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EXPLORATION OF THE BIOACTIVE POTENTIAL OF RHIZOPHORACEAE MANGROVE PLANTS: IMPLICATIONS IN THE FIELD OF FISHERIES

Eksplorasi Potensi Bioaktif Tumbuhan Mangrove Rhizophoraceae: Implikasinya di Bidang Perikanan

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ABSTRACT

Mangrove forests, as coastal ecosystems rich in biodiversity, play an important role in ecology and the fisheries sector. Mangroves not only function as coastal protectors and habitats for aquatic organisms but also produce bioactive compounds that have potential as antibacterial, antioxidant, antifungal, and antiviral agents. Research on mangrove plants from the Rhizophoraceae family, such as Bruguiera, Kandelia, Ceriops, and Rhizophora, has shown that compounds like flavonoids, tannins, alkaloids, and saponins have significant biological activities. Flavonoids act as antimicrobials, while tannins inhibit bacterial growth by precipitating proteins. Alkaloids disrupt bacterial cell walls and have potential in combating cancer cells. Studies also reveal significant antioxidant activity, with some mangrove extracts showing great potential in combating free radicals. Moreover, these compounds offer potential in reducing reliance on synthetic antibiotics for the treatment of cultured fish diseases and provide opportunities for the development of natural-based health products. This review aims to integrate recent findings on the bioactivity of mangrove plants and propose innovative applications of bioactive compounds in fisheries and conservation with a focus on ecosystem sustainability and optimal use of natural resources.

Keywords: *Bioactive compounds, Bruguiera, Ceriops, Kandelia, Rhizophora*.

ABSTRAK

Hutan mangrove sebagai ekosistem pesisir yang kaya akan keanekaragaman hayati memiliki peran penting dalam ekologi dan sektor perikanan. Mangrove tidak hanya berfungsi sebagai pelindung pantai dan habitat biota perairan, tetapi juga menghasilkan senyawa bioaktif yang memiliki potensi sebagai agen antibakteri, antioksidan, antifungi, dan antivirus. Penelitian terhadap tanaman mangrove dari famili Rhizophoraceae, seperti Bruguiera, Kandelia, Ceriops, dan Rhizophora, menunjukkan bahwa senyawa flavonoid, tanin, alkaloid, dan saponin

memiliki aktivitas biologis yang signifikan. Flavonoid berfungsi sebagai antimikroba, sedangkan tanin menghambat pertumbuhan bakteri dengan mengendapkan protein. Alkaloid mengganggu dinding sel bakteri. Beberapa penelitian yang telah dilakukan mengungkapkan aktivitas antioksidan yang signifikan, dengan beberapa ekstrak mangrove menunjukkan potensi besar dalam melawan radikal bebas. Selain itu, senyawa-senyawa ini berpotensi mengurangi ketergantungan pada antibiotik sintetis dalam pengobatan penyakit ikan budidaya, serta memberikan peluang pengembangan produk kesehatan berbasis alam. Ulasan ini bertujuan untuk mengintegrasikan temuan terkini mengenai bioaktivitas tanaman mangrove, serta menyarankan aplikasi inovatif senyawa bioaktif dalam perikanan dan konservasi, dengan fokus pada keberlanjutan ekosistem dan pemanfaatan sumber daya alam secara optimal.

Kata Kunci: *Bruguiera*, *Ceriops*, *Mangrove*, *Rhizophora*, *Senyawa Bioaktif*.

INTRODUCTION

Mangrove forests are a unique and distinctive form of forest ecosystem, found in tidal areas in coastal areas and are a very potential natural resource (Novianty *et al.*, 2011). Mangrove forests have ecological functions including protecting the coastline, preventing seawater intrusion, and as a habitat for various aquatic biota (Qadrini, 2022). Mangroves act as a fence between the coast and the estuary ecosystem. Plant species in this environment tend to tolerate high levels of salt concentration, thus providing protection and food for many related plants and animals in their ecosystem. In order to survive, mangrove plants adapt to the environment by forming roots that come out of the soil and excrete excess salt from their bodies (Purnobasuki, 2024).

