**HARNESSING THE POTENTIAL OF HERBAL BIOMEDICINES IN AQUACULTURE**

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**Abstract**

Aquaculture stands as a pivotal sector driving global prosperity and well-being by rapidly producing animal food. This chapter explores the historical use of medicinal herbs as immunostimulants over thousands of years. Growing awareness of the adverse impacts of antibiotics has spurred a widespread shift towards natural products. The potential of various extracts from plants and animals as potent immunomodulators, appetite stimulants, anti-stress agents, antioxidants, antibacterial, antifungal, and antiviral agents is evident. These biomedicines also play a role in stimulating development while mitigating the risk of infections that pose threats to both the ecosystem and the health of fish. Despite the conventional use of pesticides and antibiotics for treating illnesses, infections, and pests, their long-term negative effects and biomagnification within fish necessitate the exploration of alternative solutions. Herbal compounds, including phenolics, polyphenols, alkaloids, quinones, terpenoids, lectins, and polypeptides, emerge as highly effective alternatives to antibiotics and synthetic compounds. This chapter reviews into the promising potential of herbal biomedicines in aquaculture, offering sustainable alternatives for fostering growth and ensuring the health of aquatic ecosystems.

**Keywords:**Antioxidant, Anti stress, Antiviral, Appetite Stimulants, Growth promoter,Immunostimulants

**Introduction**

Aquaculture plays a dynamic role in addressing global concerns such as food security, economic stability, and employment opportunities. With a considerable gap between the fish supply from capture fisheries and the escalating demand for fish, aquaculture emerges as a more sustainable alternative. However, the intensive exploitation of capture fishery resources has led to a plateau in fish production.

In the realm of aquaculture, common practices for disease control involve the use of antibiotics and chemotherapeutics. Unfortunately, the widespread application of these preventive measures has detrimental effects on the water environment, contributing to antibiotic-resistant bacterial strains (Done *et al.*, 2015). Recognizing the need for more environmentally friendly prophylactics, there is a growing interest in medicinal plants as a promising preventive measure to uphold fish welfare and ensure a healthy aquatic environment (Bruce, Brown, 2017; Guardiola *et al.*, 2016).

Medicinal plants hold particular promise due to their rich content of biological compounds, including alkaloids, terpenoids, saponins, and flavonoids. These plant-derived elements find widespread use in aquaculture to enhance growth performance, fortify the immune system, and provide antioxidant effects (Reverter *et al.*, 2017). Furthermore, incorporating plant products into the diet is seen as a strategic approach to mitigate risks associated with antibiotic and chemotherapeutic use, representing a crucial step in preventing disease resistance in aquaculture (Nayak, 2010). The increasing reliance on natural products, with a specific emphasis on medicinal plants as substitutes for antibiotics, underscores a positive shift towards more sustainable aquaculture practices.

**Significance of Biomedicines in Aquaculture**

Biomedicines play a crucial role in aquaculture due to the sector's rapid growth and intensification, leading to a stressful environment and disease challenges (Kennedy *et al.*, 2016). In response to the limitations of antibiotics and chemotherapeutics in intensive aquaculture (FAO, 2003), there is a rising interest in immune stimulants, which, unlike vaccines, enhance the innate immune response, providing a potential alternative for disease control (Galeotti, 1998; Sakai, 1999).

Medicinal plants, recognized as immunostimulants for centuries (Tan and Vanitha, 2004), offer a natural and safe alternative to traditional antibiotics and immune prophylactics. These plants, used as feed additives and chemotherapeutics, contain beneficial compounds like phenolics, polyphenolics, alkaloids, quinones, terpenoids, lectins, and polypeptides, serving as effective substitutes for synthetic substances (Harikrishnan *et al.*, 2011).

Numerous studies highlight the positive impact of herbal components in fish diets, presenting cost-effective and eco-friendly alternatives with fewer adverse effects on both fish and consumers. Plant extracts exhibit antipathogenic, stress-relieving, appetite-stimulating, tonicity- and immunostimulation-enhancing, maturation-facilitating, and maturation-promoting effects on fish (Reverter *et al.*, 2014). Herbal fish diets are associated with improved immune system efficiency (Dügenci and Candan, 2003; Dügenci *et al.*, 2003; Bai *et al.*, 2009), heightened stress tolerance (Ji *et al.*, 2009) and enhanced growth performance (Ji *et al.*, 2007; Dada, 2012).

