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Research Article
Antibacterial Efficacy of *Garcinia mangostana* Extracts Against Multidrug-Resistant and Clinically Significant Bacterial Pathogens

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Abstract

Background and Objective: *Garcinia mangostana*, commonly known as mangosteen, is rich in bioactive compounds, particularly xanthones such as α-mangostin, which have exhibited potent antibacterial activity against a range of pathogenic bacteria in numerous *in vitro* studies. This research aimed to assess the antibacterial activity of *G. mangostana* extracts against eight clinically significant human pathogenic bacteria. **Materials and Methods:** Powdered *G. mangostana* was subjected to solvent extraction using ethanol, dichloromethane and hexane. The resulting extracts were evaluated for their antibacterial activity by determining the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) against eight clinically relevant human pathogenic bacteria using the microbroth dilution method. The MIC and MBC data were analyzed using ANOVA under a CRD with three replicates and means were compared using DMRT at $p<0.05$ in SPSS v28. **Results:** The lowest MIC value of 0.049 mg/mL was observed for the ethanol, dichloromethane and hexane extracts against *Pseudomonas aeruginosa* TISTR 2370. Correspondingly, the lowest MBC values, at <0.049 mg/mL, were also recorded for these extracts against the same bacterial strain. **Conclusion:** This study is the first to report the antibacterial efficacy of *G. mangostana* against antibiotic-resistant bacteria, including colistin-resistant *P. aeruginosa*, carbapenem-resistant Enterobacteriaceae, multidrug-resistant *Klebsiella pneumoniae* and *Acinetobacter baumannii*. These findings are significant and hold promise for the development of novel antibiotic agents for the treatment of infections caused by these clinically challenging pathogens.

Key words: Antibacterial activity, *Garcinia mangostana*, antibiotic-resistant bacteria, multidrug-resistant *Klebsiella pneumonia*, *Acinetobacter baumannii*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The rapid emergence and widespread dissemination of antibiotic-resistant bacteria represent a critical global health challenge. This phenomenon significantly undermines the efficacy of existing antimicrobial therapies, leading to increased rates of morbidity and mortality, as well as escalating healthcare costs worldwide. As traditional antibiotics lose their effectiveness against resistant bacterial strains, the urgency to develop new therapeutic strategies becomes paramount[1]. The World Health Organization (WHO) has published a priority list of pathogens that significantly threaten public health, prominently including *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* species. These organisms have been categorized as the highest priority due to their critical role in antimicrobial resistance and profound impact on clinical outcomes[2]. Addressing antimicrobial resistance demands a comprehensive strategy that encompasses the development of novel antibiotics, strengthening infection prevention and control practices, enhancing surveillance systems and promoting the prudent use of existing antimicrobial agents.

Given the critical challenge posed by antibiotic-resistant bacteria and the diminishing efficacy of existing antimicrobial therapies, the exploration of new and effective treatment options is urgently needed. Plant-based sources of antimicrobial agents offer a promising and vital avenue in this pursuit[3]. Rich in diverse bioactive compounds with unique mechanisms of action, plants represent an underutilized reservoir of natural products that can potentially overcome existing resistance mechanisms[4]. Harnessing plant-derived antimicrobials not only broadens the spectrum of therapeutic options but also aligns with sustainable and eco-friendly approaches to drug development[5]. Therefore, integrating plant-based compounds into the fight against antimicrobial resistance is both necessary and urgent to address this escalating global health threat effectively.

Garcinia mangostana L., commonly referred to as mangosteen, is a tropical evergreen tree indigenous to Southeast Asian countries, including Sri Lanka, Malaysia, India, the Philippines, Myanmar and Thailand[6]. The mangosteen fruit is distinguished by its thick pericarp, varying from deep purple to reddish, which encases an edible white arillate pulp. This pulp exhibits a characteristic mildly acidic yet sweet taste, complemented by a distinctive aroma, earning the fruit its colloquial title, the "queen of fruits." Mature mangosteen trees typically attain heights between 6-25 m and are characterized by their leather, glabrous leaves and notably slow growth. Historically, the seeds and pericarps of the mangosteen fruit have been extensively employed in traditional medicinal practices throughout Southeast Asia. Contemporary commercial interest in mangosteen has expanded globally, with beverages and dietary supplements formulated from mangosteen pulp and pericarp extracts increasingly recognized for their nutritional value and potential therapeutic properties[7].

