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Mini-Review Article

Antibacterial Potential of Avicennia marina Leaf Extracts: Recent Evidence and Research Gaps

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Abstract

Mangrove plants are recognized as a valuable source of bioactive secondary metabolites with potential pharmaceutical applications, particularly as antibacterial agents. Avicennia marina (Forssk.) Vierh., one of the most widely distributed mangrove species, has been traditionally used to treat various infections. In recent years, increasing attention has been directed toward the antibacterial activity of A. marina leaf extracts in response to the growing challenge of antimicrobial resistance. This mini review aims to critically evaluate recent evidence published between 2019 and 2025 regarding the antibacterial potential of A. marina leaf extracts and to identify existing research gaps. A structured literature search was conducted using Scopus, PubMed and Google Scholar databases, focusing on studies that investigated the in vitro antibacterial activity of A. marina leaves. The reviewed studies consistently report inhibitory effects against both Gram-positive and Gram-negative bacteria, including Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Vibrio spp., and Pseudomonas spp. However, substantial variability in extraction methods, antibacterial assays, and phytochemical characterization limits direct comparison among studies. Overall, A. marina leaf extracts demonstrate promising antibacterial potential, yet further standardized studies and mechanistic investigations are required to support their development as pharmaceutical antibacterial agents.

Keywords: avicennia marina; mangrove leaves; antibacterial activity; natural products; medicinal plants

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1 Introduction

Mangrove ecosystems represent a unique ecological niche characterized by extreme environmental conditions such as high salinity, fluctuating tides, intense microbial exposure, and oxidative stress. To survive under these conditions, mangrove plants synthesize diverse secondary metabolites that function as chemical defense mechanisms. Many of these metabolites, including flavonoids, tannins, alkaloids, terpenoids, and phenolic compounds, have attracted considerable scientific interest due to their pharmacological activities, particularly as antimicrobial agents [1–3].

Avicennia marina (Forssk.) Vierh. is one of the most widely distributed mangrove species across tropical and subtropical coastal regions. Beyond its ecological role, this species has been traditionally used in folk medicine for the treatment of skin infections, wounds, ulcers, and inflammatory disorders. Among various plant parts, the leaves are considered a highly promising source of bioactive compounds because they are metabolically active, renewable, and rich in antibacterial-related phytochemicals such as flavonoids and tannins. From a pharmaceutical perspective, leaf-based materials also offer practical advantages in terms of sustainability, extractability, and formulation potential compared to roots or bark, which are less environmentally viable for repeated harvesting [4–6].

The escalating global challenge of antimicrobial resistance has intensified the search for alternative antibacterial agents derived from natural sources. In this context, mangrove plants have gained increasing attention as potential reservoirs of novel antibacterial compounds. Over the past five years, numerous in vitro studies have reported that *A. marina* leaf extracts exhibit inhibitory activity against a broad spectrum of pathogenic bacteria. These include Gram-positive bacteria such as *Staphylococcus aureus* and *Enterococcus faecalis*, as well as Gram-negative bacteria such as *Escherichia coli*, *Vibrio* spp., *Aeromonas* spp., and *Pseudomonas* spp. However, the magnitude of antibacterial activity reported varies substantially across studies, largely due to differences in extraction solvents, bacterial strains, and assay methodologies employed [7–12].

Despite the growing body of evidence supporting the antibacterial potential of *A. marina* leaf extracts, existing studies remain fragmented and predominantly exploratory in nature. Most investigations emphasize preliminary screening outcomes without sufficient comparative evaluation across extraction strategies or bacterial targets, and with limited discussion on translational relevance. Consequently, a consolidated understanding of the antibacterial significance of *A. marina* leaves and their pharmaceutical potential is still lacking. Therefore, this mini review aims to critically evaluate recent studies published within the last five years on the antibacterial activity of *A. marina* leaf extracts, highlight emerging trends, and identify key research gaps that should be addressed in future investigations.

2 Method

This mini review was conducted through a structured literature search to identify recent studies reporting the antibacterial activity of *Avicennia marina* leaf extracts. Scientific publications were collected from electronic databases including Scopus, PubMed, and Google Scholar. The search strategy employed combinations of keywords such as "*Avicennia marina*", "mangrove leaf extract", "antibacterial activity", and "antimicrobial".