Mangrove plants have a multifunctional role in coastal ecosystems and the fisheries sector. In addition to functioning as habitat protectors and ecosystem balancers, mangroves also produce bioactive compounds that have high potential to be developed as antibacterial agents, antioxidants, and others (Dewi *et al.*, 2023). This potential is very relevant for the development of bioproducts in fisheries conservation and cultivation. In addition to its ecological function, mangroves also have significant economic value. These mangroves contain secondary metabolite compounds flavonoids and saponins (Mulyani *et al.*, 2013). Secondary metabolite compounds from mangrove plants are compounds that are easily decomposed in water, have the potential to kill and inhibit bacterial growth. Coastal communities utilize mangroves as a source of food, traditional medicines, and a calmer fishing area, thus supporting the livelihoods of small fishermen.

Indonesia as a country with high mangrove biodiversity. Based on Wardiman *et al.*, (2024) have identified various bioactive compounds contained in mangroves. This study shows that parts of the mangrove such as leaves, bark, and fruit contain compounds such as flavonoids, tannins, and alkaloids that have significant biological activity. Flavonoids act as compounds that can cause the release of essential metabolites, inactivate enzymes, and block the entry of active substances into cells, which ultimately leads to bacterial death (Widjajanti *et al.*, 2015). Tannins act as antimicrobials by binding and precipitating proteins, causing dehydration in mucosal tissue and forming a strong protective layer. In addition, tannins can also cause shrinkage in bacterial cells (Ismunanto *et al.*, 2025). Alkaloids act as inhibitors of the peptidoglycan formation process in bacterial cell walls, which ultimately causes cell damage and death. In addition, alkaloids also act as DNA intercalators and interfere with the activity of topoisomerase enzymes in bacteria (Hasanah & Gultom, 2020).

Pambudi *et al.*, (2022), revealed the potential pharmacological activities of various mangrove bioactive compounds. Compounds such as flavonoids, tannins, and alkaloids found in species such as Laguncularia racemosa have shown antibacterial and antioxidant properties

(Cruz *et al.*, 2019). Laguncularia racemosa leaf extract showed antioxidant activity with a significant IC50 value in quenching free radicals (Zakyani *et al.*, 2023).

The use of bioactive compounds from mangroves in bioproduct development offers great opportunities for the fisheries and health sectors. Apart from mangroves, bioactivity can also be obtained from microbes. Microorganisms such as bacteria, fungi, and microalgae have great potential in producing beneficial bioactive compounds (Mulyani *et al.*, 2023). Natural antibacterial compounds from mangroves have the potential to be used as an alternative treatment for farmed fish diseases, thereby reducing dependence on synthetic antibiotics and minimizing the risk of resistance. In addition, the antioxidant properties of these compounds provide opportunities for the development of health supplements and medicines based on local natural resources. The purpose of this review is to integrate recent research findings on the bioactivity of the genera *Bruguiera*, *Kandelia*, *Ceriops*, and *Rhizophora*. These findings are expected to support innovative applications of mangrove bioactive compounds in the fisheries, health, and conservation sectors, thereby supporting ecosystem sustainability and optimal utilization of natural resources.

RESEARCH METHODS

This study uses a systematic literature search approach through leading academic databases, such as Google Scholar and ScienceDirect (Nurhidayah, 2024). The search process is carried out by entering specific keywords that include "bioactive compounds," "mangrove Rhizophoraceae," and "antibacterial, antioxidant" The search is focused on articles relevant to the topic of mangrove plant bioactivity, especially from the genera *Bruguiera*, *Kandelia*, *Ceriops*, and *Rhizophora*.

The articles obtained are evaluated based on their quality, including the journal impact factor, the research methods used, and their relevance to the study objectives. A total of 24 articles are accredited journals, 2 books, 1 proceeding, 1 dissertation, and other articles. Only articles with valid data and significant contributions to the development of bioproducts in the fisheries sector are considered for further analysis. This step ensures that this review is based on credible data sources and supports science-based innovation.

