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The Potential of Herbal Plants in the Prevention and Treatment of Fish Diseases: A Review

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ABSTRACT

The use of herbal plants in aquaculture has emerged as a sustainable and eco-friendly approach to improving fish health, enhancing immunity, and boosting growth performance. Various herbs are rich in bioactive compounds that stimulate non-specific defense mechanisms, enhance phagocytic activity, and reduce oxidative stress through their antioxidant properties. These immunostimulatory effects improve disease resistance and overall well-being in fish. Additionally, herbal supplementation has demonstrated significant growth-promoting effects by improving feed conversion efficiency and productivity in aquaculture systems. This review summarizes the roles of key herbal plants in aquaculture, highlighting their potential as natural alternatives to synthetic chemicals and antibiotics. The findings underscore the importance of integrating herbal remedies into aquaculture practices to enhance fish health and sustainability.

INTRODUCTION

Aquaculture plays a pivotal role in meeting the global demand for fish and seafood, contributing significantly to food security and economic development (Pradeepkiran, 2019). However, the sector faces persistent challenges, with fish diseases being one of the most critical. These diseases not only reduce productivity but also lead to substantial economic losses for farmers (Stentiford *et al.,* 2012). Effective management of fish health is essential to ensure sustainable aquaculture practices and prevent the spread of infectious agents.

Conventional treatments for fish diseases, such as antibiotics and chemical drugs, have been widely used but present several limitations (Valladão *et al*., 2015). Over-reliance on antibiotics has led to the emergence of antimicrobial resistance (AMR), posing a threat to both aquaculture and public health. Chemical treatments, on the other hand, often leave harmful residues in fish and the aquatic environment, raising concerns about food safety and ecological impacts. These issues underscore the need for alternative approaches to disease management in aquaculture (Mishra *et al*., 2024).

In recent years, herbal plants have gained attention as a promising solution for fish disease prevention and treatment (Andriani, 2023). These plants are known to enhance non-specific immune responses, promote growth, and improve resistance to diseases in aquatic species, making them particularly valuable in sustainable aquaculture practices. Rich in

bioactive compounds such as alkaloids, flavonoids, terpenoids, and essential oils, these plants exhibit diverse pharmacological properties, including antimicrobial, anti-inflammatory, and immunostimulatory effects. Unlike synthetic drugs, herbal remedies are biodegradable, eco-friendly, and less likely to cause resistance, making them suitable for sustainable aquaculture practices (Gadallah *et al*., 2024).

Herbal plants such as turmeric (*Curcuma longa*), garlic (*Allium sativum*), and ginger (*Zingiber officinale*) have been studied for their antimicrobial, anti-inflammatory, and antioxidant properties (Ajanaku *et al*., 2022). Research indicates that including these herbs in fish diets can enhance immune responses, growth rates, disease resistance, feed conversion ratios, and overall health, leading to improved production efficiency and reduced mortality rates (Ahmadifar *et al*., 2021).

This review explores the potential of herbal plants in addressing fish diseases. It focuses on their bioactive compounds, mechanisms of action, and applications in aquaculture. Through this compilation, we aim to provide a comprehensive overview of the current research and to support further exploration of herbal plants as a viable alternative in aquaculture nutrition and disease management.

METHODS

This review was conducted by systematically analyzing and synthesizing relevant literature from various scientific databases, including Scopus, PubMed, and Google Scholar. The selection criteria focused on peer-reviewed articles, review papers, and conference proceedings published within the last two decades, addressing the use of herbal plants in the prevention and treatment of fish diseases. Keywords such as “herbal plants,” “fish diseases,” “aquaculture,” “natural remedies,” and “disease prevention” were used to identify relevant studies. Articles were evaluated for their scientific rigor, relevance to aquaculture, and the documented efficacy of herbal plant applications. The gathered information was categorized based on the type of herbal plants, their active compounds, mechanisms of action, and potential applications in aquaculture. This review aims to provide a comprehensive understanding of the role of herbal plants in fish health management and their prospects for sustainable aquaculture practices.

