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Terminalia catappa IN ORNAMENTAL AQUACULTURE: A PHYTOTHERAPEUTIC INNOVATION AGAINST ANTIMICROBIAL RESISTANCE

Terminalia catappa NA AQUICULTURA ORNAMENTAL: INOVAÇÃO FITOTERÁPICA E ALTERNATIVA SUSTENTÁVEL FRENTE À RESISTÊNCIA ANTIMICROBIANA

Terminalia catappa EN ACUICULTURA ORNAMENTAL: INNOVACIÓN HERBARIA Y ALTERNATIVA SOSTENIBLE A LA RESISTENCIA ANTIMICROBIANA

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Abstract

Ornamental fish farming is a prominent sector in global aquaculture, generating billions of dollars and playing a significant socioeconomic role. However, increased fish farming density and inadequate sanitary management favor the occurrence of bacterial diseases, especially those caused by *Aeromonas* spp., leading to the recurrent use of synthetic antimicrobials. This scenario has contributed to the emergence of resistant strains and adverse environmental impacts, requiring safer and more sustainable therapeutic alternatives. In this context, the use of medicinal plants emerges as a promising strategy, particularly *Terminalia catappa*, a species widely distributed in tropical regions and recognized for its pharmacological properties. Studies have reported that almond leaf extracts are rich in phenolic compounds, tannins, flavonoids, and terpenes, which are responsible for their antioxidant, antimicrobial, and immunomodulatory effects in ornamental fish. The application of the leaves or their extracts improves water quality, reduces stress, increases resistance to pathogens, and can partially replace the use of synthetic antibiotics. Thus, *T. catappa* stands out as

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a natural and ecological alternative for the health management of ornamental aquaculture, thereby contributing to the sector's productive and environmental sustainability.
Keywords: Almond tree; ornamental fish; herbal medicines; antimicrobial resistance; aquaculture sustainability.

Resumo

A piscicultura ornamental é um setor de destaque na aquicultura mundial, movimentando bilhões de dólares e desempenhando importante papel socioeconômico. No entanto, o aumento da densidade de cultivo e as falhas no manejo sanitário favorecem a ocorrência de enfermidades bacterianas, especialmente as causadas por *Aeromonas* spp., levando ao uso recorrente de antimicrobianos sintéticos. Esse cenário tem contribuído para o surgimento de cepas resistentes e impactos ambientais adversos, exigindo alternativas terapêuticas mais seguras e sustentáveis. Nesse contexto, o uso de plantas medicinais surge como uma estratégia promissora, destacando-se a *Terminalia catappa*, espécie amplamente distribuída nas regiões tropicais e reconhecida por suas propriedades farmacológicas. Estudos relatam que os extratos foliares da amendoeira são ricos em compostos fenólicos, taninos, flavonoides e terpenos, responsáveis por efeitos antioxidantes, antimicrobianos e imunomoduladores em peixes ornamentais. A aplicação das folhas ou de seus extratos melhora a qualidade da água, reduz o estresse, aumenta a resistência a patógenos e pode substituir parcialmente o uso de antibióticos sintéticos. Assim, a *T. catappa* se destaca como uma alternativa natural e ecológica no manejo sanitário da aquicultura ornamental, contribuindo para a sustentabilidade produtiva e ambiental do setor.
Palavras-chave: Amendoeira; peixes ornamentais; fitoterápicos; resistência antimicrobiana; sustentabilidade aquícola.

Resumen

La piscicultura ornamental representa un sector destacado en la acuicultura mundial, generando miles de millones de dólares y desempeñando un importante papel socioeconómico. Sin embargo, el aumento de la densidad de piscicultura y la gestión sanitaria inadecuada favorecen la aparición de enfermedades bacterianas, especialmente las causadas por *Aeromonas* spp., lo que lleva al uso recurrente de antimicrobianos sintéticos. Este escenario ha contribuido a la aparición de cepas resistentes e impactos ambientales adversos, lo que requiere alternativas terapéuticas más seguras y sostenibles. En este contexto, el uso de plantas medicinales surge como una estrategia prometedora, en particular, *Terminalia catappa,* una especie ampliamente distribuida en regiones tropicales y reconocida por sus propiedades farmacológicas. Estudios indican que los extractos de hojas de almendro son ricos en compuestos fenólicos, taninos, flavonoides y terpenos, responsables de efectos antioxidantes, antimicrobianos e inmunomoduladores en peces ornamentales. La aplicación de las hojas o sus extractos mejora la calidad del agua, reduce el estrés, aumenta la resistencia a patógenos y puede reemplazar parcialmente el uso de antibióticos sintéticos. Así, *T. catappa* se destaca como una alternativa natural y ecológica para la gestión sanitaria de la acuicultura ornamental, contribuyendo a la sostenibilidad productiva y ambiental del sector.
Palabras clave: Almendro; peces ornamentales; fitoterapia; resistencia a los antimicrobianos; sostenibilidad de la acuicultura.

1. Introduction

Ornamental fish farming is an aquaculture activity of growing economic importance, established as a global sector generating billions of dollars annually. The global market was valued at approximately US$ 5.4 billion in 2021, with a projected annual growth rate of over 8% through 2030, underscoring its significance in generating income and employment opportunities in several countries (Hoseinifar

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et al., 2023). Ornamental aquaculture cultivates a diverse range of aquatic organisms, including fish, mollusks, crustaceans, amphibians, and reptiles (Siqueira, 2017). Among the most commercialized ornamental fish are koi (*Cyprinus carpio*), goldfish (*Carassius auratus*), bettas (*Betta splendens*), and guppies (*Poecilia reticulata*), prized for their diverse colors and shapes (Rezende; Fujimoto, 2021).

The ornamental fish sector, driven by innovation and demand for unique species, requires the supply of healthy and visually attractive animals (Rezende; Fujimoto, 2021). However, poor management and water quality contribute to the emergence of infectious and parasitic diseases, often associated with stress and the presence of opportunistic pathogens (Anjur et al., 2021).

Bacterial diseases are among the primary obstacles to aquaculture production, as they affect various stages of the production chain, from fish cultivation to transportation (Rezende; Fujimoto, 2021). Among the most important pathogens, the genus *Aeromonas* stands out for causing hemorrhagic septicemia in several fish species. Species such as *A. veronii* and *A. hydrophila* are associated with severe infections in catfish (*Ictalurus punctatus*) (Hoai et al., 2019), tilapia (*Oreochromis niloticus*) (Hassan et al., 2017; Raj et al., 2019), and goldfish (*C. auratus*) (Shameena et al., 2020), among many others.

Conventional treatments with synthetic antimicrobials have demonstrated limited efficacy and pose risks of bacterial resistance and environmental harm. In this context, interest in the use of herbal medicines in ornamental fish farming is growing as a natural, economical, and ecologically sustainable alternative (Allessi; Carvalho Filho; Marengoni, 2019; Anjur et al., 2021).

Among the plants with therapeutic potential, the almond tree (*Terminalia catappa*) stands out. It is a species widely distributed in tropical regions, and its leaves contain bioactive compounds such as tannins, flavonoids, phenols, and saponins, which are associated with antioxidant, immunomodulatory, and antimicrobial actions (Allessi; Carvalho Filho; Marengoni, 2019). The use of *T. catappa* leaf extracts has been reported in ornamental fish farming systems, with beneficial effects on immunity, stress resistance, and the prevention of bacterial diseases, especially those caused by *A. hydrophila.*

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This review aimed to gather and discuss the primary scientific evidence on the phytotherapeutic potential of *T. catappa* leaf extract in ornamental fish farming, highlighting its effects on the health, immunity, and performance of ornamental fish, as well as its potential applications as a natural alternative to conventional antimicrobials.

2. Literature review

2.1. Ornamental aquaculture worldwide and in Brazil

The term ornamental aquaculture, also known as aquariophily, is defined by SAP/MAPA Ordinance nº. 17/2021 as the breeding or sale of aquatic organisms kept in aquariums, tanks, or lakes for leisure or entertainment purposes. According to this regulation, ornamental use encompasses both living and non-living organisms, used for decorative or aesthetic purposes (Brazil, 2021).