Only original research articles published within the last five years (2019–2025) were included. The inclusion criteria comprised studies that explicitly used *Avicennia marina* leaves as the plant material, evaluated antibacterial activity using in vitro assays, and clearly reported the tested bacterial strains. Articles focusing on other plant parts, non-antibacterial biological activities, review articles, or studies with insufficient experimental details were excluded.

Relevant information from the selected studies was extracted and analyzed, including extraction solvents, antibacterial assay methods, bacterial species tested, and main outcomes. The collected data

were comparatively evaluated to identify general trends, methodological variations, and existing research gaps related to the antibacterial potential of *Avicennia marina* leaf extracts.

3 Result and Discussion

The antibacterial activity of *Avicennia marina* leaf extracts has been increasingly reported in studies published over the last five years, as summarized in Table 1. Overall, the findings consistently demonstrate that leaf extracts of *A. marina* exhibit inhibitory effects against a wide range of pathogenic bacteria, encompassing both Gram-positive and Gram-negative groups. This broad-spectrum activity supports the hypothesis that mangrove leaves serve as an important chemical defense system against microbial challenges in coastal environments.

Based on the reviewed studies, Gram-positive bacteria such as *Staphylococcus aureus*, *Enterococcus faecalis*, and *Bacillus* spp. generally exhibited higher susceptibility to *A. marina* leaf extracts compared to Gram-negative bacteria. This pattern may be attributed to structural differences in bacterial cell walls, where the absence of an outer membrane in Gram-positive bacteria facilitates the penetration of bioactive compounds. In contrast, Gram-negative bacteria such as *Escherichia coli*, *Pseudomonas aeruginosa*, and *Vibrio* spp. often showed reduced sensitivity, which is consistent with the protective role of their lipopolysaccharide-rich outer membrane.

Extraction solvent emerged as a critical factor influencing antibacterial efficacy. Ethanolic and methanolic leaf extracts were most frequently reported and generally demonstrated stronger antibacterial activity than aqueous extracts. This observation suggests that semi-polar compounds, including flavonoids, tannins, and phenolic constituents, play a major role in the antibacterial effects of *A. marina* leaves. These compounds are known to exert antibacterial action through multiple mechanisms, such as disruption of cell membrane integrity, inhibition of essential enzymes, and interference with nucleic acid synthesis.

Despite the consistent demonstration of antibacterial activity, considerable variability was observed across studies in terms of assay methods, bacterial strains, and reported outcomes. Most investigations relied on preliminary screening techniques such as disk diffusion or agar well diffusion assays, while quantitative parameters such as minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were less frequently reported. This methodological heterogeneity limits direct comparison between studies and hampers the accurate assessment of antibacterial potency.

Furthermore, the majority of studies focused on crude extracts without comprehensive phytochemical characterization or isolation of active constituents. As a result, the specific compounds responsible for antibacterial activity remain largely unidentified, and mechanistic insights are still speculative. Few studies attempted to correlate phytochemical profiles with antibacterial outcomes, highlighting a significant gap in translating in vitro findings into pharmacologically relevant applications.

Taken together, the reviewed evidence confirms the antibacterial potential of *Avicennia marina* leaf extracts while simultaneously revealing important research gaps. Future studies should emphasize standardized extraction procedures, quantitative antibacterial assays, and systematic phytochemical analysis to better elucidate the antibacterial mechanisms and support the development of *A. marina*-derived antibacterial agents for pharmaceutical applications.

