanol leaf extracts, and might act as a latent source of natural antibacterial substances. The research also highlights the dissimilarity in microbial vulnerability, with Gram-positive microbes being more susceptible as compared with Gram-negative microbes.*

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Keywords*:* *Food preservation; Food-borne diseases; plant extracts; antibacterial activity; zone of inhibition; aqueous extract; ethanol extract; inhibition zone; natural antibacterial substances*

Introduction

Soil-borne ailments are considered a main obstacle in Preservation of food from the prehistoric era played a main part in the existence of mankind, boosting the stability and safety of various food items. Conventional methods applied to control food spoilage in the past, such as heating, fermentation, drying, and salting, have been overcome in the contemporary food industry. The knowledge about the key reasons for spoilage and decay has augmented considerably compared to before, and suffering because of deterioration, decay, and food infection has been minimized (Gram et al., 2002). Infectious diseases are countable healthiness issues in developing countries. Currently, research continues on active and harmless antimicrobial substances synthesized from plants as an alternative source of medication and to resolve the microbial resistance issues faced by antibiotics. This evidence has focused researchers on discovering plants for antimicrobial properties (Ahmet et al., 2011). Minimum-revenue individuals commonly in countryside societies utilize them as medication for various diseases in budding states like Pakistan. As populations from unreachable areas attain a disease, they go to traditional experts for treatments, because of their skills to diagnose diseases, bone settings, treat wounds, and make herbal-based drugs. They claim that traditional medicines are additionally cheaper and more efficient as compared with artificial medicines (Altaf et al., 2014). The prehistoric human beings used therapeutic ingredients easily available to them, and therefore plants have been applied as medicine since prehistoric times. Therefore, plants are the oldest resources of useful medication for human beings. The existence of bioactive substances in plants revealed various activities like antibacterial, immunostimulant, antifungal, anti-radiation, anti-inflammatory, antioxidant, cytoprotective, hepatoprotective, anticancer, anti-ulcer, anti-atherosclerosis, anti-diabetic, and wound healing (Harshit et al., 2013).

The control of microorganisms is one of the most significant problems for the food industry. Various pathogenic bacteria have been documented to be responsible for food spoilage and foodborne illnesses (Rivera et al., 2014). Artificial chemical stabilizers, additives, and preservatives are applied to control the growth of spoilage- and pathogen-causing bacteria in the food system, and their utilization is controlled by

each country (Woo et al., 2023). However, worries occur concerning the remaining toxicity of artificial chemical additives and bacterial resistance to conventional artificial additives and preservatives (Lebelo et al., 2021). Various artificial chemical preservatives and additives have teratogenic and carcinogenic properties (Kamal et al., 2018). The spoilage of food is a complex process, and a high quantity of foods are vanished owed to microbial decay even with current protection methods. Notwithstanding the heterogeneity in processing conditions and raw materials, the microorganisms that grow during storage and in decomposing food might be predicted based on data of the source of the food, substrate base, and a scarce dominant additive parameter like pH, a(w), atmosphere, and temperature (Gram et al., 2002). The constant exploitation, adaptation, and evolution of novel vehicles produced from recent technology, new trends of food commercialization/retail shops, and alteration in the behavior of diet eating enforce tasks in the management of these pathogenic microbes. In this situation, the continuous monitoring of emerging novel species of well-known food spoilage, clinical manifestations, outbreaks, and transmission routes is essential to raise knowledge and innovate novel techniques of deterrence and control of foodborne ailments (Newell et al., 2010).

Melia azedarach is an important medicinal plant, it leaves have ethnomedicinal applications reported to be diuretic, deobstruent, antidiarrhoeal, and to control pests, nematodes, and insects (Joy et al., 1998). It applied as fodder and are extremely nutritious, uses as antifever, relived in rheumatic pain, pain of tooth or loosening, for brushing teeth and against skin ailments such as scabies (Rahmatullah et al., 2010) used outside on burns, applied as mouth was for gingivitis; bloody piles and pyrexia (Khan et al., 2011), cure pimples, blood purifier, and diabetes (Sultana et al., 2011), hysteria (Kaneria et al., 2009; Husain et al., 2008) and snake bite (Handa et al., 2006). Leaves are applied to expel parasitic worms, treat malaria, jaundice, measles, eczema, and anemia. Decoction is applied as stomachic and astringent (Sen et al., 2010). So, keeping in view the above, it is essential to develop non-artificial additives and preservatives applying natural resources that could substitute chemical additives and preservatives, minimize the propagation of food spoilage and food-borne diseases, and expand food safety. The research study was designed for the evaluation of ethanol and aqueous extracts of *Melia azedarach* leaf and fruit against foodborne bacterial strains.