Ornamental aquaculture involves the maintenance and reproduction of marine, brackish, and freshwater aquatic species, including algae, plants, invertebrates, fish, amphibians, and reptiles (Rezende; Fujimoto, 2021). From an economic perspective, ornamental fish farming is highly profitable, as several species achieve significant values in national and international trade (Carvalho et al., 2017). In addition to its economic aspects, the activity has recreational and educational components, driven by the aesthetic appreciation of the species (Novák; Kalous; Patoka, 2020). The global pet market, encompassing ornamental fish, is experiencing sustained growth. In 2022, the total number of pets increased by 2% compared to 2021, with ornamental fish representing the largest group, exceeding 642 million individuals (ABINPET, 2023). This popularity is attributed to their practical handling and reduced daily care requirements (Novák; Kalous; Patoka, 2020).

On the international scene, Indonesia, Singapore, and Japan stand out as the primary producers and exporters of ornamental fish, recognized for their diverse range of species and high export capacity (Rezende; Fujimoto, 2021; Costa et al., 2024).

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In Brazil, according to the Brazilian Association of the Pet Products Industry (ABINPET, 2023), the pet sector saw a 3.6% increase in 2022, totaling 167.6 million individuals, placing the country as the third-largest global market in terms of revenue (US$ 7.4 billion). Ornamental fish account for approximately 22.2 million animals, representing a 4% increase compared to 2021, surpassing the growth observed in dogs (3.5%). In during the same period, the global pet market grew by 3.2%, generating US$ 149.82 billion.

Between 2013 and 2017, 14 Brazilian states stood out as exporters of ornamental fish, with five main hubs: Belém (PA), Manaus (AM), Fortaleza (CE), Vitória (ES), and Goiânia (GO) (Brazil, 2018). Another notable region is the Zona da Mata in Minas Gerais, particularly the municipality of Muriaé, which is responsible for around 90% of the national production of freshwater species, with approximately 12 million units sold annually. In the North and Northeast regions, extractive fishing and the capture of ornamental marine organisms are predominant, with the state of Ceará serving as an example of government incentives for this activity (Aquaculture Brazil, 2022).

In the national market, the most commercialized ornamental fish species include goldfish (*Carassius auratus*), Platy (*Xiphophorus maculatus*), Betta (*Betta splendens*), Oscar (*Astronotus ocellttus*), Guppy (*Poecilia reticulata*), Cardinal tetra (*Paracheirodon axelrodi*), Mato Grosso (*Hyphessobrycon eques*), Flag angelfish (*Pterophyllum scalare*), and Discus angelfish (*Symphysodon discus*), with the diversity and intensity of colors being determining criteria for their commercial value (Rezende; Fujimoto, 2021).

In Brazil, the commercial exploitation of these resources requires prior authorization from the competent authority, as stipulated in Law No. 11,959 of 2009, which aims to ensure the sustainable use of resources and protect communities that hold traditional knowledge (Brazil, 2009).

Given the economic and ecological importance of the sector, it is essential to develop sustainable strategies that promote the well-being and health of ornamental fish, including the use of natural products with therapeutic properties, such as plant extracts of phytotherapeutic value.

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2.2. *Carassius auratus as a model species in ornamental aquaculture*

Brazil, home to remarkable biodiversity, is home to approximately 3,147 species of Neotropical fish distributed across different regions (Antunes; Alcântara, Santos, 2021). Despite this native richness, exotic species such as Carassius auratus (Linnaeus, 1758), popularly known as goldfish or kinguio, have played a fundamental role in both the ornamental market and scientific research. Belonging to the class Actinopterygii, order Cypriniformes, and family Cyprinidae, this species is native to Asia and closely related to the common carp (*C. carpio*), with which it shares genetic and behavioral aspects relevant to studies of reproduction, physiology, and management (Moyses et al., 2015).

In Brazil, *C. auratus* stands out for its widespread use in aquariums and the growing economic importance of ornamental fish farming, which drives the adoption of more sustainable management practices. The species is widely studied for its adaptation to various environmental conditions; however, it is susceptible to parasitic infestations and bacterial diseases when kept under conditions of inadequate water quality and high population density (Rocha et al., 2017). Biologically, goldfish are omnivorous fish with herbivorous tendencies, high fecundity, and short reproductive cycles, characteristics that favor their intensive reproduction and widespread dissemination (Dananjaya et al., 2020; Chen et al., 2020).

The species exhibits significant phenotypic diversity, resulting from centuries of artificial selection, which is reflected in variations in coloration, morphology, and behavior. These differences influence not only aesthetics but also physiological and adaptive parameters. Due to its hardiness, attractive appearance, and ease of handling, the goldfish is widely recommended for beginners in aquarium maintenance. Regarding water quality, it tolerates a temperature range of 15° and to 28°C, a neutral pH (7.0) to slightly alkaline (7.2), and low dissolved oxygen levels (< 4 ppm). In hypoxic situations, it exhibits a unique mechanism for converting lactate to ethanol, eliminating it through the gills, thus avoiding metabolic acidosis (Chen et al., 2020).

C. auratus can reach up to 30 cm in length and adapts easily to different environmental conditions, making it a versatile experimental model for physiology,

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toxicology, and immunology studies. Its hardiness and well-characterized immune response justify its frequent use in experiments evaluating the effect of natural compounds, including herbal medicines, on disease resistance (Dananjaya et al., 2020; Araujo et al., 2020).

However, due to its widespread distribution and intense commercialization, goldfish are frequently affected by opportunistic pathogens, especially bacteria from the genera *Aeromonas, Shewanella, Citrobacter*, and *Vibrio*, which can cause skin ulcers, eye lesions, septicemia (Zhang; Xu; Shoemaker, 2016), and even skin neoplasms (Armando et al., 2021). These diseases compromise the well-being and longevity of the fish, resulting in the recurrent use of synthetic antibiotics for treatment (Armando et al., 2021).

In recent years, the use of herbal products has emerged as a promising and environmentally safe alternative for the health management of ornamental fish (Elgendy et al., 2024). Thomas et al. (2023) observed a significant immunomodulatory effect of Andrographis paniculata leaf extract on *C. auratus* infected with *A. hydrophila*, with efficacy observed at low concentrations (50 µg/mL). However, studies focusing on the control of bacterial infections in goldfish using herbal extracts remain limited (Allessi; Carvalho Filho; Marengoni, 2019). Most research on herbal products focuses on species of zootechnical interest for human consumption, highlighting a significant gap in ornamental aquaculture. In this context, investigations into the phytotherapeutic potential of tropical plant species, such as the almond tree (*T. catappa*), represent a sustainable and innovative alternative for controlling bacterial diseases in ornamental fish, especially *C. auratus*.

2.3. Main diseases in ornamental fish farming

The success of ornamental fish farming depends on the adoption of good management practices, including strict water quality control, quarantine of new batches, balanced feeding, and preventive biosecurity measures, which are essential to reduce losses caused by infectious outbreaks. Intensified and increased stocking densities can increase stress levels in fish, compromising their immune systems and favoring the emergence of diseases, which can result in significant

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economic losses. Modern management strategies have incorporated the use of functional nutrition and immunomodulators (vitamins, amino acids, and minerals), which can strengthen the immune response, increase resistance to environmental stress, and reduce dependence on synthetic antibiotics (Abdul Kari, 2025).

Water quality is another determining factor in maintaining the health of ornamental fish. According to Sipaúba-Tavares, Baccarin, and Braga (2006), proper management of water's physical, chemical, and biological parameters is essential to reduce pathogen proliferation and maintain the homeostasis of aquatic organisms. Allessi, Carvalho Filho, and Marengoni (2019) emphasize that, although ornamental fish farming shares similar principles to broiler farming, it requires specific adaptations, such as proportional tank sizing, efficient filtration systems, and less stressful fishing methods suited to ornamental species.

Observing clinical and behavioral signs is a crucial tool for early disease diagnosis. Changes in swimming behavior, isolation of individuals, and loss of appetite are indicative of physiological imbalance and may reflect bacterial infections or changes in environmental quality (Rezende; Fujimoto, 2021).

Several bacterial genera have been reported to cause disease in ornamental fish, including *Aeromonas, Pseudomonas, Edwarsiella, Streptococcus, Flavobacterium, Vibrio,* and *Enterococcus* (Zhang; Xu; Shoemaker, 2016; Jatobá et al., 2018). The genus *Streptococcus* is one of the most relevant, as it can infect both symptomatic fish and apparently healthy individuals, is transmitted through water, and is often responsible for high-mortality outbreaks. Systemic infection caused by *Streptococcus* spp. can reach the central nervous system, leading to bacterial meningoencephalitis, characterized by disturbed swimming, ocular necrosis, and changes in the sclera and cornea (Hernández-Hernández et al., 2023).

