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POTENTIAL OF PLANT EXTRACTS AS ANTIBACTERIAL AGAINST *Vibrio parahaemolyticus*: A LITERATURE REVIEW

Potensi Ekstrak Tanaman sebagai Antibakteri terhadap *Vibrio parahaemolyticus*: Sebuah Tinjauan Pustaka

Hosia Anisa[1], Muhamad Amin[3], Akhmad Taufiq Mukti[2*], Gunanti Mahasri[2]

[1]Magister of Fisheries Sains, Airlangga University, [2]Department Aquaculture, Airlangga University, [3]Department of Environmental and Life Sciences Programme, Universiti Brunei Darussalam

Mulyorejo Street, Surabaya 60115 East Java, Indonesia

[*]Corresponding author: akhmad-t-m@fpk.unair.ac.id

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ABSTRACT

Aquaculture faces serious threats, one of which is infectious disease caused by *Vibrio parahaemolyticus* bacteria. These bacteria have shown antibiotic resistance and cause significant economic losses. The need for safe and sustainable antibacterial alternatives is crucial given the negative impact of using synthetic antibiotics. This review explores the potential of *Shorea beccariana*, *Uncaria gambir*, and *Swietenia macrophylla* as natural antibacterial agents against *Vibrio parahaemolyticus*. A systematic descriptive study method was used to integrate primary literature. Results showed that *V. parahaemolyticus* is a pathogenic Gram-negative bacterium with a complex virulence mechanism. Various studies have confirmed the antibacterial activity of plant secondary metabolites, such as flavonoids, tannins, and terpenoids, against *Vibrio* spp. Although the specific effectiveness of these three plants against *V. parahaemolyticus* has not been widely studied, the bioactive compounds identified in their extracts show strong potential. These compounds work by damaging the integrity of bacterial cells and disrupting their metabolism, offering a promising natural solution for Vibriosis control.

Keywords: Antibacterial Agents, Plant Extracts, Pathogens, Resistance, *Vibrio parahaemolyticus*

ABSTRAK

Akuakultur menghadapi ancaman serius salah satunya serangan penyakit infeksius yang disebabkan oleh bakteri *Vibrio parahaemolyticus*. Bakteri ini telah menunjukkan resistensi antibiotik dan menimbulkan kerugian ekonomi signifikan. Kebutuhan akan alternatif antibakteri yang aman dan berkelanjutan menjadi krusial mengingat dampak negatif penggunaan antibiotik sintetis. Tinjauan ini mengeksplorasi potensi *Shorea beccariana*, *Uncaria gambir*, dan *Swietenia macrophylla* sebagai agen antibakteri alami terhadap *Vibrio parahaemolyticus*. Metode studi deskriptif sistematis digunakan untuk mengintegrasikan literatur primer. Hasil menunjukkan bahwa *V. parahaemolyticus* adalah bakteri Gram-negatif patogen dengan mekanisme virulensi kompleks. Berbagai studi telah mengonfirmasi aktivitas antibakteri metabolit sekunder tanaman, seperti flavonoid, tanin, dan terpenoid, terhadap *Vibrio* spp. Meskipun efektivitas spesifik ketiga tanaman ini terhadap *V. parahaemolyticus* belum banyak dikaji, kandungan senyawa bioaktif yang teridentifikasi dalam ekstraknya menunjukkan potensi kuat. Senyawa-senyawa ini bekerja dengan merusak integritas sel bakteri dan mengganggu metabolismenya, menawarkan solusi alami yang menjanjikan untuk pengendalian Vibriosis.