Materials and Methods

Collection of plant material

The fruits and leaves of *Melia azedarach* (*M. azedarach*) were collected from the Medicinal Botanical Garden of Pakistan Council of Scientific and Industrial Research (PCSIR) Laboratories Complex, Peshawar, Khyber Pakhtunkhwa, Pakistan. The collected fruits and leaves were detached from unwanted items and were shade-dried at 35- 50°C for two weeks. The dried materials were ground into coarse powder using Standard Model No. 3, Wiley Mill (USA). The powder was kept in an airtight bottle and placed in a dry, dark, and cool place till extraction began.

Preparation of Ethanol Extracts

Exactly 200 g of powdered fruits and leaves was weighed and taken in a clean, flat-bottomed amber glass vessel and drenched with one liter of ethanol. The vessel with this mixture was closed and reserved for 10 days of period, attended via nonstop shaking. The entire blend afterward underwent a brief filtration through a piece of a sterilize white cotton cloth. Afterward, they were sieved by applying filter paper #1 (Whatman®-England), and the ethanol was recovered by evaporation under reduced pressure using,.a rotary evaporator (Buchi Rotavapor R-200, Switzerland, Buchi Heating Bath B-490). The received extracts were further evaporated in a vacuum oven to obtain ethanol-free extracts in dry form. The extracts were kept in a cooled incubator (Gallenkamp, England) until further experiments.

Preparation of Aqueous Extracts

The dried plant material powder (200g) was soaked in 1L double distilled H_2O using a 5 L *Erlenmeyer flask* and was incubated at room temperature for 72hours. The flask was afterward refluxed over a hot water bath (PCSIR-Pakistan) for ten hours, and the mother mixture was sieved. The water (distilled) was again refluxed and sifted. This procedure was recurrent for 4 times. The filtrate was reduced to dryness under reduced pressure using a rotary evaporator (Buchi Rotavapor R-200; Buchi Heating Bath B-490). Therefore, the remainder was plant water extract and kept in a cooled incubator (Gallenkamp- England) till further experiments.

Collection and Maintenance of Bacterial Cultures

All the microbial species, i.e., *Bacillus cereus (B. cereus), Escherichia coli (E. coli), Staphylococcus aureus (S. aureus), Pseudomonas aeruginosa (P. aeruginosa), and Salmonella typhi (S. typhi)*, were collected from the Microbiology Research Section of PCSIR Laboratories Complex Peshawar, Khyber Pakhtunkhwa, Pakistan. All the experimental strains were revived, maintained on Nutrient Agar (NA) slopes, and were sub-cultured at 35°for 24 hrs.

Sterilization

The antimicrobial assay was carried out in a Laminar Air Flow Hood (Lahore-Pakistan) upholding wholly safeguard obligatory to avoid any pollution originating from the experiments. The UV light was kept "ON" for 30 min before working in the Laminar Hood to avoid any unintentional pollution. The glassware and Petri dishes were decontaminated through autoclaving at a pressure of 15 lbs/sq. inch and 121°C for 15 min. Blank discs were set aside in an enclosed Petri dish and exposed to 180°C for one hour to dry heat in an oven (Memmert, Germany) or

kept in an autoclave. Afterward, they were placed in a Laminar Air Flow Hood for 30 min under UV light.

Preparation of Inoculums

Every microbial species was subcultured overnight in Mueller-Hinton agar (MHA) slants at 35 °C. The microbial culture was harvested by applying sterilized distilled H_2O (5mL); its density was adjusted using a spectrophotometer at 580 nm and diluted to obtain a viable cell count of 10^7 CFU/mL (Ashraf et al., 2018).