Another notable agent is *Flavobacterium columnare*, which causes "Columnar disease," easily recognized by the presence of pale spots and reddish areas on the skin of fish. Ornamental species such as goldfish (*C. auratus*), carp (*C. carpio)*, zebrafish (*Danio rerio*), platys (*Xiphophorus maculatus*), swordtails (*Xiphophorus helleri*), mollies (*Poecilia latipina* and *P. sphenops*), and guppies (*P. reticulata*) are among the most susceptible to infection (Declercq et al., 2013). The disease, which initially affects the epidermis and gills, can progress to systemic conditions and is

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often exacerbated by co-infection with other pathogens, such as *Aeromonas* spp., *Edwardsiella tarda*, and *E. ictaluri* (Rezende; Fujimoto, 2021).

Ferreira et al. (2022) investigated the virulence of *F. columnare* in pacu (*P. mesopotamicus*) and reported that after 40 minutes of exposure (1 x 10^2 CFU/mL), the animals exhibited symptoms such as lethargy and gray spots on the dorsal region within 24 hours.

Table 1 presents studies that systematize the main symptoms of bacterial diseases affecting ornamental fish, as well as the species involved.

Table 1. Some of the main infectious diseases in fish are caused by bacteria.

Bacteria	Fish species	Main symptoms	References
Streptococcus agalactiae	Tilápia (*O. niloticus)*	Eye with exophthalmos, hemorrhage, and corneal opacity. Brain with hemorrhage and diffuse fibrinous exudate. Ulcer, hemorrhage, and caseous necrosis at the base of the caudal peduncle.	Hernández-Hernández et al. (2023).
Vibrio cholerae and *V. anguillarum*	Kinguio (*C. auratus*) and Paulistinha (*P. reticulata*)	Darkening of the skin, lethargy, anorexia, skin ulcers and septicemia, eye damage, ascites, and anemia.	Rezende; Fujimoto (2021)
Aeromonas hydrophila	Tilápia (*O. niloticus)*	Skin hemorrhages, fin hemorrhages, and exophthalmos.	Aboyadak et al. (2015)
Francisella asiatica (F. noatunensis subsp. *orientalis) and F. noatunensis*	Tilapia (Oreochromis sp.) and ornamental cichlids (various species)	Lethargy, loss of appetite, gill pallor, and spiral or circular swimming patterns, skin erosions, and loss of scales.	Rezende; Fujimoto (2021)
Mycobacteriosis (*Mycobacterium* spp.)	Neon tetra (*Paracheirodon* sp.), Black cichlid (*C. bimaculatum*), Goldfish (*C. auratus*), Blackfish (*A. ocellatus*) and Napoleon fish (*C. undulatus*)	Loss of appetite, weak and isolated fish; unilateral or bilateral exophthalmos, skin ulcerations, abdominal distension, subcutaneous masses and nodules in the main organs.	Rezende; Fujimoto (2021)

Source: The author.

Given the increasing incidence of bacterial diseases and the risk of antimicrobial resistance, it is essential to seek safe and environmentally sustainable therapeutic alternatives. In this context, the use of natural compounds with antimicrobial and immunomodulatory properties, such as plant extracts, has generated increasing interest in ornamental aquaculture due to their potential to reduce the use of synthetic antibiotics and promote fish welfare.

2.4. The genus *Aeromonas*

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The genus *Aeromonas*, belonging to the class Gammaproteobacteria, order Aeromonadales, and family Aeromonadaceae, also encompasses the genera *Tolumonas* and *Oceanonimonas*. Currently, 32 species of *Aeromonas* are recognized (Figueras et al., 2017). These bacteria are short, Gram-negative, facultatively anaerobic, oxidase- and catalase-positive rods (Pessoa et al., 2019). They range in size from 0.3 to 1.0 µm in diameter and 1.0 to 3.5 µm in length (Percival; Williams, 2014). They ferment glucose and tolerate NaCl concentrations ranging from 0.3% to 5% (Parker; Shaw, 2011).

Considered emerging pathogens, *Aeromonas* possess broad adaptability and can colonize a variety of aquatic and terrestrial hosts (Elala; Afifi; Taha, 2015). In addition to being present in water and sediments, they are also isolated from food and various animals, including fish, birds, and invertebrates (Pessoa et al., 2019). Their health importance stems not only from their high pathogenicity but also from the growing issue of antimicrobial resistance, a critical challenge for modern aquaculture (Devi et al., 2016).

Aeromonas species are associated with several diseases in fish, being responsible for hemorrhagic septicemia and skin lesions, and are thus one of the main etiological agents in culture systems (Devi et al., 2016). Virulence is associated with the production of extracellular enzymes, including hemolysins and aerolysins (Anjur et al., 2021). Hemolysins degrade hemoglobin, promoting hemolysis of erythrocytes, where α-hemolysin causes partial and reversible lysis, while β-hemolysin forms pores in the cell membrane, resulting in complete lysis due to osmotic imbalance (Pemberton; Kidd; Schmidt, 1997). Aerolysins, in turn, bind to glycoprotein receptors in the eukaryotic membrane, inserting themselves into the lipid bilayer and compromising cellular integrity (Uma et al., 2010). Other enzymes, such as proteases, lipases, and collagenases, act in the degradation of proteins, lipids, and collagen, intensifying tissue destruction (Peixoto et al., 2012).

Another important virulence factor is the ability to form biofilms, which confer resistance to adverse environmental conditions and antimicrobial treatments, favoring the persistence and recurrence of infections in aquaculture systems (Parker; Shaw, 2011).

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The infective dose of *Aeromonas* varies according to the species, host, and environmental conditions. Chen et al. (2012) reported that *A. schubertii* caused 50% mortality in snakehead fish (*Channa maculata*) at a concentration of 1.4 x 10^4 CFU/g. Liu et al. (2018) reported that doses of 3.75 x 10^6 CFU/g resulted in 100% mortality in tilapia within two days, while concentrations of 10^7 CFU/g were lethal to 100% of zebrafish (*D. rerio*) within 24 hours.

Clinical signs in infected fish include fin erosions and hemorrhages (Figure 1), abdominal distension, gill bleeding, and lesions in internal organs such as the liver and kidneys (Barcellos et al., 2008). *Aeromonas* are classified into two main groups based on their motility and the range of growth temperature. The first group, called motile mesophilic, develops between 5° and 37°C, with optimal growth between 35° and 37°C. It includes species pathogenic to humans and fish, such as A*. hydrophila, A. caviae*, and *A. sobria* (Tavares et al., 2015). Among the species of greatest health importance, *A. veronii* is considered an emerging pathogen, associated with infections in catfish (Hoai et al., 2019), tilapia (Raj et al., 2019), European sea bass (Smyrli et al., 2017), goldfish (Shameena et al., 2020), and cyprinids (Ran et al., 2018).

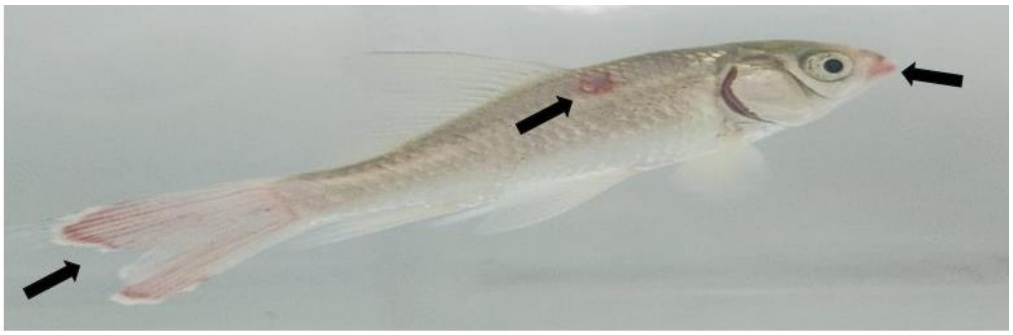

Figure 1. Diffuse hemorrhage in the mouth, body, and caudal fin resulting from *Aeromonas veronii* infection in goldfish (*Carassius auratus*). Source: The author.