Extensive phytochemical investigations have revealed that mangosteen pericarp is particularly rich in bioactive compounds, notably prenylated xanthones. These compounds have demonstrated significant antioxidants, antitumoral, antiallergic, anti-inflammatory, antibacterial[8], antifungal and antiviral activities in various studies[9]. Historical and contemporary evidence underscores mangosteen as a medicinally valuable plant, traditionally employed to treat gastrointestinal and urinary tract infections, scurvy, constipation and fever. Contemporary therapeutic applications extend its use to addressing infection-associated symptoms such as diarrhea, abdominal pain, dysentery and fever, as well as inflammatory and immunological conditions, including acne, arthritis, skin infections, wounds and food allergies[10]. Consequently, mangosteen pericarp extracts represent a promising natural source for developing therapeutic agents with antimicrobial, anti-inflammatory and immune-modulatory potentials[11]. Many phytochemical constituents of *G. mangostana* including xanthones (mangostin), benzophenones, flavonoids and anthocyanins have been reported[12,13].

The antimicrobial efficacy of *G. mangostana* peel extract was evaluated for its ability to reduce airborne microbial contamination in livestock farming environments. The results demonstrated that mangosteen peel extract exhibited potent antimicrobial activity against a variety of bacterial and fungal species typically associated with swine and poultry farms, including *Exiguobacterium indicum*, *Staphylococcus epidermidis*, *Bacillus siamensis* and *Bacillus cereus*. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values ranged between 0.015 and 0.061 mg/mL[14].

In light of the escalating global threat posed by antibiotic-resistant bacteria and the diminishing effectiveness of current antimicrobial therapies, the urgent need to discover and evaluate novel natural compounds with potent antibacterial properties has become increasingly apparent. Plant-derived extracts represent a promising reservoir of bioactive molecules that may offer alternative therapeutic solutions, particularly against multidrug-resistant pathogens that challenge conventional treatment strategies.

Investigating the antibacterial activity of such natural products not only facilitates the identification of new antimicrobial agents but also aligns with the growing emphasis on sustainable, eco-friendly approaches in healthcare and agriculture. Moreover, leveraging plant-based antimicrobials could reduce the reliance on synthetic antibiotics, thereby mitigating the further development of resistance. In this context, the present study focuses on assessing the antibacterial efficacy of *G. mangostana* peel extracts against clinically significant multidrug-resistant bacterial strains.

MATERIALS AND METHODS

Study area: This research was carried out between December, 2024 and March, 2025 at the Microbiology Laboratory, Faculty of Liberal Arts and Science, Department of Science and Technology, Roi Et Rajabhat University, located in Roi Et, Thailand.

Human pathogenic bacteria: Four antibiotic-resistant bacterial strains, including colistin-resistant *Pseudomonas aeruginosa*, Carbapenem-resistant enterobacteriaceae, Multidrug-resistant *Klebsiella pneumoniae* and *Acinetobacter baumannii*, were obtained from Roi Et Hospital, Roi Et, Thailand. Four reference bacterial species, including *Staphylococcus aureus* TISTR1466, *Bacillus subtilis* TISTR008, *Pseudomonas aeruginosa* TISTR2370 and *Escherichia coli* PK, were obtained from the Thailand Institute of Scientific and Technological Research culture collection (TISTR culture collection) and the Department of Biotechnology, Maha Sarakham University, Maha Sarakham, Thailand.

Human pathogenic bacterial preparation and cultivation: Each frozen bacterial stock was thawed, inoculated into 5 mL of nutrient broth (NB) and incubated overnight at 37°C with agitation using a shaking incubator (JSSI-300CL, KITISIT ENTERPRISE Co. Ltd., Thailand). Subsequently, bacterial cultures were streaked onto nutrient agar (NA) plates and incubated at 37°C for 18 hrs. Individual bacterial colonies were then selected and inoculated into 5 mL of fresh NB, followed by overnight incubation with shaking at 37°C. Before experimental use, bacterial suspensions were standardized to an optical density (OD) of 0.1 at 600 nm, ensuring uniformity in bacterial concentration across assays[15-17].