Antibacterial Activity of Plant Extracts

The disk diffusion technique was applied to assess the antibacterial property of each part's extracts. The dried crude plant extract 250 mg was dissolved in a small volume of dimethyl sulfoxide (DMSO) and adjusted with sterilized distilled H_2O to gain an ending dose of 100 mg/mL. The final concentration of DMSO in wholly treatment solution was maintained <10% (v/v). The solution was swirled carefully to confirm complete disintegration, and then decontaminated by a Millipore membrane filter (0.22 µm). After that, burdened over autoclaved 8 mm in diameter filter paper disc was loaded to achieve the final dose of 100 mg/disc. The medium MHA (10 mL) was transferred as a basal layer into sterilized Petri dishes, followed by 15 mL of inoculated medium formerly seeded with microbial suspension (100 mL of medium/1 mL of 10^7 CFU) to achieve 10^5 CFU/mL of medium. Sterilized filter paper discs filled with *M. azedarch* extracts at a dosage of (100mg/mL) were kept on the top of MHA plates. Gentamicin was used as a positive control, with a filter paper disc loaded with 10 µg, while DMSO was used as a negative control. The plates were incubated for two hours at 5 °C in a fridge (*Dawlance) to facilitates extracts dispersal*, and then *kept in an incubator (Memmert-Germany) for 24 hours at* 35 °C. The occurrence of a zone of inhibition was quantified using a Vernier caliper, noted and measured as a sign for antimicrobial activities (Ashraf et al., 2018).

Determination of MIC (Broth Microdilution Technique)

The MIC of the *M. azedarach* extracts was measured using the broth microdilution technique. A stock solution of the dried *M. azedarach* extracts was prepared by dissolving the required quantity of extracts in water comprising dimethyl sulfoxide (DMSO; final concentration <10% v/v) to guarantee complete solubility. The solution was decontaminated by a membrane filter (0.22 µm). Various dosages of the extracts (250, 225, 200, 175, 150, 125, 100, 75, 50, 25, 12.5, 6,25 and 3.125 mg/mL) were prepared in sterilized nutrient broth. Every tube holding the corresponding dosage was seeded with a standard microbial inoculum suspension adjusted to 0.5 McFarland and incubated for 24 hours at 35°C. Afterward, the tubes were checked for noticeable microbial density. The MIC was documented as the lowest dose of the extracts that displayed no noticeable cloudiness, demonstrating whole microbial growth inhibition.

Determination of Minimum Bactericidal Concentration (MBC)

To measure the MBC, a liquid from the tubes showing no evident growth in the MIC analysis was subcultured onto renewed MHA plates. These plates were kept in an incubator (Memmert, Germany) for 24 hours at 35°C. The MBC was noted as the lowest dose of the extracts that displayed no bacterial colony development on agar, representing whole microbial killing.

Statistical Analysis

The final results were expressed as the form of mean of triplicate (n=3) values and ± standard deviation. The statistical analyses were achieved applying SPSS Version 18.0 (SPSS Inc., Chicago, IL, USA). Differences with $P < 0.05$ are considered statistically significant.