The second group comprises psychrophilic species, which prefer temperatures between 22° and 25°C (Pessoa et al., 2019; Gazal et al., 2020). Notable among these are *A. salmonicida* and *A. media*, the latter of which is non-pathogenic to humans but causes furunculosis in fish (Pessoa et al., 2019). Given the widespread distribution and high pathogenicity of the genus *Aeromonas*, it is crucial to develop therapeutic strategies that balance antimicrobial efficacy with environmental safety. In this context, the use of natural compounds with antibacterial and

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immunomodulatory action, such as plant extracts, especially from *T. catappa*, has emerged as a sustainable and promising alternative in ornamental fish farming.

2.5. Use of antimicrobials in ornamental fish farming

In aquaculture, as in terrestrial animal husbandry, antibiotics are extensively used to prevent and control bacterial infections, playing a key role in maintaining fish health and ensuring the economic viability of production (Gazal et al., 2020). However, the responsible and judicious use of these substances must be aligned with current international guidelines and regulations to minimize potential impacts on aquatic ecosystems and public health (FAO, 2023). The route of antimicrobial administration varies depending on to the species, pathogen, and severity of the infection. The most common methods include immersion or bath treatments, in which fish are exposed to antibiotic solutions through the water, and injectable applications, typically reserved for species of higher commercial value, such as ornamental fish and shrimp, due to their precision in dosing and therapeutic efficacy (Cabello et al., 2016).

Although the use of antibiotics significantly reduces mortality caused by pathogens, the indiscriminate use of these substances has contributed to the emergence and spread of resistant bacteria in aquaculture systems (Gazal et al., 2020). In Brazil, the use of antimicrobials in fish farming is regulated by Anvisa resolutions RDC nº. 20/2011 and nº. 471/2021, which establishes criteria for prescribing, dispensing, and monitoring these medications, restricting their use to just three drugs: oxytetracycline, neomycin sulfate, and florfenicol (Pereira et al., 2021).

The increase in bacterial resistance has been widely documented. Cizek et al. (2010) reported resistance to oxytetracycline in 41% of *Aeromonas* spp. strains isolated from carp (*C. carpio*). Similarly, Carriero et al. (2016), when evaluating 15 antibiotics against *A. dhakensis* isolated from pacu (*P. mesopotamicus*), observed resistance to ampicillin (MIC ≥ 32 µg/mL), ampicillin/sulbactam (MIC ≥ 32 µg/mL), cefoxitin (MIC ≥ 64 µg/mL), and meropenem (MIC ≥ 16 µg/mL).

Antimicrobial residues released into effluents from farming systems compromise water quality and promote the spread of resistant strains, threatening

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aquatic biodiversity (Fauzi et al., 2021). Furthermore, the presence of resistant bacteria poses a public health risk, as resistance genes can be transferred to humans through direct contact with contaminated water or infected animals (Kimera et al., 2020).

Given the growing antimicrobial resistance and the environmental impacts resulting from the indiscriminate use of antibiotics, the search for safer and more sustainable therapeutic alternatives has become urgent. In this context, natural compounds of plant origin, such as phytotherapeutics, have attracted interest due to their antimicrobial, antioxidant, and immunomodulatory properties. Obtained from plant extracts rich in secondary metabolites such as tannins, flavonoids, and phenols, these compounds have the potential to prevent and control infections, reducing dependence on synthetic antibiotics and the risks associated with their use (Elgendy et al., 2024).

Thus, the incorporation of herbal medicines into ornamental fish farming emerges as a promising strategy for promoting fish health, mitigating environmental impacts, and contributing to more sustainable production. Among the plant species with the greatest therapeutic potential is the almond tree (*T. catappa*), whose extracts have demonstrated broad antimicrobial activity and the ability to modulate the immune response in aquatic organisms.

2.6. Use of herbal plants in ornamental fish farming

The use of medicinal plants dates back to antiquity, representing one of the oldest forms of therapeutic care employed by humanity. Currently, it is estimated that more than 3.3 billion people in developing countries rely on herbal medicines for their primary healthcare. Plants are important sources of raw materials for the pharmaceutical industry, as they are rich in secondary metabolites such as tannins, alkaloids, terpenoids, saponins, phenolic compounds, steroids, and flavonoids (Pedroso; Andrade; Pires, 2021).

The search for natural alternatives to antibiotics has driven research into plant-based compounds, particularly extracts and essential oils, due to their antimicrobial, antioxidant, and immunomodulatory properties (Hyldgaard; Mygind; Meyer, 2012).

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Thus, herbal remedies stand out as promising tools for controlling pathogens and promoting fish health, supporting more sustainable aquaculture practices (Seyedalinaghi et al., 2025).

Several plant species have been studied in the context of ornamental fish farming, including almond (*T. catappa*) and garlic (*Allium sativum*) (Santos et al., 2015), rosemary pepper essential oil (*Lippia sidoides*) (Medeiros, 2021), cockscomb (*Erythrina crista-galli*) (Siqueira et al., 2019), jurema (*Mimosa tenuieflora*) (Crepaldi, 2019), ginger (*Zingiber officinale*) (Trentin et al., 2020), seven-bark (*Samanea tubulosa*) (Garcêz, 2021), among others.

In addition to their antimicrobial activity, herbal medicines have immunomodulatory, anti-stress, and growth-stimulating effects. Supplementing fish diets with herbs has been shown to offer benefits, including increased weight gain, improved feed conversion, and enhanced resistance to pathogens and environmental stressors (Aly et al., 2016). In ornamental crops, certain plant species are utilized directly in tanks to improve water quality and enhance the fish's immune system. Such practices are considered ecological, sustainable, and low-impact when compared to the use of antibiotics (Hodar et al., 2021).

The variety of bioactive compounds present in medicinal plants enables the extraction of different classes of metabolites, including tannins, alkaloids, terpenoids, saponins, phenolics, steroids, and flavonoids, from various parts of the plants. Studies involving ornamental fish use extracts obtained from leaves (Harikrishnan; Balasundaram; Heo, 2011), seeds (Ekanem et al., 2004), fruits (Pan et al., 2013), roots (Zhang et al., 2014), rhizomes (Talpur; Ikhwanuddin, 2013), and barks (Zhou et al., 2017), with solvents such as petroleum ether (Ekanem et al., 2004), water (Chyau; Ko; Mau, 2006), chloroform (Wu et al., 2011), ethyl acetate (Hu et al., 2014), methanol (Tasneem et al., 2018) and ethanol (Wattanuruka; Detraksab, 2023).

Garlic (*A. sativum*), in particular, stands out for its potent antimicrobial activity, attributed to allicin and ajoene. Including garlic in the diet of tilapia (*O. niloticus*) promoted an increase in specific growth rate, greater protein efficiency, and an immunomodulatory effect, in addition to demonstrating action against *A. hydrophila*

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and pathogenic protozoa such as *Spironucleus vortens* and *Ichthyophthirius multifiliis* (Tanekhy; Fall, 2015).

Table 2 presents some studies conducted with ornamental species, demonstrating the antibacterial efficacy of different herbal remedies. In general, the administration of bioactive compounds, whether by immersion, oral, or injection, enhances the innate and adaptive immune systems of fish, providing protection against a wide variety of infectious diseases.

Table 2. Some examples of antibacterial doses of herbal plants.

Phytotherapeutics	Method of administration	Dose	Species	Pathogens	References
Seaweed (*D. gimnospora*)	Immersion with aqueous and ethanolic extract	100-150 mg/L for 15 days	Tilápia (*O. mossambicus*)	*P. aeruginosa*	Thanigaivel et al. (2019)
Urtiga (*U. dioica*)	Methanolic extract in feed	0.1 and 0.5 g/kg	Rainbow trout (*O. mykiss*)	*A. hydrophila*	Bilen et al. (2016)
Turmeric extract	Methanolic extract in feed	10 mg/mL	*P. dilectus*	*P. mirabilis*	Devi et al. (2016)
Almond (*T. catappa*)	Immersion with 95% ethanolic extract	0,5 g/L	Betta (*B. splendens*)	*A. hydrophila*	Nugroho et al. (2017)
Rosemarypepper (*L. Sidoides*)	Supplemented in feed with 100 mL of cereal alcohol with *L. sidoides* oil	0,063%	Carp (*C. carpio*)	*Aeromonas* spp.	Medeiros (2021)

Source: The author.