**Fish Immunity through Immunostimulants**

Immunostimulants, encompassing chemicals, medications, or activities, fortify the immune system in animals, bolstering their innate defenses against pathogens. Dietary supplementation with immunostimulants elevates critical markers such as myeloperoxidase, phagocytic activity, serum lysozyme, and NBT, offering insights into non-specific defense mechanisms in fish. Studies by Yin*et al.* (2006) and Ardo *et al.* (2008) revealed heightened phagocytic and lysozyme activities in tilapia fed with *Astragalus radix* and Lonicera extracts.

Various studies, including Celik *et al.* (2017), Bilen *et al.* (2018), and Aline *et al.* (2017), demonstrated lysozyme activity induction in rainbow trout, common carp, and tilapia with black cumin, garden cress, dill, and clove basil supplementation. Conversely, Barroso *et al.* (2014) noted lymphocyte reduction in sole challenged with *Photobacterium damselae*.

Studies on Indian major carp, common carp, Zebrafish, and rainbow trout, as conducted by Srivastava *et al.* (2018), Yousefi *et al.* (2019), Ahmadifar *et al.* (2019), Mehrabi *et al.* (2019), and others, showed increased lysozyme activity. Feeding gilthead seabream with fenugreek seeds and leaf extracts elevated fish serine peroxidase activity (Beltrán *et al.*, 2018; Guardiola *et al.*, 2018).

Significantly, dietary administration of gotu kola powder (Naphakorn Srichaiyo *et al.*, 2020), and coriander seed extract (Farsani *et al.*, 2019), induced heightened phagocytic ability and respiratory burst in various fish species. *Oncorhynchus mykiss*exhibited elevated serum immunoglobulin levels and gene expression after coriander powder supplementation (Safari *et al.*, 2019). These findings underscore the diverse and potent immunostimulatory effects of herbal compounds in aquaculture.

**Herbal Growth Promotion and Appetite Stimulation in Aquaculture**

Research in aquaculture highlights the effectiveness of medicinal plants in influencing the growth parameters of fishes (Rao *et al.*, 2006; Palacios *et al.*, 2006; Aly *et al.*, 2008). Studies on common carp (*Cyprinus carpio*) and tilapia (*Oreochromis niloticus*) revealed that incorporating Quillaja saponin plant in the feed enhances specific growth rate, protein efficiency ratio, lipid utilization, and energy utilization, while reducing feed conversion ratio (Francis *et al.*, 2001; Francis *et al.*, 2002a; Francis *et al.*, 2002b). Various herbs, including *Coriandrum sativum, Curcuma longa, Zingiber officinale, Rosmarinus officinale,* and *Allium cepa,* have been employed in aquaculture studies.

After 60 days, Nile tilapia fed diets containing 400, 800, and 1200 mg of vegetable choline per kilogram of feed showed increased live weight, weight gain, corporal length, and feed intake, as reported by Matheus *et al.* (2019). In a study by Luo *et al.* (2016), supplementing yellow catfish (*Pelteobagrus fulvidraco*) with 1156.4 mg of vegetable choline per kilogram of feed for 60 days resulted in enhanced weight gain, specific growth rate, and feed intake. Esin Baba *et al.* (2017) conducted a 45-day study in which Nile tilapia was fed diets containing 0.5%, 1%, and 2% argan oil. The findings demonstrated that argan oil stimulated certain aspects of the non-specific immune system in Nile tilapia during both the pre- and post-challenge periods.