RESULT

Mangroves are unique ecosystems rich in biodiversity, including various types of plants with significant biological capabilities. One prominent mangrove plant family is Rhizophoraceae, which is known to have medical potential due to its bioactive compound content (Angio *et al.*, 2022). Various studies have revealed that genera such as Bruguiera, Kandelia, Ceriops, and Rhizophora in this family contain chemical compounds with promising antibacterial, antioxidant, antifungal and antiviral activities.

In addition to playing a role in providing bioactive compounds, mangrove plants from the Rhizophoraceae family also make a major contribution to coastal ecosystems. They not only support local biodiversity but also act as natural protectors that maintain the stability of the coastline and protect the ecosystem from abrasion. With its unique characteristics, this plant continues to be a relevant research object for applications in the fields of health, environment, and fisheries cultivation and can be seen in Table 1.

Table 1. Bioactive Compounds and Biological Activities in the Mangrove Genus

Genus	Bioactive Compounds	Research result	References
Bruguiera	Flavonoid, Tanin, Saponin	Bruguiera gymnorhiza extract showed antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. *Bruguiera sexangula* showed antibacterial potential against *Bacillus subtilis* and *Escherichia coli*	Zulkifli *et al.*, (2022)
	Asam Fenolat, Triterpenoid	*Bruguiera gymnorhiza* leaf extract has a high antioxidant capacity, IC50 50 µg/mL. Flavonoid compounds in *Bruguiera sexangula* showed antioxidant activity through DPPH test	Ismunanto *et al.*, (2025)
Kandelia	Flavonoid, Alkaloid, Triterpenoid	Kandelia candel extract is effective against *Pseudomonas aeruginosa* and *Vibrio cholerae*. In addition, this extract also showed antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*	Pambudi *et al.*, 2022; Kusumawati *et al.*, 2014
	Flavonoid, Triterpenoid	Kandelia candel has high antioxidant activity through DPPH and ABTS tests. Phenolic compounds in Kandelia candel showed free radical inhibition activity	Ishikawa *et al.*, (2019); Pambudi & Haryoto *et al.*, (2022)
Ceriops	Flavonoid, Tannin, Saponin	Ceriops tagal showed antibacterial activity against *Vibrio cholerae* and *E. coli*. This compound shows antibacterial effects against *Staphylococcus aureus* and *Pseudomonas aeruginosa*	Sundari *et al.*, (2021);

	Asam Fenolat, Saponin	Ceriops tagal extract shows antioxidant activity with IC50 40 µg/mL. Flavonoid compounds in Ceriops tagal have significant antioxidant potential	Masdar (2022)
Rhizophora	Asam Fenolat, Tanin	Rhizophora mucronata has significant antioxidant activity through DPPH test	Ridlo *et al.*, (2017); Rina *et al.*, (2024)

1. Antibacterial Activity

Mangrove plants from the Rhizophoraceae family have been widely studied for their ability to produce bioactive compounds with antibacterial potential. Various methods have been used to evaluate the antimicrobial activity of these plants, including disc diffusion tests and minimum inhibitory concentration measurements. These methods help identify the effectiveness of mangrove plant extracts in inhibiting the growth of harmful pathogenic microorganisms.

The results showed that certain genera in the Rhizophoraceae family have significant antibacterial abilities. Ethanol extract from *Bruguiera gymnorhiza*, was shown to be effective against *Staphylococcus aureus* and *Escherichia coli* bacteria (Zulkifli *et al.*, 2022). Meanwhile, methanol extract from *Kandelia candel* showed strong activity against *Pseudomonas aeruginosa* and *Vibrio cholerae* (Kurniawati *et al.*, 2021). These findings indicate that bioactive compounds from both genera have the potential to be developed as natural antimicrobial agents.