2.7. *Terminalia catappa*

The genus *Terminalia* is the second-largest in the Combretaceae family, comprising approximately 240 species distributed throughout the tropical regions of Africa, Asia, Oceania, and the Americas. The trees can reach heights of between 25 and 45 meters and have simple, alternate leaves concentrated at the branch tips. The flowers are usually unisexual or monoclinous, without petals, and the fruits are dry, flattened, or rounded, containing seeds with convoluted cotyledons (Ramanan et al., 2025).

Terminalia catappa, commonly known as the almond, chestnut, or parasol, has a wide range of medicinal and pharmacological applications. Its leaves contain a rich variety of secondary metabolites, including phenolic compounds, terpenes, tannins, alkaloids, and nitrogenous compounds, recognized for their antioxidant,

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anti-inflammatory (Silva; Sousa; Costa, 2020), antitumor, and antidiabetic properties (Pandya et al., 2013).

In aquaculture, advances in the use of *T. catappa* have demonstrated significant benefits for both water quality and fish health. The leaves release antimicrobial and antioxidant compounds that can regulate acidity, reduce pathogen load, and simulate the natural environment, thereby promoting well-being and ecological balance (Wang; Taufek; Arshad, 2024). Segaran et al. (2019) reported that acetone, chloroform, and petroleum ether extracts of *T. catappa* leaves exhibit remarkable antibacterial activity against *S. aureus* and *P. mirabilis*, with the acetone extract showing the highest inhibition zone (31 mm) at a concentration of 10 mg. The extracts also demonstrated antioxidant and anti-inflammatory properties, confirming the presence of bioactive compounds including phenols, alkaloids, tannins, anthraquinone glycosides, and flavonoids.

The antioxidant effects of *T. catappa* have also been widely documented. Belina, Lopes, and Oliveira (2019) identified a median lethal concentration (LC_{50}) of 512 µg/mL in the hexane extract of the leaves, which exceeds that of the ethanolic extract (LC_{50} of 689 µg/mL). Gonçalves et al. (2017) reported LC_{50} values of 574 and 584 µg/mL for the methanolic and ethanolic extracts, respectively.

In ornamental fish farming, *T. catappa* leaves are traditionally used to improve the physicochemical and biological conditions of the water, acting as antimicrobial and antioxidant agents, while also reducing stress and increasing fish resistance to disease (Santos et al., 2015). According to the authors, the inclusion of 0.25% leaf meal in the diet of male *B. splendens* promoted improved performance and well-being. However, there is still no standardization regarding the ideal dosage for direct application of the leaves to tanks (Figure 2).



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Figure 2. Use of almond leaves (*Terminalia catappa*) in an ornamental fish pond. Source: The author.

The plant's toxicity, however, requires attention. Hashim et al. (2020) reported LC_{50} values of 349.89 g/L for carp (*C. carpio*), 33.865 g/L for goldfish (*C. auratus*), and 31.848 g/L for tiger barbs (*B. tetrazona*), indicating the need to define safe concentrations to avoid lethal effects. Stratev et al. (2018) emphasize that the inappropriate use of plant extracts can lead to adverse effects, depending on the concentration and the sensitivity of the species.

Recent studies confirm the immunomodulatory potential of *T. catappa* in fish. Yakubu et al. (2020) observed that the methanolic extract administered to red hybrid tilapia (*O. niloticus*) at a dose of 62.5 mg/kg significantly increased the immune response and resistance to infection by *S. agalactiae*. In contrast, Siqueira et al. (2019) found that when using *Erythrina crista-galli* extract in *C. auratus*, high doses (>100,000 µg/mL) did not cause mortality but altered blood parameters, such as glucose and electrolytes, suggesting possible effects of physiological stress.

Faced with growing bacterial resistance to synthetic antimicrobials and the search for safe alternatives, *T. catappa* emerges as a sustainable and economically viable solution. Its leaves, widely available and rich in bioactive compounds, have been show to exhibit antimicrobial, antioxidant, and immunomodulatory activities, thereby contributing to the strengthening of fish immune systems and reducing stress. In addition to reducing dependence on antibiotics, its use favors environmentally friendly and low-cost management practices (Wang; Taufek; Arshad, 2024).

The application of natural extracts from *T. catappa* therefore, represents a promising approach for disease control in ornamental fish, offering biodegradable alternatives with a lower environmental impact and reduced risk of antimicrobial resistance. Responsible use of this plant species has the potential to promote the gradual replacement of synthetic drugs, enhance fish health, and contribute to a more sustainable ornamental aquaculture.

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3. Final considerations

This review highlighted the phytotherapeutic potential of *T. catappa* a promising alternative for controlling bacterial infections in ornamental fish, especially those caused by *A. hydrophila*. The evidence gathered suggests that its extracts exhibit significant antioxidant and antimicrobial activity, as well as benefits associated with fish survival and well-being, reinforcing the role of natural products in the sustainable management of ornamental aquaculture.

In addition to their antimicrobial properties, the bioactive compounds present in *T. catappa* leaves, such as flavonoids, phenols, and tannins, are notable for their immunomodulatory effects, contributing to strengthening the fish's natural defenses. The use of phytotherapeutic agents can reduce the environmental impact of antibiotic disposal and minimize the risk of spreading resistant strains, a growing challenge in aquaculture production.

Future studies are recommended to advance the standardization of doses and application methods, the toxicological evaluation of different ornamental species, and the analysis of long-term effects in cultivation systems. Expanding knowledge about *T. catappa* and other medicinal species will contribute to the development of safe, sustainable, and economically viable therapeutic strategies, consolidating ethical, technically advanced, and environmentally responsible ornamental aquaculture.

References

ABDUL KARI, Z. Nutritional immunomodulation in aquaculture: functional nutrients, stress resilience, and sustainable health strategies. **Aquaculture International**, v. 33, p. 441, 2025. Doi: 10.1007/s10499-025-02122-5

ABINPET. 2023. Mercado Pet Brasil. **Dados de mercado: Crescimento do mercado pet no Brasil**. Disponível em: <https://www.abinpet.org.br>. Acesso em: 13 set 2024.

ABOYADAK, I. M. et al. Molecular detection of *Aeromonas hydrophila* as the main cause of outbreak in tilapia farms in Egypt. **Journal of Aquaculture & Marine Biology**, v. 2, n. 6, p. 2-5, 2015. Doi: 10.15406/jamb.2015.02.00045

ALLESSI, F. E.; CARVALHO FILHO, J. W.; MARENGONI, N. G. Potencial fitoterápico da *Terminalia catappa* na aquicultura: uma revisão. **Revista Brasileira de Plantas Medicinais**, v. 21, n. 3, p. 160-165, 2019. Doi: 10.70151/0fgtad40

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

ALY, S. M. et al. Trials to enhance *Orechromis niloticus* response to *Aeromonas hydrophila* vaccine using immunostimulants (garlic, *Echinacea*) and probiotics (Organic Green™ and Vet-Yeast™). **African Journal of Biotechnology**, v. 21, n. 21, p. 989 - 994, 2016. Doi: 10.5897/AJB2015.15155

ANJUR, N. et al. An update on ornamental fish industry in Malaysia: *Aeromonas hydrophila*-associated disease and its treatment control. **Veterinary World**, v. 14, n. 5, p. 1143 - 1152, 2021. Doi: 10.14202/vetworld.2021.1143-1152

ANTUNES, D.; ALCÂNTARA, B.; SANTOS, E. Diversidade e conservação de peixes neotropicais da Caatinga, Nordeste, Brasil - revisão integrativa. **Revista Multidisciplinar de Educação e Meio Ambiente**, v. 2, 2-3, 2021. Doi: 10.51189/rema/3085

AQUACULTURE BRASIL. 2022. Produção de peixes ornamentais conquista a Zona da Mata. **Aquaculture Brasil**. Disponível em: <https://www.aquaculturebrasil.com/noticia/360/piscicultura-ornamental:-um-mar-de-infinitas-possibilidades>. Acesso em: 23 set 2024.