Plant extract preparation: The powdered *G. mangostana* was obtained commercially from Chemipanshop in Roi Et, Thailand, as shown in Fig. 1. A total of 50 g of this powder was subjected to extraction using solvents of varying polarity, namely ethanol, dichloromethane and hexane (ITALAMAR (THAILAND) Co. LTD.). The resulting extracts were filtered and the solvents were subsequently evaporated by drying the filtrates in a hot-air oven (POL-EKO-APARATURA, Wodzisław Śląski, Poland) at 50°C for 48 hrs. The dried extracts were

Fig. 1: *Garcinia mangostana* powder

stored under appropriate conditions before further analysis. The dried extracts were dissolved in dimethyl sulfoxide (DMSO, Sigma, USA) to obtain a final concentration of 500 mg/mL[18-20]. The prepared solutions were subsequently stored at 4°C until further use.

MIC and MBC values determination: The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values were determined using the broth microdilution technique[18,21-23]. Briefly, serial two-fold dilutions of the 100 µL *G. mangostana* extracts (500 mg/mL) were prepared in 100 µL NB and dispensed into 96-well microtiter plates. Each well was inoculated with a standardized bacterial suspension adjusted to an optical density (OD) of 0.1 at 600 nm. Following incubation at 37°C for 18-24 hrs, bacterial growth was assessed by adding iodonitrotetrazolium chloride (INT) solution to each well and incubating at 37°C for an additional 30 min. The minimum inhibitory concentration (MIC) was determined as the lowest concentration of *G. mangostana* extract that inhibited bacterial growth, as evidenced by the presence of a color change to pink following the addition of INT. The minimum bactericidal concentration (MBC) was defined as the lowest concentration of *G. mangostana* extract that eliminated viable bacteria, confirmed by no observable color change after INT addition. All tests were conducted in triplicate to confirm reproducibility and ensure accuracy of results.

Data analysis: The MIC and MBC values were analyzed using SPSS software version 28. The experiment followed a Completely Randomized Design (CRD) with three replicates per treatment. Statistical differences among treatments were evaluated using One-way Analysis of Variance (ANOVA). Subsequently, mean comparisons were performed using Duncan's Multiple Range Test (DMRT), with statistical significance defined at $p<0.05$.

RESULTS AND DISCUSSION

MIC and MBC values: The minimum inhibitory concentration (MIC) values of *G. mangostana* extracts against eight clinically significant human pathogenic bacteria were summarized in Table 1. Among the tested extracts, the dichloromethane fraction exhibited the lowest MIC values (0.049 mg/mL) against six bacterial strains: *P. aeruginosa* TISTR2370, carbapenem-resistant Enterobacteriaceae, *S. aureus* TISTR1466, *A. baumannii*, *E. coli* PK and *B. subtilis* TISTR008. The ethanol and hexane extracts also demonstrated inhibitory effects, with the lowest MIC values (0.049 mg/mL) observed against *P. aeruginosa* TISTR2370 (Table 2).

Pseudomonas aeruginosa TISTR2370 was identified as the most sensitive strain, exhibiting the lowest MIC value (0.049 mg/mL) across all three extract types. In contrast, colistin-resistant *P. aeruginosa* and *E. coli* PK displayed the highest MIC values, particularly with the hexane

Table 1: Human pathogenic bacteria

Bacterial strain	Description
Colistin-resistant *Pseudomonas aeruginosa*	Antibiotic resistant strain, clinical isolate
Carbapenem-resistant enterobacteriaceae	Antibiotic resistant strain, clinical isolate
Multidrug-resistant *Klebsiella pneumonia*	Antibiotic resistant strain, clinical isolate
Acinetobacter baumannii	Antibiotic resistant strain, clinical isolate
Staphylococcus aureus TISTR1466	Reference strain
Escherichia coli PK	Reference strain
Bacillus subtilis TISTR 008	Reference strain
Pseudomonas aeruginosa TISTR 2370	Reference strain