RESULTS AND DISCUSSION

Herbal Plants and Its Use in Aquaculture

Herbal plants are those that contain bioactive compounds known for their therapeutic properties. In the context of aquaculture, these plants offer valuable alternatives for managing fish health and diseases. Herbal plants can be classified based on their bioactive components, which can include alkaloids, flavonoids, terpenoids, phenolics, and essential oils. Each of these compounds possesses distinct biological activities that make them relevant to aquaculture. For example, alkaloids have shown strong antimicrobial properties, while flavonoids are known for their antioxidant and anti-inflammatory effects, which are beneficial for fish immunity (Citarasu, 2012; Mariappan *et al*., 2023).

Herbal plants in aquaculture are generally categorized according to their active compounds and their targeted application. Commonly used plant species include garlic (*Allium sativum*), turmeric (*Curcuma longa*), and neem (*Azadirachta indica*), all of which have been studied for their bioactive constituents and their potential use in fish health management.

These plants can be used as feed additives, water treatments, or direct herbal extracts, depending on the specific disease or health concern being addressed (Raman, 2017).

Mechanisms of Action

Herbal plants exert their therapeutic effects through various mechanisms that support fish health and disease resistance. One of the primary mechanisms is the immunostimulatory properties of many plant compounds. These compounds can enhance the immune response of fish by promoting the activity of immune cells like macrophages and lymphocytes, leading to increased resistance against infections. For instance, compounds in garlic and turmeric have been found to stimulate the production of cytokines, molecules that play key roles in immune defense (Awad & Awaad, 2017).

In addition to boosting immunity, herbal plants also exhibit antimicrobial, antifungal, and antiviral activities. Bioactive compounds such as alkaloids and terpenoids can directly target pathogenic microorganisms, inhibiting their growth or preventing infection. Studies have demonstrated that plant extracts can be effective against a wide range of pathogens, including bacteria like *Aeromonas* and *Vibrio*, fungi like *Saprolegnia*, and viruses that affect fish (Lindholm-Lehto & Pylkkö, 2024). These findings highlight the potential of herbal plants as eco-friendly alternatives to conventional synthetic drugs.

Furthermore, herbal plants play a significant role in stress mitigation, which is crucial for maintaining overall fish health. Stress is a major factor that weakens the immune system and makes fish more susceptible to diseases (Schreck & Tort, 2016). Many herbal plants contain antioxidants and anti-inflammatory compounds that help reduce oxidative stress and inflammatory responses, improving the overall well-being and resilience of fish. For example, plants like ginger (*Zingiber officinale*) have been shown to reduce stress-induced cortisol levels, enhancing the fish's ability to fight off diseases (Fazelan *et al*., 2020).

Herbs such as *Curcuma longa* (turmeric) *and Allium sativum* (garlic) are rich in bioactive compounds that enhance the non-specific defense mechanisms of fish, boosting activities such as phagocytosis, respiratory burst, and increasing antioxidant enzyme activity (Singh *et al*., 2022). Additionally, herbal plants like greater celandine and *St. John's Wort* have been shown to stimulate granulation tissue development and promote wound healing, offering a natural approach for treating bacterial infections in fish plants like turmeric, green tea, ginger, and garlic have immunostimulatory effects, strengthening the immune system of fish and improving their resistance to diseases (Draelos & Thaman, 2005). These herbs also possess antioxidant properties that help scavenge free radicals, reducing oxidative stress and thereby enhancing the overall health and longevity of the fish. supplementation has been found to promote growth and improve feed conversion efficiency, ultimately leading to increased productivity in aquaculture. That the potential of incorporating herbal plants into aquaculture practices to improve fish health and productivity sustainably (Syahidah *et al*., 2015).