Based on Zulkifli *et al.*, (2022) and Kurniawati *et al.*, (2021), provides strong evidence of the potential of mangrove plants in the medical and fisheries fields. With proven biological activities, further exploration of Rhizophoraceae mangrove plants can open up new opportunities for applications in the fields of health and disease management in aquatic environments.

2. Antioxidant Activity

Various methods have been used to test the antioxidant activity of mangrove plants, such as DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)), and FRAP (ferric reducing antioxidant power). This method is able to measure the antioxidant capacity of bioactive compounds in inhibiting free radicals that have the potential to damage cells. Evaluation using this method provides important insights into the potential of mangrove plants as a source of natural antioxidants.

The results showed that *Ceriops tagal* leaf extract had significant antioxidant activity with an IC50 value of 40 µg/mL (Nguyen *et al.*, 2020). A low IC50 value indicates high antioxidant capacity, making Ceriops tagal one of the main candidates in the development of antioxidant-based products. This activity indicates the presence of bioactive compounds such as flavonoids and tannins which play an important role in counteracting free radicals.

In addition, flavonoid compounds isolated from *Rhizophora apiculata* showed high free radical inhibition capacity (Setyawan *et al.*, 2019). This further strengthens the evidence that the genus *Rhizophora* has great potential as a source of natural antioxidant compounds. The

findings from these studies highlight the importance of Rhizophoraceae mangrove plants in the development of health products and environmental protection from oxidative damage.

3. Antifungal Activity

Kumar *et al.*, (2011) reported the antifungal activity of seven mangrove species, namely *Avicennia marina, Excoecaria agallocha, Lumnitzera racemosa, Derris trifoliata, Bruguiera gymnorrhiza, Ceriops decandra, and Acanthus ilicifolius against several fungal pathogens such as Aspergillus niger, Rhizopus oryzae, Candida albicans*, and *Saccharomyces cerevisiae*. Chloroform and methanol extracts of *Excoecaria agallocha* showed significant activity against the tested fungi, while chloroform extract of *Avicennia marina* was effective against *C. albicans* and *A. niger*. In addition, chloroform extract of *Derris trifoliata* was found to be active against *A. niger* and *S. cerevisiae*, while Acanthus ilicifolius was able to reduce the severity of symptoms of *Aspergillus* infection in mice. The active components in these chloroform extracts are known to be absorbed through the digestive tract and produce antifungal effects.

Ethanol extracts of *Rhizophora mucronata* and *Avicennia marina* have also been shown to have significant antifungal activity against various types of fungi, including *Penicillium purpurogenum, Penicillium chrysogenum, Penicillium notatum, Aspergillus niger, Alternaria alternata*, and *Penicillium italicum* (Rategar & Gozari, 2016). The results of this study indicate that mangrove plant extracts have the potential as a natural source of antifungal compounds. Identification of the active components of this mangrove extract provides a great opportunity for the development of effective antifungal therapeutic agents. The antifungal activity of Rhizophora apiculata was tested using test pathogens (*Candida albicans, Fusarium* sp., *Microsporum gypseum, Phanerochaete chrysosporium*, and *Aspergillus niger*) (Ramya *et al.*, 2023).

4. Antivirus Activity

Mangrove plants and their companions have significant antiviral potential against various viruses that attack humans, animals, and plants. Mangrove plant extracts, especially from the *Rhizophoraceae* family, have the potential as an antiviral that can be used in the treatment of fish diseases. Several bioactive compounds contained in plants such as flavonoids, tannins, and saponins have the ability to inhibit virus replication. Previous studies have shown that mangrove plant extracts can fight various pathogenic viruses, including those that attack aquatic organisms. Several viruses that cause disease in fish are *Infectious Hematopoietic Necrosis Virus* (IHNV) and *Viral Nervous Necrosis Virus* (VNNV), which have the potential to be overcome by antiviral compounds from mangrove plants (Caruso *et al.*, 2013).