Table 2: MIC values of *Garcinia mangostana* extract against pathogenic bacteria

	Average of MIC values* (mg/mL)		
Bacterial strain	Ethanol extracts	Hexane extracts	Dichloromethane extracts
Colistin-resistant *Pseudomonas aeruginosa*	0.39^{b}	1.56^{a}	0.39^{a}
Carbapenem-resistant enterobacteriaceae	0.195^{c}	0.049	0.049^{c}
Multidrug-resistant *Klebsiella pneumonia*	-	0.39^{b}	0.098^{b}
Acinetobacter baumanii	0.78^{a}	0.098^{d}	0.049^{c}
Staphylococcus aureus TISTR1466	0.195^{c}	0.098^{d}	0.049^{c}
Escherichia coli PK	0.39^{b}	1.56^{a}	0.049^{c}
Bacillus subtilis TISTR008	0.39^{b}	0.195^{c}	0.049^{c}
Pseudomonas aeruginosa TISTR 2370	0.049^{d}	0.049^{e}	0.049^{c}
p-value	<0.001	<0.001	<0.001

Means (n = 3) in the column followed by the same common letter were not significantly different (DMRT, $p>0.05$)

extract (1.56 mg/mL), suggesting a greater degree of resistance. Notably, multidrug-resistant *K. pneumoniae* was the most resistant organism, as it was not inhibited by the ethanol extract and displayed comparatively higher MIC values for the hexane (0.39 mg/mL) and dichloromethane (0.098 mg/mL) extracts.

The dichloromethane extracts consistently demonstrated the most potent and broad-spectrum antibacterial activity, achieving MIC values of 0.049 mg/mL against the majority of the tested pathogens. While both ethanol and hexane extracts showed notable antibacterial activity, their effectiveness varied depending on the bacterial strain. For example, the ethanol extract displayed strong inhibition of *P. aeruginosa* TISTR2370, but failed to inhibit multidrug-resistant *K. pneumoniae* at the concentrations tested. Similarly, the hexane extract was highly effective against *P. aeruginosa* TISTR2370 and carbapenem-resistant Enterobacteriaceae (MIC = 0.049 mg/mL), but exhibited limited efficacy against colistin-resistant *P. aeruginosa* and *E. coli* PK (MIC = 1.56 mg/mL for both).

The broad-spectrum efficacy of the dichloromethane extract implies the presence of potent bioactive compounds that are effective against both Gram-positive and Gram-negative bacteria, including strains exhibiting multiple antibiotic resistance. In particular, the low MIC values observed against *A. baumannii*, *S. aureus* and carbapenem-resistant Enterobacteriaceae highlight the extract's therapeutic potential for combating pathogens that pose significant treatment challenges in clinical settings. Conversely, the higher resistance displayed by multidrug-resistant *K. pneumoniae*, which showed only moderate inhibition by the hexane and dichloromethane extracts and no inhibition by the ethanol extract, is consistent with previous reports[15] indicating the inherent resilience of this pathogen to plant-derived antimicrobials. This finding underscores the need for ongoing exploration and isolation of more effective phytochemicals.

Dharmaratne *et al.*[24] have demonstrated the antibacterial potential of prenylated xanthones derived from *G. mangostana*. Notably, γ-Mangostin exhibited significant activity against clinically important strains, including Methicillin-Resistant *S. Aureus* (MRSA), Methicillin-Sensitive *S. Aureus* (MSSA), Vancomycin-Resistant *Enterococcus* (VRE) and Vancomycin-Sensitive *Enterococcus* (VSE), with MICs ranging from 3.13 to 6.25 µg/mL. These MIC values are considerably lower than those observed in the present study, which reported MICs between 0.049 and 0.195 mg/mL against *S. aureus* TISTR 1466. This difference highlights variability in antibacterial efficacy, which can be attributed primarily to the purity of the extract used[24]. The results of this study demonstrated a lower MIC against *S. aureus* TISTR1466 compared to the N-hexane extract of mangosteen peel, which exhibited antibacterial activity at a concentration of 15.62 mg/mL against *S. aureus* ATCC 25923[25].