Kata Kunci: Agen Antibakteri, Ekstrak Tanaman, Patogen, Resistensi, *Vibrio parahaemolyticus*

INTRODUCTION

Aquaculture is one of the main sectors contributing to food security and the economy (Syamsudin, 2022). However, the growth of this industry is faced with various challenges, one of which is the attack of infectious diseases caused by *Vibrio parahaemolyticus*, a major pathogenic bacterium in marine and pond environments (Yuan *et al*., 2022). In aquaculture practice, *V. parahaemolyticus* infection is often associated with cases of Acute Hepatopancreatic Necrosis Disease (AHPND) in shrimp, which causes severe damage to the hepatopancreas and can lead to mass mortality (Evan *et al*., 2021). The problem is further complicated by the emergence of *V. parahaemolyticus* strains that are multi-resistant to conventional antibiotics, such as ampicillin and streptomycin (Liu *et al*., 2024).

The overuse of synthetic antibiotics triggers resistance and environmental pollution (Savitri *et al*., 2020). The use of synthetic antibiotics is currently restricted because it causes bacterial resistance and leaves residues that have the potential to cause serious health problems globally (Alamsjah *et al*., 2020). Therefore, safer and more sustainable alternatives are needed, one of which is through the use of natural ingredients as antibacterial agents. Natural ingredients have lower side effects than synthetic antibiotics, do not cause resistance, are easily obtained, and are relatively safe to use (Jumardin, 2015).

Plants contain various secondary metabolites such as flavonoids, tannins, alkaloids, and saponins that have been known to have antibacterial activity against various types of pathogenic bacteria, including Gram-negative bacteria such as *Vibrio* spp. (Liu *et al*., 2024). Several studies have shown that plant extracts can effectively inhibit the growth of *Vibrio* spp. in vitro, making them potential candidates as alternative antibacterial agents in the aquaculture sector (Gandour *et al*., 2021).

Local Indonesian plants such as *Shorea beccariana* (tengkawang bukit), *Uncaria gambir* (gambier), and *Swietenia* macrophylla (mahogany) have not been widely studied for their effectiveness against *V. parahaemolyticus*, although they are known to contain active compounds with antibacterial potential. This review aims to examine the potential of these three plants as natural antibiotics against *V. parahaemolyticus*. It is hoped that the results of this study can strengthen the scientific basis for the development of natural antibacterial agents as an alternative to *Vibrio*sis control in mariculture.

METHODS

This research was conducted at Airlangga University, located at Dr. Ir. H. Soekarno street, Mulyorejo, Surabaya, East Java. The research was conducted for two weeks, from July 1 to July 14, 2025. The tools used in this research activity include a laptop unit and supporting devices for searching library sources. The approach used involves a systematic and exploratory descriptive study method, by integrating several previous primary research results to obtain accurate and provable facts, which are taken from various literatures in national and international journals such as ResearchGate and Google Scholar. According to Sugiyono (2017), exploratory research is used to obtain basic knowledge that can be used as the basis for further theory development while descriptive research presents comprehensive and current data, but is not used to make broad generalizations or test hypotheses. The number of book sources used was one, the number of journals used as sources was 31, and the number of sources from proceedings was two. Data analysis was carried out descriptively, by describing the findings from various relevant literature and grouping information based on themes or main variables related to the research objectives. This approach allows researchers to describe the phenomenon under study in a systematic and structured manner. The keywords used to obtain information include: plant extracts, antibacterial agents, Vibrio parahaemolyticus, pathogens, resistance, and bioactive compounds. This comprehensive search approach made it easier to develop a theoretical framework that matched the main topics discussed in the literature.

RESULT

Table 1. Main virulence factors of *Vibrio parahaemolyticus* and their main functions

Virulence Factors	Main Functions	Source
TDH (Thermostable Direct Hemolysin)	Pore-forming hemolysin that causes cell lysis and intestinal mucosal injury, leading to diarrhea.	Zin *et al.* (2025)
TRH (TDH-related Hemolysin)	TDH-like hemolysin that also causes host cell damage	
Type III Secretion System (T3SS)	Two systems (T3SS1/T3SS2) for injection of effectors that cause cytotoxicity leading to host cell death and enterotoxicity (loss of intestinal fluid)	
Type VI Secretion System (T6SS)	Two systems (T6SS1/T6SS2) that play a role in cell adhesion, interbacterial competition, and gastroenteritis virulence	