The antiviral ability of mangrove plants is related to the mechanism of inhibiting virus adsorption to host cells and inhibiting virus replication. Several species of *Rhizophora apiculata, Ceriops decandra*, and *Avicennia marina* have been reported to have significant antiviral properties (Ramalingam & Rajaram 2018). Further research is needed to identify specific active compounds and their mechanisms of action on viruses that attack fish, as well as to develop practical applications in the fisheries industry.

5. Development Potential

Bioactive compounds contained in the genera of mangrove plants from the *Rhizophoraceae* family have various significant potentials in the health sector. One of the main compounds that is often found is flavonoids, which are known to have excellent antioxidant potential. Flavonoids can play a role in the body's protective mechanisms against various diseases, especially those related to oxidative stress (Mustofa & Namdes, 2024).

In addition to flavonoids, alkaloid compounds also have an important role as antibacterial agents. Alkaloids are found in several mangrove species and have been shown to be effective in inhibiting the growth of pathogenic bacteria. Saponin compounds, which are also often found in mangrove plants, are known to have antibacterial and anti-inflammatory potential, and play a role in reducing inflammation that occurs in the body. Other compounds that are no less important are tannins and phenolic acids. Tannins have strong antibacterial properties and can be used in wound treatment to accelerate healing. Meanwhile, phenolic acids have strong antioxidant and anti-inflammatory activities, making them potential bioactive compounds in overcoming degenerative and inflammatory diseases (Suryani *et al.*, 2023).

The mechanism of bioactive compounds found in mangrove plants works through various ways to support health. Compounds such as flavonoids, alkaloids, saponins, tannins, and phenolic acids have antibacterial properties that can inhibit the growth of pathogens, both bacteria and fungi. In addition, antioxidant compounds such as flavonoids and phenolic acids protect cells from oxidative damage that can trigger various degenerative diseases. Future research directions should focus on a deeper understanding of the mechanisms of bioactive compounds in mangrove plants, as well as their potential applications. Further research is needed to explore the efficacy and safety of these compounds in various disease models, as well as to identify new compounds that may have broader therapeutic benefits. In addition, the development of more efficient and environmentally friendly extraction methods, as well as clinical trials to test the effectiveness of bioactive compounds from mangrove plants, are important steps in realizing the potential of natural resource-based medicine.

Mangrove forest management needs to be considered from various aspects. Aspects that need to be considered are ecological, social, and economic aspects so that the sustainability of the ecosystem is maintained. From an ecological perspective, rehabilitation and restoration efforts of damaged areas as well as protection and preservation of mangroves are very important to maintain the existence, biodiversity, function, productivity, and carrying capacity of the ecosystem. Socially, the perception, understanding, attitude, and behavior of the community towards the existence, status, value, and function of mangroves need to be considered. In addition, empowering local communities in mangrove management is key so that they can contribute to its preservation. From an economic perspective, the utilization of mangrove resources can include various products of economic value, such as wood and non-timber forest products, tourism, and other environmental services (Kusmana, 2011).

These three aspects must be balanced so that mangrove forest management can be carried out sustainably and provide benefits to the ecosystem and the community. In addition, mangroves play an important role in creating a healthy coastal ecosystem by maintaining the balance of biodiversity, absorbing carbon, and protecting the coast from abrasion, while supporting the economy through the sustainable fisheries sector, ecotourism, and the development of high-value bioproducts (Wulandari *et al.*, 2024).

CONCLUSION

Mangrove forests, with their abundant biodiversity, have enormous potential as a source of bioactive compounds that can be utilized in various sectors, including fisheries, health, and conservation. Compounds such as flavonoids, tannins, alkaloids, and saponins found in mangrove plants from the Rhizophoraceae family show significant biological activities, such as antimicrobial, antioxidant, and disease control in farmed fish. Further research is needed to explore the full potential of these compounds, in order to reduce dependence on synthetic antibiotics and for the development of nature-based health products. The utilization of mangrove bioactive compounds can have a positive impact on the sustainability of coastal ecosystems and the optimization of natural resources.

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