According to Esin *et al.* (2017), Nile tilapia were fed diets containing 0.5%, 1%, and 2% argan oil for 45 days. The findings demonstrated that argan oil stimulated certain aspects of the non-specific immune system in Nile tilapia during both the pre- and post-challenge periods. Additionally, it enhanced the rate of survival and growth performance against *Lactococcus garvieae*. Farsani *et al.* (2019) observed a noteworthy rise in the specific growth rate and final weight of *O. mykiss* that were fed diets supplemented with 2% coriander seed extract (CSE) for eight weeks. According to Anle Xu *et al.* (2020), the Chinese herbal medicine mixture significantly affected the growth performance of *Lateolabraxjaponicus*, with Fish Weight (FW), Weight Gain (WG), and Specific Growth Rate (SGR) increasing at 20 g/kg and FCR decreasing.

According to Hassan *et al.* (2018), supplementing Nile tilapia (*O. niloticus*) with 1% rosemary increased weight gain, SGR and protein efficiency ratio significantly but had no effect on carcass composition. According to Safari *et al.* (2019), a diet containing 20–25 g/kg of ferula powder could enhance the growth performance of Koi carp (*C. carpio koi*). According to Hien*et al.* (2019) adding 5 g kg−1*Elephantopusscaber* to the diet considerably increased the WG and SGR of Nile tilapia while simultaneously lowering FCR. According to Aline Brum *et al.* (2017), feeding Nile tilapia (*O. niloticus*) essential oil of clove basil has improved the feeding conversion ratio and weight gain at 0.5%.African catfish fed a 1.5% bay laurel extract diet showed noticeably faster growth than fish fed a 0.5, 1%, or control group among the groups supplemented with bay laurel extract (Funda *et al.*, 2016).Results by Majid et al. (2018) showed that common carp fed diet containing 2% bay laurel extract had the highest specific growth rate and daily growth rate compared to fish fed diet containing 1%, 3% and control groups. According to Mohsen Ali et al. (2017), adding ajwain and marjoram extracts at a rate of 1-2% could considerably raise (P <.05) a number of growth factors in rainbow trout, such as (Body Weight Index) BWI, Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Length Gain (LG) and Condition Factor (CF) as well as lower the economic conversion ratio (ECR) following active feeding.

As an alternative to antibiotic growth promoters in the broiler diet, the addition of 0.2% soaked ajwain seed could improve nutrient absorption, enhance gut micro-flora and increase digestibility (Amar et al., 2017). The effects of feeding rainbow trout (O. mykiss) diets containing garlic extract were examined by Etyemez et al. (2018). They discovered that the fish's specific growth rate and weight gain were considerably enhanced when they were fed the diets containing garlic.

The Antioxidant Role of Herbal Drugs in Relieving Oxidative Stress in Fish

Antioxidant properties of herbal drugs play a crucial role in helping living organisms manage oxidative stress caused by free radicals. Free radicals, characterized by their extreme instability due to one or more unpaired electrons, engage in electron extraction from other molecules to attain stability. Numerous chemical compounds present in plants exhibit antioxidative properties, assisting organisms in dealing with oxidative stress induced by damage from free radicals. This process contributes to enhancing the overall physiological well-being of fish (Ali et al., 2008; Chakraborty and Hancz, 2011).

According to Hiam Elabd *et al.* (2016) after a week of starvation of *Astragalus membranaceus* and liquorice in yellow perch (*Perca flavescens*), the activities of glutathione peroxidase (GPx) and lipid peroxidase (LPx) were significantly elevated while those of superoxide dismutase (SOD) and catalase (CAT) were significantly decreased. According to Zahran *et al.* (2014), feeding *O. niloticus* Astragalus polysaccharides as a dietary supplement decreased the activities of SOD and GPx.In Nile tilapia, *O. niloticus* fed diets enriched with cinnamon nanoparticles, Mohsen Abdel *et al.* (2018) reported that the dietary particles evoked antioxidant activity wherein MDA level and activities of SOD and CAT increased significantly, whereas GPx decreased significantly. In Nile tilapia fed diets enriched with cinnamon nanoparticles, Mohsen Abdel *et al.* (2018) reported that the dietary particles evoked antioxidant activity wherein MDA level and activities of SOD and CAT increased significantly, whereas GPx decreased significantly. Al-Sagheer *et al.* (2017) found that supplementing Nile tilapia with 200 mg lemongrass and 400 mg geranium/kg−1 diet led to a notable increase in both enzymatic (CAT) and reduced glutathione nonenzymatic (GSH) antioxidants, as well as a notable decrease in MDA levels. Wang *et al.* (2018) showed that supplementing Chinese herbal medicines mixtures increased the antioxidant capacity of Japanese seabass, *L. japonicus*, as evidenced by higher activities of total antioxidant capacity (T-AOC), SOD and CAT.According to Nazeri *et al.* (2017) *O. mykiss* exhibited the highest CAT enzyme activity when fed a diet containing rutin. In common carp fed a diet supplemented with extracts from palm fruits, antioxidant gene expression, including SOD and CAT, was higher than in the control diet (Hoseinifar *et al.*, 2017b).