The mangosteen extracts also demonstrated inhibitory effects against *S. aureus* ATCC 11632 and *B. cereus* ATCC 10876. However, no inhibition was observed against *E. coli* ATCC 10536[26]. Interestingly, the *G. mangostana* extract tested in this study was able to inhibit the growth of *E. coli* PK, indicating possible strain-specific antibacterial activity. The ethanolic extract of *G. mangostana* in this study effectively inhibited both colistin-resistant *P. aeruginosa* and *P. aeruginosa* TISTR 2370, consistent with previous reports. Prior research demonstrated that ethanolic extracts from mangosteen leaves could suppress *P. aeruginosa* growth across concentrations ranging from 10 to 100%[27]. The dichloromethane extract of *G. mangostana* exhibited an MIC of 0.098 mg/mL against multidrug-resistant *K. pneumoniae*, demonstrating greater antibacterial potency compared to the avocado extract, which showed a MIC of 250 µg/mL against both aminoglycoside-sensitive and -resistant *K. pneumoniae* strains[28].

The MIC values obtained in this study demonstrated higher antibacterial potential against multidrug-resistant (MDR) clinical isolates compared to previous reports. For example, ethanolic extracts derived from *Centella asiatica* demonstrated minimum inhibitory concentration (MIC) values ranging between 2.5 and 5 mg/mL against multidrug-resistant bacteria, including methicillin-resistant *Staphylococcus aureus*, piperacillin-resistant *Pseudomonas aeruginosa,* extended-spectrum β-lactamase-producing *Klebsiella pneumoniae*, extended-spectrum β-lactamase-producing *Escherichia coli*[29].

The minimum bactericidal concentration (MBC) values of *G. mangostana* extracts against eight clinically significant human pathogenic bacteria are shown in Table 3. The dichloromethane extract demonstrated the most potent bactericidal activity, achieving an MBC of <0.049 mg/mL against both *P. aeruginosa* TISTR 2370 and *B. subtilis* TISTR008. Notably, all three extracts, ethanol, hexane and dichloromethane, were highly effective against *P. aeruginosa* TISTR 2370, with MBC values of <0.049 mg/mL, indicating this strain was the most susceptible to the tested extracts. The ethanol extracts also showed a low MBC value of 0.39 mg/mL

Table 3: MBC values of *Garcinia mangostana* extract against pathogenic bacteria

Bacterial strain	Average of MBC values* (mg/mL)		
	Ethanol extracts	Hexane extracts	Dichloromethane extracts
Colistin-resistant *Pseudomonas aeruginosa*	12.5[b]	6.25[c]	12.5[b]
Carbapenem-resistant enterobacteriaceae	0.39[d]	12.5[b]	3.125[d]
Multidrug-resistant *Klebsiella pneumonia*	-	3.125[d]	6.25[c]
Acinetobacter baumannii	6.25[c]	25[a]	25[a]
Staphylococcus aureus TISTR1466	6.25[c]	3.125[d]	0.098[e]
Escherichia coli PK	>25[a]	12.5[b]	12.5[b]
Bacillus subtilis TISTR008	6.25[c]	1.56[e]	<0.049[e]
Pseudomonas aeruginosa TISTR 2370	<0.049[d]	<0.049[f]	<0.049[e]
p-value	<0.001	<0.001	<0.001

Means (n = 3) in the column followed by the same common letter were not significantly different (DMRT, p>0.05)

against carbapenem-resistant Enterobacteriaceae, whereas the hexane extract achieved an MBC of 1.56 mg/mL against *B. subtilis* TISTR008 and 3.125 mg/mL against both multidrug-resistant *K. pneumoniae* and *S. aureus* TISTR1466. In contrast, higher MBC values were observed for colistin-resistant *P. aeruginosa*, *A. baumannii* and *E. coli* PK, with the ethanol and dichloromethane extracts showing MBCs of 12.5-25 mg/mL and the hexane extract up to 25 mg/mL, indicating a higher degree of resistance (Table 3). Among all tested strains, *E. coli* PK was the most resistant, exhibiting an MBC greater than 25 mg/mL for the ethanol extract and 12.5 mg/mL for both hexane and dichloromethane extracts. Collectively, these findings suggested that while *G. mangostana* extracts, especially the dichloromethane fraction demonstrate potent bactericidal activity against certain pathogens, the efficacy varies significantly depending on the bacterial species and resistance profile.