Examples of Promising Herbal Plants

1. Turmeric

Turmeric (*Curcuma longa*) is a rhizome-producing plant that grows abundantly in Indonesia. Its chemical composition includes 1–3% volatile oils such as turmerone and zingiberene, along with 8% protein, 30% carbohydrates, 3% fat, and various micronutrients like vitamin C and mineral salts (iron, phosphorus, and magnesium) (Asai & Miyazawa, 2001). Additionally, turmeric contains 9.61% curcumin compounds. Curcumin enhances food digestibility by stimulating bile secretion from the gallbladder wall, while its essential oils help regulate excessive gastric acid production. Bile itself contains salts derived from the combination of sodium and potassium with bile acids. Curcumin acts as an antioxidant and

increases the palatability of food, while the essential oils in turmeric, aromatic ginger, and curcuma exhibit antibacterial properties against pathogenic bacteria (Latief, 2012). Renowned for its anti-inflammatory and antimicrobial properties, turmeric has been shown to boost the immune system in fish species such as Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*), enhancing their resistance to bacterial infections, as well as improving growth performance and survival rates (Bharati *et al*., 2021).

2. Ginger

Ginger (*Zingiber officinale*), a perennial herb from the Zingiberaceae family, grows optimally at altitudes of 10–1500 m above sea level and thrives at temperatures of 25–30°C. Known for its medicinal properties, ginger contains a variety of bioactive compounds such as alkaloids, flavonoids, polyphenols, saponins, steroids, tannins, fiber, carbohydrates, vitamins, carotenoids, and natural antioxidants like gingerols, shogaols, and essential oils. Research by Arulvasu & Sivagnanam (2013) highlights ginger's ability to enhance cellular and humoral immunity, promote growth, and reduce fish mortality.

3. Curcuma

Curcuma (*Curcuma zanthorrhiza*), commonly known as temulawak, possesses antibacterial properties that help remove toxins from the intestinal wall, improving nutrient absorption and promoting growth. It also contains essential oils and curcumin, which enhance appetite and support digestive function. Curcumin stimulates bile secretion and the release of pancreatic enzymes, including amylase, lipase, and protease, aiding in the digestion of carbohydrates, fats, and proteins (Sastroamidjojo, 2001).

4. Aromatic Ginger

Aromatic ginger (*Kaempferia galanga L.*), known as "kencur," is commonly cultivated in Indonesia and used in traditional medicine, the beverage industry, and as a spice. Its rhizome contains 2.4–3.9% essential oil, along with cinnamic acid and ethyl ester (Prabowo *et al*., 2017). The essential oils in kencur have antibacterial properties against pathogenic bacteria (Belgis *et al*., 2021) and help regulate stomach acid, preventing excessive acidity and improving nutrient absorption in the small intestine (Cgizle *et al*., 2022).

5. Betel

Betel leaf (*Piper betle*) contains essential oils that inhibit microbial growth and exhibit activity against both gram-positive and gram-negative bacteria (Madhumita *et al*., 2019; Hartini *et al*., 2018). In addition to essential oils, betel leaves are rich in vitamins, organic acids, amino acids, sugars, tannins, fats, starch, and carbohydrates. The tannin compounds in betel leaf act as astringent polyphenols that bind and precipitate proteins, disrupting bacterial cell permeability by shrinking cell walls. This leads to bacterial growth inhibition or cell death (Subroto & Saputro, 2006; Ajizah, 2014).

6. Noni

Noni (*Morinda citrifolia L.*), a tropical plant from the Rubiaceae family, thrives in lowlands up to 1500 meters in altitude and grows to a height of 3–8 meters. Its fruit transitions from shiny green with spots when young to white with black spots when mature (Nelson, 2006). Noni fruit contains compounds such as xeronine, proxeronine, proxeronase, serotonin, dammacantal (anti-cancer agents), scopoletin, vitamin C, antioxidants, minerals, proteins, carbohydrates, enzymes, alkaloids, and other phytonutrients (Yusufzai & Barad, 2024). These compounds enhance cell function, strengthen the immune system, and accelerate cell healing. Noni leaves and fruit are rich in alkaloids, saponins, flavonoids, terpenoids, anthraquinones, and polyphenols (Uzoma Onu, 2024). Anthraquinones improve immunity, while terpenoids exhibit antibacterial properties, aiding organic synthesis and cell regeneration (Barad *et al*.,

2024).