Table 2. Study of plant extracts as *Vibrio* antibacterials

Plants	*Vibrio* type	Methods	Result	Source
Brazilian peppertree leaf	*V. parahaemolyticus*	Disc diffusion test	Zone of inhibition 26 mm; MIC 3.12 mg/mL	Hamad *et al.*, 2024
Cassia glauca leaf			Zone of inhibition 20.3 mm; MIC 3.12 mg/mL	
Mix *(Brazilian + Cassia*			Zone of inhibition 29.1 mm; MIC 3.12 mg/mL	
Cotylelobium lanceolatum Wood	*V. parahaemolyticus* ATCC17802	Microbial dilution, SEM	2×MBC dose → cell wall damage and membrane permeability (SEM); increased shrimp survival up to 92%	Amin *et al.*, 2025
Psidium guajava leaf	*V. cholerae*	MIC/MBC (broth microdilusi)	MIC 1.25 mg/mL, MBC 10 mg/mL	Chavan *et al.*, 2025
Punica granatum fruit peel			MIC 2.5 mg/mL, MBC 10 mg/mL	
Careya arborea stem bark			MIC 1.25 mg/mL, MBC 10 mg/mL	

DISSCUSION

Characteristics of *Vibrio parahaemolyticus*

Vibrio parahaemolyticus is a Gram-negative, comma-shaped, halophilic, and motile bacterium with polar flagellum (Bintari *et al*., 2016). In high-viscosity environments, it can produce lateral flagellum to move on solid surfaces as an important form of adaptation in biofilm colonization. This bacterium grows optimally at 3-5% salinity and 30-37°C, and its high tolerance to salinity up to 10% makes it a major pathogen in seawater and estuarine environments (Kumar *et al*., 2021).

Its habitat includes marine environments, estuaries, sediments, plankton, and aquatic organisms such as shrimp, fish, and mollusks (Kumar *et al*., 2021). In aquaculture environments (fish/shrimp ponds) rich in organic matter, *V. parahaemolyticus* can survive and proliferate. Research shows this bacterium is common in water samples and marine life such as oysters and pond fish (Nguyen *et al*., 2024). Changes in water temperature and salinity affect its distribution, generally this bacteria will increase when the water temperature rises (Nguyen *et al*., 2024).

V. parahaemolyticus is also able to form biofilms on various surfaces to survive in diverse environmental conditions (Pazhani *et al*., 2021). Biofilms protect bacterial cells from external stresses such as host immune prevention and the influence of antibiotics (Nguyen *et al*., 2024). In addition, *V. parahaemolyticus* can enter a VBNC (viable but non-culturable) state when the environment is unfavorable, i.e. cells remain viable but cannot be grown on conventional culture media (Nguyen *et al*., 2024). Overall, halophilic characteristics, flagellar motility, biofilm formation, and specialized genetic adaptations make *V. parahaemolyticus* capable of living and transmitting in aquatic ecosystems (Nguyen *et al*., 2024).

Pathogenicity of *Vibrio parahaemolyticus*

Research conducted by Zin *et al*. (2025) explained that the pathogenicity of *V. parahaemolyticus* is determined by a number of key virulence factors, including hemolysin toxins and type III and VI secretion systems. Thermostable hemolysin toxin (TDH) and hemolysin-related toxin (TRH) are the main hemolysins that form a pore in the host cell membrane. TDH and TRH induce cell lysis and inflammation of the intestinal mucosa, thus triggering gastroenteritis symptoms such as diarrhea and abdominal cramps. Bacterial strains that do not have the tdh/trh gene are generally not pathogenic to humans. Table 1 presents a summary of the main virulence factors of *V. parahaemolyticus* and their main functions.