Results

M. azedarach is an important medicinal plant and commonly known as Chinaberry tree and Persian lilac. The antimicrobial activities of Chinaberry tree fruits and leaves extracts at 100mg/mL concentration against 5 microbial strains are displayed in Table 1. Both aqueous and ethanol extracts showed suppression effects against all the tested microbes. The reference drug Gentamycin at 10 µg created the maximum zone of inhibition against all microbial strains. Among the treated extracts, the ethanolic extracts documented noteworthy maximum antimicrobial activities as compared with water extracts. The ethanol leaves extracts observed the maximum zone of inhibition against *B. cereus* (22 ± 1 mm), trailed by 20 ± 1 mm, 18 ± 1 mm, 17 ± 1 mm and 16 ± 1 mm zones of inhibition by *S. aureus*, *E.* coli, *S. typhi* and *P. aeruginosa*, respectively. Likewise, the fruit extracts of ethanol created zones of inhibition of 15 ± 0 mm, 15 ± 1 mm, 17 ± 1 mm, 19 ± 0 mm and 21 ± 0 mm against *P. aeruginosa, S. typhi, E. coli, S. aureus* and *B. cereus*, respectively. In contrast, the water extracts showed relatively minimal antibiotic activity. The water leaf extracts formed zones of inhibition ranging from 10 ± 0 to 14 ± 0 mm, whereas the water fruit extracts formed inhibition zones ranging from 10 ± 0 to 12 ± 1 mm. The maximum zone of inhibition among water extracts was shown against B. cereus, i.e., 12 ± 1 mm for fruits and 14 ± 0 mm for leaves, while the minimum zone of inhibition was noted as 10 ± 0 mm against *S. typhi* and *P. aeruginosa*. Generally, leaf extracts recorded a slightly higher maximum antimicrobial activity as compared with fruit extracts irrespective of the solvent extraction. Among the treated microbes, *B. cereus* was the most vulnerable microbe to both aqueous and ethanol extracts, while P. aeruginosa was the least vulnerable. The zones of inhibition formed by the ethanol extracts were analogous to those of Gentamycin, mainly against S. aureus and B. cereus, showing the maximum antibacterial activity of Chinaberry tree extracts.

The *M. azedarach* fruits and leaves extracts MIC against the treated microbial species are shown in Figure 1. The MIC values diverse rendering to the extraction solvents, plant parts, and microbial strains. Generally, the extracts of ethanol displayed lesser values of MIC as compared with water extracts, showing maximum antibacterial activity. Among all tested extracts, the ethanol leaf extract documented the most powerful antibacterial activity, with MIC values ranging from 25 to 125 mg/mL. The lowest MIC (25 mg/mL) was noted against B. cereus, showing the maximum vulnerability of this microbe to the extracts. The MIC values of 125, 100, 75, and 50 were observed against *P. aeruginosa, S. typhi, E. coli,* and *S. aureus,* respectively.

The water leaf extracts showed relatively minimal antibacterial properties, with MIC values ranging from 75 to 175 mg/mL. The most vulnerable microbe was B. cereus with an MIC 75mg/mL, whereas *P. aeruginosa, S. typhi, E. coli*, and *S. aureus* displayed greater MIC values, i.e., 175, 175, 175, and 125 mg/mL, respectively. The ethanol extracts of fruits showed MIC values ranging from 50 to 175 mg/mL. The lowest MIC was displayed against S. aureus, which was 50mg/mL, while *P. aeruginosa, S. typhi, E. coli*, and *B. cereus* recorded MIC values of 175, 175, 125, and 100 mg/mL, respectively. In contrast, the fruit extracts of aqueous observed the maximum MIC values among all treated extracts, ranging from 125 to 200 mg/mL. The lowest MIC was recorded as 125 mg/mL against B. cereus, while the maximum MIC against P. aeruginosa was 200mg/mL. Generally, *S. aureus* and *B. cereus* were the most vulnerable microbial strains, showing the lowest MIC values, whereas P. aeruginosa observed the greatest values of MIC and was therefore the smallest vulnerable microbe. The findings further verify that ethanol extracts, mainly those obtained from leaves, exhibited the strongest antimicrobial activities as matched with water extracts.