Role of Herbal Plants as Fish Feed Supplements

Various studies have explored the use of different herbal plants in fish feed (Table 1), providing a foundation for utilizing herbal plants as supplements. These plants can be used individually or as mixtures to enhance fish feed formulations.

Table 1. Impact of Herbal Plant Supplementation in Aquaculture Species

No.	Herbal Plants	Fish	Reference	Results
1	Ginger (*Zingiber* officinalis) Turmeric (*Curcuma longa*)	African catfish (*Clarias gariepinus*)	Purbomartono *et al*. (2021)	Dietary inclusion of ginger increases the percentage of monocytes, but this was not seen with turmeric. Dietary inclusion of turmeric did better than ginger for WG, FCR, hematocrit, and lymphocyte levels. Ginger and turmeric can be used to improve immunity of catfish hatcheries.
2	Turmeric (*Curcuma longa*)	Vannamei shrimp (*Litopenaeus vannamei*)	Alambra *et al*. (2012)	15 g/kg of turmeric extract increased survival by 74% against *Vibrio spp.*
3	Turmeric, Ginger, Curcuma, Aromatic Ginger	Red tilapia (*Oreochromis sp.*)	Badawi *et al*. (2021)	The addition of turmeric flour at 2% concentration significantly improved growth in tilapia, suggesting its potential as a growth-promoting additive
4	*Leucaena leucocephala* leaf meal	African catfish (*Clarias gariepinus*)	Amisah *et al*. (2010)	Fish fed 20% leucaena leaf meal exhibited the best growth performance in terms of body weight gain and specific growth rate (SGR), while the control group (0% leucaena meal) showed the best feed conversion ratio (FCR).
5	Thyme (*Zataria multiflora*)	Common carp (*Cyprinus carpio*)	Hasani (2022)	Significant increase in growth performance (Weight Gain) and improved feed conversion efficiency (FCE).

Applications of Herbal Plants in Fish Disease Management

1. Immunostimulants

Herbal plants have been widely explored for their potential to enhance the immune response in fish. Many bioactive compounds, such as polysaccharides, flavonoids, and alkaloids, have been shown to boost the immune system by increasing the activity of immune

cells like macrophages, lymphocytes, and neutrophils. For example, garlic (*Allium sativum*) contains organosulfur compounds, such as allicin, that have been found to stimulate immune responses in fish by enhancing phagocytic activity and cytokine production (Ghafarifarsani *et al*., 2023). Turmeric (*Curcuma longa*), with its active compound curcumin, has shown similar immunostimulatory effects, boosting the production of immune proteins like immunoglobulins (Memarzia *et al*., 2021).

In a study involving Indian carp (*Catla catla*), supplementation with turmeric extract led to increased resistance to infections caused by *Aeromonas hydrophila* (Pradhan *et al*., 2015). Echinacea (*Echinacea purpurea*), another well-known immunostimulant, has also been shown to enhance disease resistance by stimulating the production of white blood cells and improving the overall immune response (Ahmed *et al*., 2019). These examples demonstrate the potential of herbal plants as natural immunostimulants, offering a promising alternative to synthetic vaccines and antibiotics.

2. Antimicrobials and Antiparasitics

Herbal plants also serve as effective antimicrobial, antifungal, and antiparasitic agents, providing a natural solution for managing fish diseases caused by pathogens. Neem (*Azadirachta indica*), for instance, has demonstrated potent antimicrobial activity against a variety of fish pathogens, including *Vibrio* spp., *Aeromonas hydrophila*, and *Saprolegnia* spp., which are common bacterial and fungal infections in aquaculture (Abd El-Hack *et al*., 2022). Neem contains azadirachtin, a compound with strong antimicrobial properties, making it a potential candidate for managing bacterial and fungal diseases in fish.

Additionally, oregano (*Origanum vulgare*) and thyme (*Thymus vulgaris*), rich in essential oils such as carvacrol and thymol, have shown effectiveness against various fish diseases caused by bacteria and parasites (Ezzat Abd El-Hack *et al*., 2016). These plants possess both antimicrobial and antiparasitic activities. For example, oregano oil has been tested for its efficacy in treating *Aeromonas hydrophila* infections in tilapia, demonstrating a significant reduction in bacterial load (Rashidian *et al*., 2021). The efficacy of these herbal treatments often rivals that of synthetic drugs, with the added benefit of being environmentally friendly and reducing the risk of resistance development.