Clinical Symptoms of *Vibrio parahaemolyticus* Infection in Shrimp and Farmed Fish

Vibrio parahaemolyticus infection can cause *Vibrio*sis in fish and AHPND in Litopenaeus vannamei shrimp. Shrimp infected with *V. parahaemolyticus* generally show lethargy and anorexia (Soto *et al*., 2015). The carapace of the shrimp often appears soft, and the chromatophores are enlarged making the body appear darker or striped (Hadiwinata *et al*., 2023). In the acute stage of AHPND, discoloration of the hepatopancreas to a watery pallor begins to appear. The shrimp may also swim abnormally (circling or slow) before finally weakening and dying (Kumar *et al*., 2021).

Farmed fish infected with *V. parahaemolyticus* generally have a decreased appetite, are lethargic, and swim abnormally (often surfacing on the water surface). Typical external signs include skin ulcers or necrosis (ulcers) on the body, fin damage or erosion, and subcutaneous hemorrhage (e.g. red mouth or red patches on the gills). Some cases report exophthalmia (bulging/reddish eyes) and darker body coloration (Nagasawa & Cruz, 2004).

Antibacterials and Mechanism of Action

Antibacterials are compounds that control or stop biochemical processes in organisms, especially bacteria (Perez *et al*., 2025). Antibacterial compounds that kill bacteria are called cidal agents, which include bactericidal, fungicidal, and viricidal (Yu *et al*., 2022). On the other hand, static agents only inhibit bacterial growth. Some commonly used antibiotics to treat bacterial infections include penicillin, chloramphenicol, tetracycline, and others (Sapara, 2016).

The mechanism of antibacterial action in general is by inhibiting bacterial cell wall synthesis, disrupting cell membrane permeability, disrupting cell metabolism, damaging nucleic acids, and inhibiting cell protein synthesis (Sadiah *et al*., 2022). Antibacterial compounds inhibit cell wall synthesis by targeting peptidoglycan precursor enzymes, so that bacterial cells become brittle and lysis occurs due to osmotic pressure (Kohanski *et al*., 2010).

Study of Plant Extracts as Antibacterial Agents against *Vibrio* spp.

Various studies reported the antibacterial activity of plant extracts against Vibrio pathogens. Table 2 presents a summary of these studies.

Brazilian peppertree and *Cassia glauca leaves* contain phenol compounds that are antibacterial in nature. Phenol compounds inhibit the formation of bacterial cell walls, cause protein coagulation, and trigger membrane damage. This process results in the release of essential bacterial components, damages cell structure, denatures proteins, and inhibits nucleic acid synthesis (Rizki and Ferdinan, 2020). Polyphenols such as quercetin and morin can inhibit ATPase and other metabolic enzymes, reduce ATP levels and intracellular pH, thus inhibiting bacterial growth (Liu *et al*., 2024).

Psidium guajava leaves contain flavonoid and tannin compounds that are antibacterial. Flavonoids, which are one of the main groups of phenol compounds, are effective against viruses, bacteria, and fungi by damaging cell walls, stopping bacterial movement, and disrupting energy metabolism and bacterial respiration systems (Bontjura *et al*., 2015). Compounds such as gallic acid, catechins, punicalagins, and flavonoids damage the integrity of the outer membrane and cytoplasm (Liu *et al*., 2024).

Many plant compounds effectively prevent *Vibrio* biofilm formation. For example, quersetin and morin phenolic extracts reduced biofilm biomass by 63-92% (Chavan *et al*., 2025). In general, polyphenols and flavonoids in plant extracts are bactericidal by targeting the cell wall/membrane, damaging cellular components, and disrupting bacterial virulence mechanisms (Liu *et al*., 2024).