The MBC values of *M. azedarach* fruits and leaf extracts against treated microbial species are shown in Figure 2. Generally, the values of MBC were greater compared with the values of MIC, representing that greater dosages were needed to attain bactericidal properties matched to growth inhibition. Among all experiments, the leaf ethanol extracts unveiled the lowest values of MBC, representing the powerful bactericidal properties. The values of MBC ranged from 50 to 225 mg/mL, with *B. cereus* observing the greatest vulnerability (50 mg/mL), while *P. aeruginosa, S. typhi, E. coli,* and *S. aureus* MBC values were 225, 175, 125, and 75 mg/mL, respectively. The leaf aqueous extracts disclosed relatively feebler bactericidal activities, with values of MBC ranging from 125 to 250 mg/mL. *B. cereus* was again the most vulnerable microbe, showing 125mg/mL MBC value, while *P. aeruginosa, S. typhi,* and *E. coli* exhibited maximum MBC values of 250, 250, and 200 mg/mL, respectively. The fruit ethanol extract treatment formed MBC values ranging from 125 and 250mg/mL. The minimum MBC values of 125 mg/mL were displayed against S. aureus, while the 250, 250, 200, and 150 mg/mL MBC values were observed against *P. aeruginosa, S. typhi, E. coli,* and *B. cereus,* respectively. Likewise, the fruit extract of water displayed the maximum MBC values generally, ranging from 200 to 250 mg/mL, representing comparatively feeble bactericidal property. Generally, leaf extracts- especially ethanol leaf extracts documented powerful bactericidal property matched to extracts of fruit. S. aureus and B. cereus were the most vulnerable microorganisms, while P. aeruginosa steadily displayed the greatest resistance across all experiments. The outcomes verify a vibrant dose-dependent bactericidal activity of Chinaberry tree extracts, with ethanol extracts being an extra effective solvent extraction as compared with aqueous.

Table 1. Antimicrobial Activity of *M. azedarach* Extracts (100 mg/mL) against Bacteria.

Bacterial Strains	Extracts	Leaves	Fruits	DMSO	Gentamycin (10µg)
		Inhibition zones (mm)	Inhibition zones (mm)		
B. cereus	Ethanol	22±1	21±0	--	24±0
	Aqueous	14±0	12±1		
S. aureus	Ethanol	20±1	19±0	--	25±0
	Aqueous	13±1.5	12±1		
E. coli	Ethanol	18±1	17±1	--	23±0
	Aqueous	12±1	11±0		
S. typhi	Ethanol	17±1	15±1	--	22±0
	Aqueous	11±0	10±0		
P. aeruginosa	Ethanol	16±1	15±0	--	21±0
	Aqueous	10±0	10±0		

Data are means of three replicates (n = 3) ± standard error, --= No zone of inhibition.

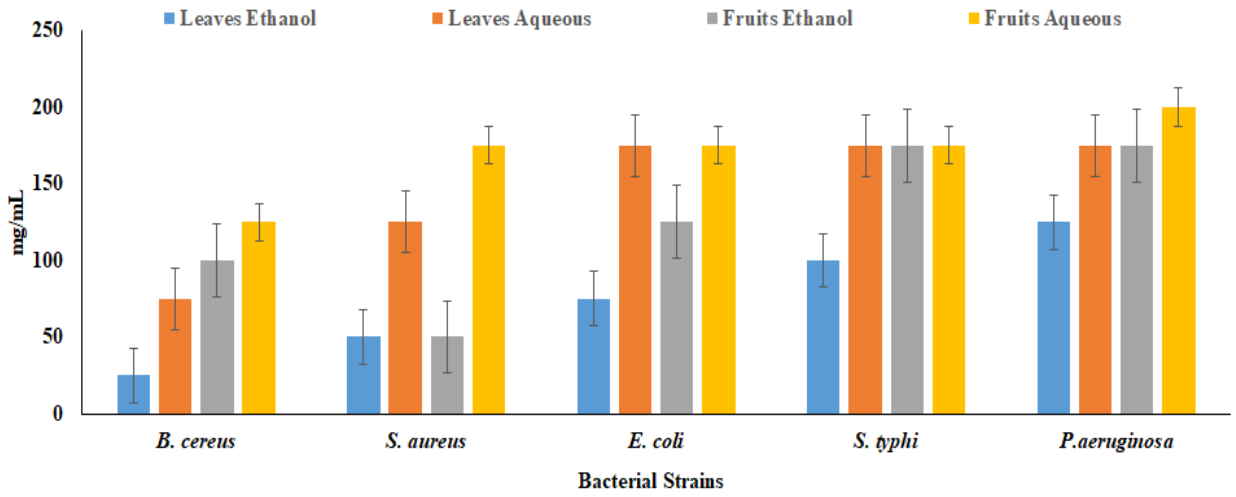

Figure 1. MIC Values of *M. azedarach* Leaves and Fruits against Bacterial Strains.