3. Preventive Use

In addition to therapeutic applications, herbal plants are also used preventively in aquaculture to reduce the incidence of disease outbreaks. Many plants contain bioactive compounds that can be incorporated into fish feed or used in the water to enhance the overall health of fish and prevent infections. Garlic and ginger have been widely used in fish feed to improve immune function and reduce susceptibility to infections (Sukumaran *et al*., 2016). Aloe vera, another beneficial plant, is often added to water to improve the skin health of fish and reduce stress, making them less prone to disease (Gabriel *et al*., 2015).

For example, a study on rainbow trout (*Oncorhynchus mykiss*) showed that feeding the fish garlic-enriched feed resulted in a marked increase in their resistance to *Vibrio anguillarum*, a common pathogen (Oz., 2019). Similarly, the addition of moringa (*Moringa oleifera*) leaves to fish feed has been shown to enhance disease resistance in fish by improving their nutritional intake and immune function (Zhang *et al*., 2020). Preventive use of herbal plants not only reduces the need for chemical treatments but also supports sustainable and eco-friendly aquaculture practices.

Future Directions and Recommendations

1. Advancements in Research for Herbal Plant Extraction and Delivery Methods

Research in herbal plant extraction methods is essential to improve the efficiency and effectiveness of plant-based treatments in aquaculture. Advances in extraction technologies, such as supercritical fluid extraction and ultrasound-assisted extraction, can increase the yield and preserve the bioactive compounds of plants. Additionally, developing novel delivery systems, such as encapsulation or nano-carriers, can enhance the bioavailability of these compounds in aquatic environments and improve their therapeutic efficacy for fish (Esfanjani et al., 2018). These advancements can ensure that herbal products are more potent, consistent, and suitable for commercial application in aquaculture.

2. Integration with Aquaculture Practices (e.g., Feed Additives, Probiotics)

The integration of herbal plants with existing aquaculture practices could offer a more sustainable approach to disease management and fish health. Using herbal plants as feed additives or combining them with probiotics may enhance the gut health and immune responses of fish, providing a synergistic effect. Studies have shown that plant-based compounds, such as those from garlic and turmeric, can boost fish immunity and help prevent diseases caused by bacteria, viruses, and parasites (Iqbal *et al*., 2024). Future research should focus on optimizing combinations of herbal plants with probiotics to further enhance fish health and reduce the reliance on antibiotics and synthetic chemicals.

3. Collaborative Efforts for Standardization and Commercialization

The commercial success of herbal plant-based products in aquaculture will depend on collaborative efforts between academia, industry, and regulatory bodies to establish standardization and guidelines. There is a need for research to develop clear protocols for dosage, extraction methods, and the safety and efficacy of herbal treatments in fish. Collaborative research initiatives can help standardize formulations and establish quality control measures to ensure consistency in the product's therapeutic effects. Furthermore, partnerships with the aquaculture industry and regulatory authorities are necessary to bring herbal products to the market, ensuring that they meet both industry and environmental standards (Ahmad *et al.,* 2021).

CONCLUSION

Herbal plants present a promising, sustainable solution for enhancing fish health and productivity in aquaculture. Their bioactive compounds exhibit immunostimulatory, antioxidant, and antimicrobial properties that strengthen fish immunity, reduce oxidative stress, and improve disease resistance. Herbs such as *Curcuma longa* (turmeric), *Allium sativum* (garlic), and *Zingiber officinale* (ginger) have shown significant potential in promoting growth and increasing feed efficiency, leading to better aquaculture outcomes. The integration of herbal supplements into aquaculture systems offers a viable alternative to chemical additives and antibiotics, aligning with the industry's need for sustainable and eco-friendly practices. Further research and standardization are required to optimize their use and ensure consistent benefits across different species and environmental conditions.

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