The remarkable sensitivity of *P. aeruginosa* TISTR 2370 to all three extracts is particularly notable, as this pathogen is often associated with multidrug resistance and hospital-acquired infections. The observation that ethanol, hexane and dichloromethane extracts could completely eradicate this strain at concentrations below 0.049 mg/mL highlights the strong bactericidal potential of *G. mangostana* phytochemicals. Similarly, the dichloromethane extract's efficacy against *B. subtilis* TISTR008 at <0.049 mg/mL underscores its broad-spectrum capability, extending to both Gram-negative and Gram-positive bacteria. In contrast, the high MBC values observed for *A. baumannii* and *Escherichia coli* PK indicate a substantial resistance to the tested extracts, particularly for the ethanol and hexane fractions. *A. baumannii*, a notorious cause of nosocomial outbreaks, required up to 25 mg/mL of hexane or dichloromethane extract for bactericidal activity, while *E. coli* PK showed even greater resistance, especially to ethanol extract. These findings align with previous reports, highlight the resilience of these pathogens and the need for higher concentrations or alternative strategies for effective eradication.

The results of this study showed MIC values ranging from 0.049 to 0.39 mg/mL and MBC values from less than 0.049 to 6.25 mg/mL against *Bacillus subtilis* TISTR008, which are consistent with previous findings. Mangosteen peel extract has been demonstrated to possess antimicrobial properties effective against a wide range of bacterial and fungal pathogens frequently isolated from swine and poultry farming environments, including *Exiguobacterium indicum, Bacillus cereus, Staphylococcus epidermidis* and *Bacillus siamensis*. The reported MIC and MBC values for these pathogens range between 0.015 mg/mL and 0.061 mg/mL, underscoring the extract's potent efficacy even at low concentrations[14]. The minimum bactericidal concentration (MBC) of *Garcinia mangostana* extract against multidrug-resistant *Klebsiella pneumoniae* in this study ranged from 3.125 to 6.25 mg/mL, demonstrating higher antibacterial activity compared to *Momordica charantia* (Morya variety), which exhibited MBC values between 12.5 and 25 mg/mL[21].

The differences in MBC values between the extracts suggest that the solvent used for extraction plays a crucial role in isolating active antibacterial compounds from *G. mangostana*. Dichloromethane appears to extract a broader spectrum of potent bactericidal compounds, as evidenced by its lower MBCs against several strains. However, certain bacteria, such as multidrug-resistant *K. pneumoniae* and colistin-resistant *P. aeruginosa*, exhibited only moderate susceptibility, further emphasizing the complexity of bacterial resistance mechanisms. Overall, these MBC findings reinforce the promising role of *G. mangostana*, particularly its dichloromethane extract, as a source of natural bactericidal agents. Nevertheless, the observed variability in susceptibility among different bacterial species highlights the importance of further phytochemical studies to identify and optimize the most effective antibacterial components. Moreover, *in vivo* assessments and mechanistic investigations are essential next steps to validate these extracts' therapeutic potential and to inform of their development as alternative or adjunct therapies for combating drug-resistant bacterial infections.

CONCLUSION

G. mangostana extracts, particularly the dichloromethane fraction, demonstrated potent antibacterial and bactericidal activity against a range of clinically significant human pathogens, including several antibiotic-resistant strains. The lowest MIC and MBC values (<0.049 mg/mL) were consistently observed against *P. aeruginosa* TISTR 2370, highlighting its high susceptibility to all three extracts. Conversely, strains such as *E. coli* PK, *A. baumannii* and multidrug-resistant *K. pneumoniae* exhibited greater resistance, requiring higher extract concentrations for inhibition and bactericidal effect. These findings underscore the potential of *G. mangostana*, especially its dichloromethane extract, as a promising source of natural antibacterial agents for combating drug-resistant bacterial infections.

SIGNIFICANCE STATEMENT

This study identified the potent antibacterial and bactericidal properties of *Garcinia mangostana* dichloromethane extract against clinically significant, antibiotic-resistant bacteria, which could be beneficial for developing alternative therapeutic agents. This study will assist researchers in uncovering critical areas of natural product-based antimicrobial resistance management that have remained unexplored by many. Consequently, a new theory on plant-derived antimicrobials as viable alternatives to conventional antibiotics may be developed.