Potential of *Shorea beccariana* (Tengkawang Bukit)

Research conducted by Musa *et al*. (2024) revealed that the stem of the Tengkawang Bukit plant (*Shorea beccariana*) contains active compounds in the form of asiatic acid, oleanolic acid, and lup-20(29)-en-3-one (also known as lupanone) which were successfully isolated from the wood. These three compounds are classified as terpenoids, a group of secondary metabolites commonly found in plants and known to have various biological activities. This report is the first to document the presence of these three compounds in *S. beccariana*.

Terpenoids, also known as isoprenoids, are a very large and complex group of natural compounds, consisting of more than 40,000 types of compounds, including monoterpenes, sesquiterpenes, and diterpenes. Terpenoids are composed of the basic structural unit, isoprene (C_5H_8) and their biosynthesis takes place through two major pathways: the mevalonate pathway (MVA) that occurs in the cytosol and the methyl erythritol phosphate (MEP) pathway that takes place in the plastids (Huang *et al*., 2022). These pathways produce important precursors such as isopentenyl pyrophosphate (IPP) and dimethylal pyrophosphate (DMAPP), which are key building blocks in terpenoid biosynthesis. According to Huang *et al*. (2022), terpenoids exhibit high lipophilic properties, making them effective bioactive agents, especially in antimicrobial activity.

Shorea beccariana or tengkawang bukit is an endemic plant of Kalimantan that belongs to the Dipterocarpaceae family. Although there is no direct report on its antibacterial activity against *Vibrio parahaemolyticus*, the *Shorea* genus in general has been known to have active compounds such as tannins, flavonoids, and triterpenoids. Previous studies on other *Shorea* species showed antibacterial potential against Gram-negative and Gram-positive bacteria. Therefore, the exploration of S. beccariana is very important as it could be a new candidate in the development of natural antibacterials based on local Indonesian plants.

Potential of *Uncaria gambir* (Gambir)

Gambir contains active compounds that can be an alternative natural treatment in fish farming. Phytochemical analysis revealed that gambir leaves contain secondary metabolite compounds such as alkaloids, flavonoids, steroids, terpenoids, saponins and phenolics (Isromarina *et al*., 2019). These various active compounds have an effective mechanism of action in inhibiting the growth of microorganisms. Alkaloid, polyphenol, saponin, and flavonoid compounds can interfere with the formation of bacterial cell walls by damaging the peptidoglycan structure (Dwiyanti *et al*., 2015). The damage changes membrane permeability, inhibits enzymes in the cell, and causes excessive water entry, which ultimately results in bacterial death (Ainurrochmah *et al*., 2013).

Flavonoids, which are one of the main groups of phenol compounds, are effective against viruses, bacteria, and fungi by damaging cell walls, stopping bacterial movement, and disrupting energy metabolism and bacterial respiration systems (Bontjura *et al*., 2015). Alkaloids also inhibit bacteria by damaging bacterial cell walls that interact with DNA, inhibiting protein synthesis, and preventing the formation of strong cell walls, thus causing cell lysis or destruction (Marbun and Situmorang, 2020). Steroid compounds act by penetrating the lipophilic layer of the membrane, causing a decrease in the integrity of the membrane structure and disrupting cell morphology, which leads to bacterial cell rupture (Kumalasari *et al*., 2020). Meanwhile, phenol compounds inhibit bacterial cell wall formation, cause protein coagulation, and trigger membrane damage (Cahyaningtyas *et al*., 2019). This process results in the release of essential bacterial components, damages cell structure, denatures proteins, and inhibits nucleic acid synthesis (Ngazizah *et al*., 2017). With these varied mechanisms, the active compounds in the gambir plant are a potential source for the development of natural antibacterial products for disease control in fish.

This activity provides a strong indication that gambir extract also has potential against *V. parahaemolyticus*, which is also an enteric Gram-negative bacterium.