Table 1. Summary of Antibacterial Activity of *Avicennia marina* Leaf Extracts (2019–2025)

No	Author (Year)	Extraction Solvent	Tested Bacteria	Assay Method	Main Findings
1	Prabanita et al. (2025)	Ethanol	*Enterococcus faecalis*	Disk diffusion	Significant inhibition indicating oral antibacterial potential
2	Sravya et al. (2025)	Methanol	*Aeromonas hydrophila*, *Vibrio* spp.	Agar diffusion	Strong antibacterial activity against aquatic pathogens
3	Sibarani et al. (2024)	Ethanol	*Vibrio alginolyticus*, *Pseudomonas* spp.	Disk diffusion	Dose-dependent antibacterial effect
4	Sarkar et al. (2024)	Ethanol	MDR *Staphylococcus aureus*	MIC/MBC	Effective inhibition of multidrug-resistant strains
5	Thomas & Koshy (2024)	Methanol	*Escherichia coli*, *S. aureus*	Agar well diffusion	Higher activity against Gram-positive bacteria
6	Ramasubramanian et al. (2023)	Methanol	*Staphylococcus aureus*	Disk diffusion	Clear inhibition zone observed
7	Al-Malki et al. (2023)	Ethanol	*Klebsiella pneumoniae*	MIC	Moderate antibacterial activity
8	Roy et al. (2023)	Ethanol	*Pseudomonas aeruginosa*	Agar diffusion	Growth inhibition at higher concentrations
9	Prakash et al. (2022)	Methanol	*E. coli*, *Salmonella* spp.	Disk diffusion	Broad-spectrum antibacterial activity
10	Hidayati et al. (2022)	Ethanol	*Aeromonas hydrophila*	Agar diffusion	Significant inhibition relevant to aquaculture
11	Kannan et al. (2022)	Methanol	*Bacillus subtilis*	MIC	Low MIC value indicating strong activity
12	Rahman et al. (2021)	Ethanol	*Staphylococcus epidermidis*	Disk diffusion	Effective antibacterial response
13	Nugroho et al. (2021)	Ethanol	*Vibrio harveyi*	Agar diffusion	Potential as natural antibacterial agent
14	Ismail et al. (2021)	Methanol	*Escherichia coli*	MIC/MBC	Growth inhibition at moderate concentration
15	Karthikeyan et al. (2021)	Ethanol	*Proteus mirabilis*	Disk diffusion	Noticeable inhibition zone
16	Hasan et al. (2020)	Methanol	*Streptococcus mutans*	Agar diffusion	Inhibition of oral pathogens
17	Sari et al. (2020)	Ethanol	*Salmonella typhi*	Disk diffusion	Moderate antibacterial activity
18	Rahim et al. (2020)	Methanol	*Pseudomonas* spp.	MIC	Reduced bacterial growth
19	Devi et al. (2019)	Ethanol	*E. coli*, *S. aureus*	Agar well diffusion	Consistent antibacterial effect
20	Kumar et al. (2019)	Methanol	*Bacillus cereus*	Disk diffusion	Clear inhibition zone
21	Ali et al. (2019)	Ethanol	*Shigella* spp.	Agar diffusion	Antibacterial potential confirmed

4. Conclusion

Recent studies consistently demonstrate that *Avicennia marina* leaf extracts possess notable antibacterial potential against a broad range of pathogenic bacteria, including both Gram-positive and Gram-negative strains. Evidence from the last five years indicates that ethanolic and methanolic leaf extracts are the most frequently reported preparations, showing inhibitory effects particularly against *Staphylococcus aureus*, *Enterococcus faecalis*, *Escherichia coli*, *Vibrio* spp., and *Pseudomonas* spp. These findings support the relevance of *A. marina* leaves as a promising natural source of antibacterial agents derived from mangrove ecosystems.

Despite the encouraging antibacterial activity reported across multiple studies, this mini review highlights several critical research gaps. Variations in extraction solvents, assay methods, and bacterial strains limit direct comparison between studies, while most investigations remain at the preliminary screening stage without standardized MIC/MBC determination or detailed phytochemical–activity correlation. Moreover, mechanistic insights and translational evaluations relevant to pharmaceutical or clinical applications are still limited. Therefore, future research should focus on standardized antibacterial testing, identification of active compounds, and deeper exploration of mechanisms of action to fully elucidate the therapeutic potential of *Avicennia marina* leaf extracts.

5. Declarations

5.1 Author contributions

All authors contributed equally to the conception, literature collection, analysis, and writing of this mini-review article. All authors have read and approved the final version of the manuscript.

5.2 Ethics

Ethical approval was not required for this study because this article is a review based on previously published literature and does not involve human participants, animals, or clinical interventions.

5.3 Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

5.4 Funding Statement

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