ARAUJO, D. M. et al. Apparent digestibility coefficient of proteic and energetic ingredients for goldfish. **Ensaios e Ciência: Ciências Biológicas, Agrárias e da Saúde**, v. 24, n. 1, p. 16-21, 2020. Doi: 10.17921/1415-6938.2020v24n1p16-21

ARMANDO, F. et al. Peripheral nerve sheath tumors resembling human atypical neurofibroma in goldfish (*Carassius auratus*, Linnaeus, 1758). **Animals**, v. 11, n. 9, p. 2621, 2021. Doi: 10.3390/ani11092621

BARCELLOS, L. J. G. et al. The effects of stocking density and social interaction on acute stress response in Nile tilapia (*Oreochromis niloticus*). **Aquaculture Research**, v. p. 283-289, 2008. Doi: 10.1046/j.1365-2109.1999.00419

BELINA, M. C.; LOPES, J. T.; OLIVEIRA, C. S. Abordagem fitoquímica e farmacológica das folhas de *Terminalia catappa* Linn (Combretaceae). In: Guilherme, W. D. (org). **Desafios e soluções da sociologia.** Ponta Grossa: Atena, 2019, p.15-26. Doi: 10.22533/at.ed.2691925062

BILEN, S. et al. Effects of *Urtica dioica* (stinging nettle) on growth performance, immune system and disease resistance of rainbow trout (*Oncorhynchus mykiss*). **Fish & Shellfish Immunology**, v. 49, p. 174-182, 2016. Doi: 10.1016/j.aquaculture.2015.12.010

BRAZIL. Lei nº 11.959, de 29 de junho de 2009. Dispõe sobre a política nacional de desenvolvimento sustentável da aquicultura e da pesca, regula as atividades pesqueiras, revoga a Lei nº 7.679, de 23 de novembro de 1988, e dispositivos do Decreto-Lei nº 221, de 28 de fevereiro de 1967, e dá outras providências. **Diário Oficial da União**, Brasília, DF, 30 jun. 2009. Disponível em:

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

<https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l11959.htm>. Acesso em: 23 set 2024

BRAZIL. Portal AliceWeb: **Exportação de peixes ornamentais no Brasil entre 2013 e 2017**. Ministério da Indústria, Comércio Exterior e Serviços, 2018. Disponível em: <http://aliceweb.mdic.gov.br>. Acesso em: 23 ago 2023.

BRAZIL. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Aquicultura e Pesca. Portaria SAP/MAPA nº 17, de 26 de janeiro de 2021. Estabelece normas, critérios e padrões para o uso sustentável de peixes nativos de águas continentais, marinhas e estuarinas, com finalidade ornamental e de aquariofilia. **Diário Oficial da União**, Brasília, DF, 27 jan. 2021. Disponível em: <https://www.in.gov.br/en/web/dou/-/portaria-sap/mapa-n-17-de-26-de-janeiro-de-2021-300775558>. Acesso em: 28 abr 2023.

CABELLO, F. C. et al. Aquaculture as yet another environmental gateway to the development and globalisation of antimicrobial resistance. **The Lancet Infectious Diseases**, v. 16, n. 7, p. e127-e133, 2016. Doi: https://doi.org/10.1016/S1473-3099(16)00100-6

CARRIERO, M. M. et al. Characterization of a new strain of *Aeromonas dhakensis* isolated from diseased pacu fish (*Piaractus mesopotamicus*) in Brazil. **Journal of Fish Diseases**, v. 39, n. 11, p. 1285-1295, 2016.
Doi: https://doi.org/10.1111/jfd.12457

CARVALHO, M. N. Workforce in the pharmaceutical services of the primary health care of SUS, Brazil. **Revista de Saúde Pública**, v. 51, suppl. 2, 2017. Doi: 10.11606/S1518-8787.2017051007110

HERNÁNDEZ-HERNÁNDEZ, M. et al. *Oreochromis niloticus* shows a higher prevalence of Betahaemolytic streptococci when are maintained in cages than in ponds. **Abanico Veterinario**, v. 13, p. 1-16, 2023. Doi: http://dx.doi.org/10.21929/abavet2023.19

CHEN, D. et al. The evolutionary origin and domestication history of goldfish (*Carassius auratus*). **Proceedings of the National Academy of Sciences**, v. 117, n. 47, p. 29775-29785, 2020. Doi: https://doi.org/10.1073/pnas.2005545117

CHEN, Y. F. et al. Isolation and characterization of *Aeromonas schubertii* from diseased snakehead, *Channa maculata* (Lacepède). **Journal of Fish Diseases**, v. 35, n. 6, p. 421-430, 2012. Doi: https://doi.org/10.1111/j.1365-2761.2012.01362.x

CHYAU, C.-C.; KO, P.-T.; MAU, J.-L. Antioxidant properties of aqueous extracts from *Terminalia catappa* leaves. **LWT-Food Science and Technology**, v. 39, n. 10, p. 1099-1108, 2006. Doi: https://doi.org/10.1016/j.lwt.2005.07.016

ČÍŽEK, A. et al. Antimicrobial resistance and its genetic determinants in aeromonads isolated in ornamental (koi) carp (*Cyprinus carpio koi*) and common

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

carp (*Cyprinus carpio*). **Veterinary Microbiology**, v. 142, n. 3-4, p. 435-439, 2010. Doi: https://doi.org/10.1016/j.vetmic.2009.10.00

COSTA, M. F.; MAFRA, R. F.; BARBALHO, C. R. Estudos prospectivos das tecnologias e mercados relacionados aos peixes ornamentais. **Cadernos de Prospecção**, v. 17, n. 2, p. 621-638, 2024. Doi: https://doi.org/10.9771/cp.v17i2.56563

CREPALDI, A. L. et al. Triagem fitoquímica, toxicidade e atividade antimicrobiana de diferentes extratos de *Mimosa tenuiflora* sobre cepas de *Aeromonas*. **Semina: Ciências Agrárias**, v. 43, n. 2, p. 641-656, 2019. Doi: https://doi.org/10.5433/1679-0359.2022v43n2p641

DANANJAYA, S. H. et al. Growth performance and color enhancement of goldfish, Carassius auratus, fed diets containing natural dyes extracted from annatto (*Bixa orellana*) seeds. **Journal of Applied Aquaculture**, v. 32, n. 1, p. 53-69, 2020. Doi: https://doi.org/10.1080/10454438.2019.1629371

DECLERCQ, A. M. et al. Columnaris disease in fish: a review with emphasis on bacterial-host interactions. **Veterinary Research**, v. 44, p. 8-10, 2013. Doi: http://www.veterinaryresearch.org/content/44/1/27

DEVI, K. N. et al. In vitro and in vivo efficacy of partially purified herbal extracts against bacterial fish pathogens. **Aquaculture**, v. 458, p. 121-133, 2016. Doi: https://doi.org/10.1016/j.aquaculture.2016.02.035

EKANEM, A. P. et al. Effects of crude extracts of *Mucuna pruriens* (Fabaceae) and *Carica papaya* (Caricaceae) against fish parasitic protozoan *Ichthyophthirius multifiliis*. **Parasitology Research**, v. 92, p. 361–366, 2004. Doi: 10.1007/s00436-003-1038-8

ELALA, N. M.; AFIFI, H. M.; TAHA, H. A. Comparative analysis of *Aeromonas* species isolates. **Letters in Applied Microbiology**, v. 61, p. 429–436, 2015. Doi: 10.1111/lam.12484

ELGENDY, M. Y. et al. Alternative therapies recently applied in controlling farmed fish diseases: mechanisms, challenges, and prospects. **Aquaculture International**, v. 32, p. 9017-9078, 2024. Doi: https://doi.org/10.1007/s10499-024-01603-3

FAO. **Responsible use of antimicrobials in aquaculture**. Food and Agriculture Organization of the United Nations. 2023. https://www.fao.org

FAUZI, N. N. F. N. M. et al. Prevalence, antibiotic susceptibility, and presence of drug resistance genes in *Aeromonas* spp. isolated from freshwater fish in Kelantan and Terengganu states, Malaysia. **Veterinary World**, v. 14, n. 8, p. 2064-2072, 2021. Doi: 10.14202/vetworld.2021.2064-2072

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

FERREIRA, D. A. R. Morpho-molecular identification, pathogenicity for *Piaractus mesopotamicus*, and antimicrobial susceptibility of a virulent *Flavobacterium columnare* isolated from Nile tilapia cultured in Brazil. **Aquaculture**, v. 560, p. 738486, 2022. Doi: https://doi.org/10.1016/j.aquaculture.2022.738486

FIGUERAS, M. J. et al. *Aeromonas intestinalis* and *Aeromonas enterica* isolated from human faeces, *Aeromonas crassostreae* from oyster and *Aeromonas aquatilis* isolated from lake water represent novel species. **New Microbes and New Infections**, v. 15, p. 74-76, 2017. Doi: 10.1016/j.nmni.2016.11.019

GARCÊZ, K. F. **Extrato aquoso da *Samanea tubulosa* (Benth.) Barneby & Grimes na alimentação da tilápia-do-Nilo: efeitos sobre o crescimento, saúde e atividade antioxidante no tecido muscular**. Dissertação (Mestrado em Zootecnia). Universidade Tecnológica Federal do Paraná. Dois Vizinhos. 2021.