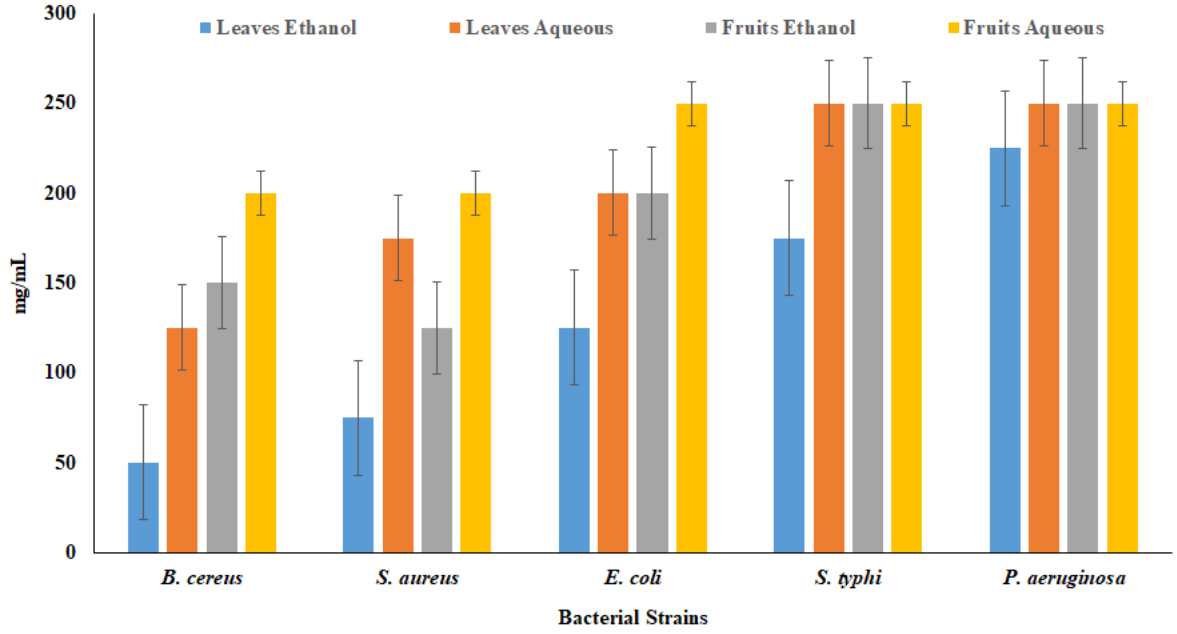

Figure 2. MBC Values of *M. azedarch* Extracts against Bacterial Strains

Discussion

The current study documented that Chinaberry tree fruits and leaves extracts hold noteworthy antimicrobial activities against Gram-negative and Gram-positive microbes, with ethanol extracts observing maximum efficiency as compared with water extracts. These dissimilarities in efficiency might be directly associated with the bioactive ingredients of the herbs. Earlier results have documented that Chinaberry tree holds vital bioactive substances like tannins, saponins, flavonoids, and phenols (Jeba et al., 2020). These substances are well known for their antibiotic's activities, as they might interfere with genetic materials, inhibit enzyme activity, and disrupt microbial cell membranes. Likewise, Bashir and Javid, (2013) emphasized that terpenoids, tannins, alkaloids, flavonoids, and phenolic compounds play a main role in herbal-based antibiotic properties, supporting the powerful suppression efficiencies displayed in the current study. The maximum antimicrobial activities of ethanol extracts matched to water extracts in the current study are consistent with earlier outcomes. Farook et al. (2019) also documented that solvents such as ethanol and other organic extracts of Chinaberry tree leaves showed powerful antimicrobial activities against *S. aureus*, *P. aeruginosa*, *E. coli*, and *B. subtilis* matched to water extracts. This proposes that ethanol is extra effectual in isolating non-polar and moderately polar bioactive compounds responsible for antibacterial activities. In contrast, water extracts might lack adequate dosages of these bioactive substances, which explains their relatively minimal activity in the current research.