Potential of *Swietenia macrophylla* (Mahoni)

Mahogany is widely known among the public as a medicinal plant used to treat wounds, itching, and skin diseases such as eczema (Rasyida *et al*., 2023). Various active compounds are contained in this plant, including saponins, flavonoids, terpenoids, and alkaloids (Triwahyuono and Hidajati, 2020). These compounds have antibacterial activity that can inhibit the growth and kill certain bacteria, such as Salmonella typhi. Research by Nisyak *et al*. (2018) showed that concentrated methanol extract from mahogany bark contains various secondary metabolites, including alkaloids, tannins, saponins, phenolic compounds, hydroquinone, and flavonoids. Mahogany seeds also contain alkaloid, saponin, and flavonoid phytochemicals (Mursiti, 2016).

The utilization of mahogany root parts, especially as antibacterials, has not been widely studied. Based on research conducted by Mohammed *et al*. (2015) S. Macrophylla root extract contains n-Hexadecanoic acid, Octadecanoic acid, Dimethyl Phthalate (DEP), and cis-Vaccenic acid. The compound is a fatty acid that has antibacterial activity. n Hexadecanoic Acid (Palmitic Acid) is a compound that can act as a protonophore, affecting proton gradients and membrane potential in bacteria. This leads to membrane depolarization and a decrease in intracellular pH, disrupting energy metabolism and bacterial protein synthesis (Cartron *et al*., 2014). Octadecanoic Acid (Stearic Acid), as a saturated fatty acid can disrupt the integrity of bacterial cell membranes, increase membrane permeability, and interfere with enzyme function and ion transport, which contributes to bacterial cell death (Idris, 2022). Cis-vaccenic acid, as an unsaturated fatty acid, can interfere with bacterial respiration and growth by affecting cell membrane function and enzyme activity involved in bacterial energy metabolism. DEP can increase the fluidity of bacterial cell membranes, leading to changes in membrane structure and increasing its permeability. This affects membrane stability and can cause damage to the bacterial cell structure (Chen *et al*., 2022).

The active compounds in mahogany can disrupt the membrane structure and metabolism of bacterial cells, including possibly against *V. parahaemolyticus*. These three plants show great potential as natural antibacterial sources that can be used in pathogen control in aquaculture. The paucity of data regarding specific effectiveness against *V. parahaemolyticus* only reinforces the urgency to conduct exploratory studies investigating the in vitro potential of these plants. Thus, the current study is not only scientifically important but also beneficial for the development of sustainable aquaculture systems.

Prospects for Using Plant Extracts

The use of plant extracts as natural antibiotics in aquaculture has promising prospects because plants contain bioactive compounds such as alkaloids, flavonoids, tannins, saponins and terpenoids that are known to have antimicrobial activity against various pathogens. In the context of bacterial diseases such as *Vibrio*sis caused by *Vibrio parahaemolyticus*, this natural approach is seen as an environmentally friendly alternative to synthetic antibiotics, which often lead to resistance and environmental pollution.

The application of plant extracts as feed additives, immuno-stimulants, or soaking agents in aquaculture systems can increase host resistance to bacterial infections. This approach is in line with the principles of sustainable aquaculture as it minimizes the use of synthetic antibiotics, reduces the risk of antibiotic resistance, and does not pollute the environment.

However, the successful application of plant extracts is highly dependent on the identification of active compounds, extraction methods, effective concentrations, and proper application methods. In addition, toxicity tests and in vivo efficacy tests are also important to ensure the safety of their use on a production scale.

CONCLUSION

Vibrio parahaemolyticus infection is a major challenge in aquaculture, compounded by antibiotic resistance and the environmental impact of synthetic agents. This study concludes that local Indonesian plants such as *Shorea beccariana*, *Uncaria gambir*, and *Swietenia* macrophylla have significant potential as sources of natural antibacterial agents. Their bioactive secondary metabolites may provide a sustainable alternative to control *Vibrio*sis, reduce dependence on antibiotics, and minimize ecological impacts. Further studies, both in vitro and in vivo, are urgently needed to validate the specific efficacy and safety of their use in cultivation practices.

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