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REFERENCES

1. Abdus Salam, M., M.Y. Al-Amin, M.T. Salam, J.S. Pawar, N. Akhter, A.A. Rabaan and M.A.A. Alqumber, 2023. Antimicrobial resistance: A growing serious threat for global public health. Healthcare, Vol. 11. 10.3390/healthcare11131946.
2. Mancuso, G., A. Midiri, E. Gerace and C. Biondo, 2021. Bacterial antibiotic resistance: The most critical pathogens. Pathogens, Vol. 10. 10.3390/pathogens10101310.
3. Hossain, T.J., 2024. Methods for screening and evaluation of antimicrobial activity: A review of protocols, advantages, and limitations. Eur. J. Microbiol. Immunol., 14: 97-115.
4. Newman, D.J. and G.M. Cragg, 2020. Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. J. Nat. Prod., 83: 770-803.
5. Momekov, G., D. Ferdinandov, D. Zheleva-Dimitrova, P. Nedialkov, U. Girreser and G. Kitanov, 2008. Cytotoxic effects of hyperatomarin, a prenylated phloroglucinol from *Hypericum annulatum* Moris subsp. *annulatum*, in a panel of malignant cell lines. Phytomedicine, 15: 1010-1015.
6. Pedraza-Chaverri, J., N. Cardenas-Rodriguez, M. Orozco-Ibarra and J.M. Perez-Rojas, 2008. Medicinal properties of mangosteen (*Garcinia mangostana*). Food. Chem. Toxicol., 46: 3227-3239.
7. Ovalle-Magallanes, B., D. Eugenio-Pérez and J. Pedraza-Chaverri, 2017. Medicinal properties of mangosteen (*Garcinia mangostana* L.): A comprehensive update. Food Chem. Toxicol., 109: 102-122.
8. Muhammad, A.A.N., F. Amaq, H. Suhailah, S.R.J. Kuncoroningrat, I. Bilqis, W. Dwi and H.S. Akhmad, 2020. A review on medicinal properties of mangosteen (*Garcinia mangostana* L.). Res. J. Pharm. Technol., 13: 974-982.
9. Gutierrez-Orozco, F. and M.L. Failla, 2013. Biological activities and bioavailability of mangosteen xanthones: A critical review of the current evidence. Nutrients, 5: 3163-3183.
10. Aizat, W.M., I.N. Jamil, F.H. Ahmad-Hashim and N.M. Noor, 2019. Recent updates on metabolite composition and medicinal benefits of mangosteen plant. PeerJ, Vol. 7. 10.7717/peerj.6324.
11. Majdalawieh, A.F., B.K. Khatib and T.M. Terro, 2025. α-Mangostin is a xanthone derivative from mangosteen with potent immunomodulatory and anti-inflammatory properties. Biomolecules, Vol. 15. 10.3390/biom15050681.
12. Meepagala, K.M. and K.K. Schrader, 2018. Antibacterial activity of constituents from mangosteen *Garcinia mangostana* fruit pericarp against several channel catfish pathogens. J. Aquat. Anim. Health, 30: 179-184.
13. Abdul Rohman, A., F.H. Arifah, I. Irnawati, G. Alam, M. Muchtaridi and M. Rafi, 2020. A review on phytochemical constituents, role on metabolic diseases, and toxicological assessments of underutilized part of *Garcinia mangostana* L. fruit. J. Appl. Pharm. Sci., 10: 127-146.
14. Semangoen, T., R. Chotigawin, T. Sangnim, N. Chailerd, S. Yodkeeree, T. Pahasup-anan and K. Huanbutta, 2025. Antimicrobial efficacy of mangosteen (*Garcinia mangostana*) peel extracts in airborne microbial control within livestock farming environments. Microb. Pathogen., Vol. 204. 10.1016/j.micpath.2025.107618.
15. Rattanasuk, S., P. Hamcumpai, M. Wongkamjan, R. Boongapim and A. Junsongdua, 2025. Potential antibacterial activity of *Oroxylum indicum* (L.) Kurz extracts against antibiotic-resistant bacteria isolated from Roi Et Hospital. Pak. J. Biol. Sci., 28: 88-94.