The observed vulnerability pattern, where Gram-positive (*S. aureus* and *B. cereus*) were extra weak as compared with Gram-negative microbes (*P. aeruginosa* and *E. coli*), agrees with previous

findings. Gram-negative microbes are commonly more hardy due to the presence of an outer membrane rich in polysaccharides, which limits the diffusion of antibiotic substances. *E. coli* is a general facultative anaerobic bacterium of the intestine and is extensively found in animals and humans and is famous for its adaptive confrontation mechanisms (Lorenzo et al., 2018). Likewise, *P. aeruginosa* showed the maximum resistance in the current findings, which might be attributable to its well-reported capability to grow polydrug resistance and create defensive biofilms. The outcomes of the present research are also verified by previous reports on Chinaberry tree. Farook et al. (2019) documented noteworthy antimicrobial activities of leaf extracts at doses of 100 and 200mg/mL against Gram-negative and gram-positive microbes. Similarly, Touzout et al. (2023) reported that *M. azedarach* methanol leaf extracts displayed a powerful antimicrobial activity against *P. aeruginosa*, *E. coli*, and *S. aureus*. In addition, Balasubramaniam et al. (2019) documented concentration-dependent antimicrobial activities of methanol and water leaf extracts, with maximum doses creating greater inhibition zones, which line up with the dose-dependent properties shown in the current findings by MBC and MIC values.

The MBC and MIC findings in the current study further verify the bactericidal and bacteriostatic activities of Chinaberry tree. Weak MBC and MIC values displayed in ethanol leaf extracts show powerful antibacterial activity, predominantly against *S. aureus* and *B. cereus*. Similar tendencies were documented by Maroua et al. (2016), who reported powerful effects of ethanol leaf extracts with minimum preventive dosages against *Bacillus subtilis*, Enterococcus faecalis and *E. coli*. The maximum inhibition shown in *S. typhi* and *P. aeruginosa* in the current study is consistent with earlier findings telling these microbes as extremely hardy because of their intrinsic resistance mechanisms and capability to live under punitive ecological circumstances. Additionally, the significant activities of *M. azedarch* showed in the current study are predominantly pertinent in the background of growing foodborne infections and antimicrobial resistance. *Staphylococcus aureus* has been recognized as a main pathogen accountable for foodborne intoxication and other human infections globally, with growing incidence in various countries (Shylaja et al., 2012; Tayel and El-Taras, 2010). *S. aureus* is a noteworthy cause of foodborne diseases, supporting the significance of emerging substitute antibacterial compounds. In this background, the antibacterial activities of Chinaberry tree extract suggest their potential utilization as non-synthetic antimicrobial substances for managing clinical and foodborne pathogens. Generally, the current results are in agreement with the earlier findings, verifying that *M. azedarach* is an auspicious source of bioactive substances with noteworthy antimicrobial activities. The powerful activities of ethanol extracts, maximum vulnerability of Gram-positive microbes, and dose-dependent suppression jointly provide the probable utilization of this plant in food preservation, clinical, and pharmaceutical applications. However, additional research is needed to characterize and isolate the precise bioactive molecules responsible for this activity and to assess their mechanism of action and toxicity.

Conclusion

The current research documented that *M. azedarch* fruits and leaves hold significant antibacterial activities against both Gram-negative and Gram-positive microbes. Among all the experimental samples, the ethanol extracts displayed steadily maximum zones of inhibition, lower MIC values, and lower MBC values as matched to water extracts, showing that ethanol is an additional effective solvent for isolating bioactive antibacterial substances. Leaf extracts were commonly more efficient as compared with fruit extracts, signifying a higher dosage of antimicrobial plant-based compounds in leaves. The minimum MBC and MIC values were displayed against *S. aureus* and *B. cereus*, whereas P. aeruginosa showed the maximum confrontation diagonally all conditions. Generally, Gram-positive microbes were more vulnerable as compared with Gram-negative microbes. The results verify that Chinaberry tree is an auspicious source of natural antimicrobial substances, predominantly its leaf extracts of ethanol, which showed powerful bactericidal and inhibitory effects. Additional studies are suggested to separate and characterize the bioactive substances responsible for these activities and to assess their potential utilization in food preservation systems and pharmaceutical industries.

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