GAZAL, L. E. S. et al. Antimicrobials and resistant bacteria in global fish farming and the possible risk for public health. **Arquivos do Instituto Biológico**, v. 87, p. 1-11, 2020. Doi: 10.1590/1808-1657000362019

GONÇALVES, A. J. et al. Antioxidant capacity of *Terminalia catappa* leaves from solvents methanol, ethanol and hexane. **LIPH Science Journal**, v. 4, n. 1, p. 18-26, 2017.

HARIKRISHNAN, R.; BALASUNDARAM, C.; HEO, S. Impact of plant products on innate and adaptive immune system of cultured finfish and shellfish. **Aquaculture**, v. 317, p. 1-15, 2011. Doi: 10.1016/j.aquaculture.2011.03.039

HASHIM, E. F. et al. Evaluation on toxicity level of *Terminalia catappa* leaves extract on selected cyprinids under different bath concentrations. **Pertanika Journal of Tropical Agricultural Science**, v. 43, n. 4, p. 445-456, 2020. Doi: https://doi.org/10.47836/pjtas.43.4.02

HASSAN, M. A. et al. Molecular identification and epizootiology of *Aeromonas veronii* infection among farmed *Oreochromis niloticus* in Eastern Province, KSA. **Egyptian Journal of Aquatic Research**, v. 43, n. 2, p. 161-167, 2017. Doi: https://doi.org/10.1016/j.ejar.2017.06.001

HOAI, T. D. et al. *Aeromonas veronii* caused disease and mortality in channel catfish in Vietnam. **Aquaculture**, v. 5013, p. 734425, 2019. Doi: https://doi.org/10.1016/j.aquaculture.2019.734425

HODAR, A. R. et al. Herbs and phytotherapeutics: A prominent source for sustainable aquaculture. **Journal of Experimental Zoology India**, v. 24, p. 719-732, 2021. Doi: https://connectjournals.com/03895.2021.24.719

HOSEINIFAR, S. H. et al. Sustainable ornamental fish aquaculture: the implication of microbial feed additives. **Animals**, v. 13, n. 10, p. 1583, 2023. Doi: https://doi.org/10.3390/ani13101583

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

HU, Y. et al. Screening of medicinal plants for use against *Dactylogyrus intermedius* (Monogenea) infection in goldfish. **Journal of Aquatic Animal Health**, v. 26, n. 3, p. 127-136, 2014. Doi: https://doi.org/10.1080/08997659.2014.902872

HYLDGAARD, M.; MYGIND, T.; MEYER, R. L. Essential oils in food preservation: mode of action, synergies, and interactions with food matrix components. **Frontiers in Microbiology**, v. 3, art. 12, 2012. Doi: 10.3389/fmicb.2012.00012

JATOBÁ, A. et al. Action time and feed frequency of *Lactobacillus plantarum* for Nile tilapia. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 70, p. 327-332, 2018. Doi: 10.1590/1678-4162-9870

KIMERA, Z. I. et al. Antimicrobial use and resistance in food-producing animals and the environment: an African perspective. **Antimicrobial Resistance & Infection Control**, v. 9, n. 37, p. 1-12, 2020. Doi: https://doi.org/10.1186/s13756-020-0697-x

LIU, C. et al. *Aeromonas shubertia*s a cause of multi-organ necrosis in internal organs of Nile tilapia,*Oreochromis niloticus*. **Journal of Fish Diseases**, v. 41, p. 1529-1538, 2018. Doi: 10.1111/jfd.12848

MEDEIROS, P. B. 2021. **Suplementação alimentar com óleo essencial de *Lippia sidoides* para *Cyprinus carpio* Koi como prevenção contra *Aeromonas hydrophila***. Dissertação (Mestrado em Aquicultura). Universidade Federal de Santa Catarina. Florianópolis. 2021.

MOYSES, C. R. S. et al. Ectocommensal and ectoparasites in goldfish *Carassius auratus* (Linnaeus, 1758) farmed in the State of São Paulo. **Revista Brasileira de Parasitologia Veterinária**, v. 24, n. 3, p. 283-289, 2015. Doi: https://doi.org/10.1590/S1984-29612015054

NOVÁK, J.; KALOUS, L.; PATOKA, J. Modern ornamental aquaculture in Europe: early history of freshwater fish imports. **Reviews in Aquaculture**, v. 12, n. 4, p. 2042-2060, 2020. Doi: https://doi.org/10.1111/raq.12421

NUGROHO, R. A. et al. *Terminalia catappa* L. extract improves survival, hematological profile and resistance to *Aeromonas hydrophila* in *Betta* sp. **Fisheries & Aquatic Life**, v. 25, n. 2, p. 103-115, 2017. Doi: 10.1515/aopf-2017-0010

PAN, T. S. et al. Effects of ten traditional Chinese herbs on immune response and disease resistance of *Sciaenops ocellatus* (Actinopterygii: Perciformes: Sciaenidae). **Acta Ichthyologica et Piscatoria**, v. 43, p. 41-49, 2013. Doi: 10.3750/AIP2013.43.1.06

PANDYA, N. B. et al. Antitumor and antioxidant status of *Terminalia catappa* against Ehrlich ascites carcinoma in Swiss albino mice. **Indian Journal of Pharmacology**, v. 45, n. 5, p. 464-469, 2013. Doi: 10.4103/0253-7613.117754

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

PARKER, J. L.; SHAW, J. G. *Aeromonas* spp. clinical microbiology and disease. **The Journal of Infection,** v. 62, n. 2, p. 109-118, 2011. Doi: https://doi.org/10.1016/j.jinf.2010.12.003

PEDROSO, R. S. ANDRADE, G.; PIRES, R. H. Plantas medicinais: uma abordagem sobre o uso seguro e racional. **Physis: Revista de Saúde Coletiva**, v. 31, n. 2, p. e310218, 2021. Doi: 10.1590/S0103-73312021310218

PEIXOTO, L. J. S. et al. *Aeromonas* spp.: fatores de virulência e perfis de resistência a antimicrobianos e metais pesados. **Arquivos do Instituto Biológico**, v. 79, p. 453-460, 2012.

PEMBERTON, J. M.; KIDD, P. K.; SCHMIDT, R. Secreted enzymes of *Aeromonas*. **FEMS Microbiology Letters**, v. 152, p. 1-10, 1997. Doi: 10.1111/j.1574-6968.1997.tb10401.x

PERCIVAL, S. L.; WILLIAMS, D. W. Chapter Three - *Aeromonas*. In: **Microbiology of Waterborne Diseases**, p. 49–64, 2014. Doi: 10.1016/B978-0-12-415846-7.00003-2

PEREIRA, A. L. F. O. et al. Principais normas que regulamentam a aquicultura no Brasil: uma perspectiva histórica. Aquaculture Brasil. **Revista Aquaculture Brasil**, Ed. 23, abr/jun, 2021.

PESSOA, R. B. G. et al. The genus *Aeromonas*: A general approach. **Microbial Pathogenesis**, v. 130, p. 81-94, 2019. Doi: https://doi.org/10.1016/j.micpath.2019.02.036

RAJ, N. S. et al. *Aeromonas veronii* causou exoftalmia bilateral e mortalidade em massa em tilápia do Nilo cultivada (*Oreochromis niloticus*) na Índia. **Aquaculture**, v. 512, p. 734278, 2019. Doi: https://doi.org/10.1016/j.aquaculture.2019.734278

RAMANAN, S. et al. Tropical almond (*Terminalia catappa*): A holistic review. **Heliyon**, v. 11, p. e41115, 2025. Doi: https://doi.org/10.1016/j.heliyon.2024.e41115

RAN, C. et al. *Aeromonas veronii* and aerolysin are important for the pathogenesis of motile aeromonad septicemia in cyprinid fish. **Environmental Microbiology**, v. 20, n. 9, p. 3442-3456, 2018. Doi: https://doi.org/10.1111/1462-2920.14390

REZENDE, F. P.; FUJIMOTO, R. Y. **Peixes Ornamentais no Brasil - Mercado, legislação, sistemas de produção e sanidade**. Brasília, DF. 2021. 297 p.