16. Armassa, N., D. Wongsorn, B. Saenmahaya and S. Rattanasu, 2025. Evaluation of the antibacterial potential of ethanolic *Cannabis sativa* L. (Hang Kra Rog Phu Phan ST1) extracts against human pathogenic bacteria. Pak. J. Biol. Sci., 28: 1-7.
17. Khlongkhlaeo, A., S. Sookruksawong and S. Rattanasuk, 2024. The comparison of antibacterial efficacy, cell proliferation, and wound healing properties in extracts derived from leaves and inflorescences of Hang Kra Rog Phu Phan ST1 (*Cannabis sativa* L.). Trends Sci., Vol. 21. 10.48048/tis.2024.8446
18. Armassa, N., D. Wongsorn, B. Saenmahaya, S. Rayan and S. Rattanasuk, 2024. *In vitro* antibacterial activity of ethanolic Tanao Si Kan Dang RD1 (*Cannabis sativa* L.) extracts against human antibiotic-resistant bacteria. Pak. J. Biol. Sci., 27: 119-124.
19. Rattanasuk, S., K. Wechgama, T. Chumroenphat, O.A. Chaiyachet and K. Charoensopharat, 2023. Potential antibacterial activity of ethanolic *Curcuma longa* L. rhizome extract against antibiotic-resistant bacteria. Pak. J. Biol. Sci., 26: 119-123.
20. Rattanasuk, S. and T. Phiwthong, 2021. A new potential source of anti-pathogenic bacterial substances from *Zamioculcas zamiifolia* (Lodd.) Engl. extracts. Pak. J. Biol. Sci., 24: 235-240.
21. Sawisit, A., S. Payakapan, P. Rodpon, A. Charoenpha and B. Khamboonlh *et al*., 2025. Comparative antibacterial activities of extracts from two varieties of bitter gourd (*Momordica charantia*). Pak. J. Biol. Sci., 28: 246-252.
22. Rattanasuk, S., R. Boongapim, T. Phiwthong, S. Phuangsriken and N. Putthanachote, 2021. Antibacterial profile of *Cissus quadrangularis* extracts against antibiotic-resistant bacteria isolated from Roi Et Hospital. Int. J. Pharmacol., 17: 97-102.
23. Rattanasuk, S., R. Boongapim and T. Phiwthong, 2021. Antibacterial activity of *Cathormion umbellatum*. Bangladesh J. Pharmacol., 16: 91-95.
24. Dharmaratne, H.R.W., Y. Sakagami, K.G.P. Piyasena and V. Thevanesam, 2013. Antibacterial activity of xanthones from *Garcinia mangostana* (L.) and their structure-activity relationship studies. Nat. Prod. Res., 27: 938-941.
25. Andani, R., A. Fajrina, R. Asra and A. Eriadi, 2021. Antibacterial activity test of mangosteen plants (*Garcinia mangostana* L.): A review. Asian J. Pharm. Res. Dev., 9: 164-171.
26. Lim, Y.S., S.S.H. Lee and B.C. Tan, 2013. Antioxidant capacity and antibacterial activity of different parts of mangosteen (*Garcinia mangostana* Linn.) extracts. Fruits, 68: 483-489.
27. Suhartati, R., F. Apriyani, Khusnul, D.P. Virgianti and M. Fathurohman, 2019. Antimicrobial activity test of mangosteen leaves ethanol extract (*Garcinia mangostana* Linn) against *Pseudomonas aeruginosa* bacteria. J. Phys. Conf. Ser., Vol. 1179. 10.1088/1742-6596/1179/1/012167.
28. Kızılyıldırım, S., T. Kandemir, G. Kendir, M.T. Muhammed, A. Köroğlu and F. Ozogul, 2024. Antibacterial activity of avocado extract (*Persea americana* Mill.) against aminoglycoside-resistant *Klebsiella pneumoniae* strains. Food Biosci., Vol. 60. 10.1016/j.fbio.2024.104523.
29. Manilal, A., K.R. Sabu, A. Tsefaye, T. Teshome and A. Aklilu *et al*., 2023. Antibacterial activity against multidrug-resistant clinical isolates of nine plants from Chencha, Southern Ethiopia. Infect. Drug Resist., 16: 2519-2536.