ROCHA, C. A. M. et al. A review on occurrence of neoplasia in fish. **Acta of Fisheries and Aquatic Resources**, v. 2, n. 2, p. 19-24, 2017. Doi: 10.2312/Actafish.2017.5.2.19-24

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

SANTOS, E. L. et al. Folha da amendoeira (*Terminalia catappa*) como aditivo promotor de crescimento em rações para alevinos de Tilápia do Nilo (*Oreochromis niloticus*). **Revista Agropecuária Técnica**, v. 1, p. 190-196, 2015. Doi: 10.25066/AGROTEC.V36I1.19295

SEGARAN, G. et al. Phytochemical profiles, in vitro antioxidant, anti inflammatory and antibacterial activities of *Terminalia catappa*. **International Journal Pharmaceutical Sciences Review and Research**, v. 55, n. 2, p. 51-59, 2019.
SEYEDALINAGHI, S. et al. A systematic review on natural products with antimicrobial potential against WHO's priority pathogens. **European Journal of Medical Research**, v. 30, p. 525, 2025. Doi: https://doi.org/10.1186/s40001-025-02717-x

SHAMEENA, P. M. et al. First report of *Aeromonas veronii* as an emerging pathogen causing ulcerative skin lesions in goldfish (*Carassius auratus*) in India. **Aquaculture**, v. 528, p. 735539, 2020. Doi: https://doi.org/10.1016/j.aquaculture.2019.73481

SILVA, D. C.; SOUSA, W. P. E.; COSTA, D. A. F. Phytochemical components and evidence of the antibacterial efficacy of *Terminalia catappa* leaf extracts against *Staphylococcus aureus* strains. **Pesquisa, Sociedade e Desenvolvimento**, v. 9, p. e89691110465, 2020. Doi: 10.33448/rsd-v9i11.10465

SIPAÚBA-TAVARES, L. H.; BACCARIN, A. E.; BRAGA, F. M. S. Limnological parameters and plankton community responses in Nile tilapia ponds under chicken dung and NPK (4-14-8) fertilizers. **Acta Limnologica Brasiliensia**, v. 18, p. 335-346, 2006.

SIQUEIRA, T. V. 2017. Aquicultura: a nova fronteira para aumentar a produção mundial de alimentos de forma sustentável. **Boletim Regional, Urbano e Ambiental**, v. 17, jul./dez., 2017.

SIQUEIRA, M. S. et al. Implicações do extrato de *Erythrina crista-galli* como ansiolítico para *Carassius auratus*. **Ciência Animal Brasileira**, v. 20, p. 1-8, 2019. Doi: 10.1590/1089-6891v20e-50520

SMYRLI, M. et al. Infecção por *Aeromonas veronii* associada a alta morbidade e mortalidade em robalo europeu cultivado *Dicentrarchus labrax* no Mar Egeu, Grécia. **Fish Pathology**, v. 52, n. 2, p. 68-81, 2017. Doi: 10.3147/jsfp.52.68

STRATEV, D. et al. Beneficial effects of medicinal plants in fish diseases. **Aquaculture International**, v. 26, p. 289-308, 2018. Doi: 10.1007/s10499-017-0219-x

TALPUR, A. D.; IKHWANUDDIN, M. Dietary effects of *Azadirachta indica* (neem) leaves on immune response and disease resistance of Asian sea bass, *Lates calcarifer* challenged with *Vibrio harveyi*. **Fish Shellfish Immunology**, v. 34, p. 254-264, 2013. Doi: 10.1016/j.fsi.2012.11.003

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

TANEKHY, M.; FALL, J. Expressão de genes de imunidade inata em camarão kuruma *Marsupenaeus japonicus* após estimulação in vivo com extrato de alho (alicina). **Medicina Veterinária**, v. 60, p. 39-47, 2015. Doi: 10.17221/7924-VETMED

TASNEEM, M. I. F.; NARSEGOWDA, P. N. Antimicrobial activity of different varieties of *Terminalia catappa* leaves. **International Journal of Pharmaceutical Sciences and Research**, v. 9, n. 10, p. 4430-4435, 2018. Doi: http://dx.doi.org/10.13040/IJPSR.0975-8232.9(10).4430-35

THANIGAIVEL, S. et al. Eficácia protetora de extratos de algas marinhas microencapsulados na prevenção de infecções por *Aeromonas* em *Oreochromis mossambicus*. **Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology**, v. 218, p. 36-45, 2019. Doi: 10.1016/j.cbpc.2018.12.011

THOMAS, T. B. et al. Effects of dietary *Andrographis paniculata* extract on growth, haematological, immune responses, immune related genes expression of ornamental goldfish (*Carassius auratus*) and its susceptibility to *Aeromonas hydrophila* infection. **Aquaculture Reports**, v. 33, p. 101850, 2023. Doi: 10.1016/j.aqrep.2023.101850

TRENTIN, M. M. et al. O óleo essencial de gengibre (*Zingiber officinale* Roscoe) e peptídeo sintetizado por *Lactococcus lactis* como agentes antimicrobianos contra *Salmonella* Enteretidis e *Listeria monocytogenes*. **Revista Brasileira de Revisão de Saúde**, v. 3, p. 5381-5391, 2020. Doi: 10.34119/bjhrv3n3-112

UMA, A. et al. PCR detection of putative aerolysin and hemolysin genes in *Aeromonas hydrophila* isolate from infected Koi carp (*Cyprinus carpio*). **Tamilnadu Journal Veterinary & Animal Sciences**, v. 6, n. 1, p. 31-33, 2010.

WANG, X. et al. Recent advances of *Terminalia catappa* and its application in fish culture: A review. **Reviews in Aquaculture**, v. 16, n. 4, p. 1741-1765, 2024. Doi: 10.1111/raq.12920

WATTANURUK, D.; DETRAKSA, J. Effect of herbal plant extracts on inhibition of pathogenic bacteria in Nile tilapia (*Orechromis niloticus*). **Journal of Food Health and Bioenvironmental Science**, v. 16, n. 1, p. 46-53, 2023.

WU, Z. F. et al. In vivo evaluation of anthelmintic potential of medicinal plant extracts against *Dactylogyrus intermedius* (Monogenea) in goldfish (*Carassius auratus*). **International Journal of Pharmaceutical Sciences and Research**, v. 108, n. 6, p. 4430-4435, 2011. Doi: https://doi.org/10.1007/s00436-010-2211-5

YAKUBU, Y. et al. Effect of *Terminalia catappa* methanol leaf extract on nonspecific innate immune responses and disease resistance of red hybrid tilapia against *Streptococcus agalactiae*. **Aquaculture Reports**, v. 18, p. 100555, 2020. Doi: 10.1016/j.aqrep.2020.100555

REMUNOM
ISSN 2178-6925

Received: 22/10/2025 - **Accepted:** 01/11/2025
Vol: 20.01
DOI: 10.61164/f4cay629
Pages: 1-25

ZHANG, D.; XU, D. H.; SHOEMAKER, C. Experimental induction of motile *Aeromonas* septicemia in channel catfish (*Ictalurus punctatus*) by waterborne challenge with virulent *Aeromonas hydrophila*. **Aquaculture Reports**, v. 3, p. 18-23, 2016. Doi: 10.1016/j.aqrep.2015.11.003

ZHANG, X. P. et al. The efficacy of four common anthelmintic drugs and traditional Chinese medicinal plant extracts to control *Dactylogyrus vastator* (Monogenea). **Aquaculture**, v. 420, p. 302-307, 2014. Doi: 10.1016/j.aquaculture.2013.09.022

ZHOU, S. et al. Anthelmintic efficacy of three common disinfectants and extracts from four traditional Chinese medicinal plants against *Gyrodactylus kobayashii* (Monogenea) in goldfish (*Carassius auratus*). **Aquaculture**, v. 466, p. 72-77, 2017. Doi: 10.1016/j.aquaculture.2016.09.048