**Herbal Extracts: Alleviating Stress in Aquatic Organisms through Antistress Activity**

Herbal drugs play a pivotal role in counteracting stress in aquatic organisms by scavenging free radicals and inhibiting the production of oxygen anions. Various herbs, such as *Piper longum, Emblica officinalis, Asparagus racemosus, Ocimum sanctum, Withania somnifera*, and *Tribulus terrestris*, are recognized for their adaptogenic and anabolic properties, along with the ability to boost vital energy. Notably, *Picrorhiza kurro*a is employed in shrimp stress treatment, exhibiting similarities to xanthine oxidase inhibitors, metal-ion chelators, and superoxide dismutase (Citarasu *et al.*, 1998). Additionally, the bioflavonoid rutin, derived from *Toona sinensis*, demonstrates robust antistress and antioxidant properties in crustaceans. Research by Hsieh *et al.* (2008) indicates that rutin enhances biochemical, immunological, and hematological responses in *Litopenaeus vannamei* under stress induced by *Vibrio alginolyticus.*

Wu *et al.*(2007) found that feeding common carp (*C. carpio*) a diet containing 0.3 g/kg Qompsell extract decreased stress and stimulated immunological parameters like serum lysozyme activity, nitric oxide synthase (NOS), superoxide dismutase (SOD) and levels of albumin, globulin and total serum protein. When exposed to *Aeromonas hydrophila*, the Chinese medicinal herbs *A. membranaceus* and *L****.*** *japonica,* at 0.1% each and in combination with and without boron 0.05% in diet, enhanced the non-specific immune response in Nile tilapia (*O. niloticus*) (Ardo *et al.*, 2008). In Ayurveda, *Tinospora cordifolia*, also known as Guduchi, is a well-known anti-stress herb (Mittal *et al.*, 2014).According to Liu *et al.* (2012), anthraquinone extract and emodin from *Rheum officinale* may have an impact on *Megalobrama amblycephala's* disease resistance and physiological response to high temperatures. According to numerous studies (*Pawar et al.*, 2011; Castro *et al.*, 2008; Otero-Ferrer *et al.*, 2010), clove oil is a proven way to lessen stress during handling, transport and confinement. According to Jeyagoby *et al.* (2015), clove extract can be used as a safe and effective substitute to induce anesthesia and ensure full recovery after treatment. Feeding anthraquinone extract (1%–2%) to common carp reduced the negative effects of crowding stress (Xie *et al.*, 2008).Researchers found that anthraquinone extract enhanced the freshwater shrimp *M. rosenbergii's* ability to withstand high temperatures, while *Moringa oleifera* leaf extract enhanced the shrimp's ability to withstand ammonia stress (Kaleo IV *et al.*, 2019; Liu B, X *et al.*, 2008).

**Herbal drugs act as antiviral agent**

Several plant products have potent antiviral activity against fish and shrimp viruses. . Methanol extracts of five different herbal medicinal plants, such as *Cynodon dactylon*, *Aegle marmelos, Tinsospora cordifolia, Picrorhiza kurroa* and *Eclipta alba*, were incorporated into a diet for WSSV-infected shrimp. In other studies, *Penaeusmonodon* treated with an aqueous extract of Bermuda grass (*C. dactylon*) orally or intramuscularly showed no mortality against WSSV while the control group experienced 100% mortality (Balasubramania *et al.*, 2007).Strong antiviral activity against WSSV in P. monodon was demonstrated by Indian traditional medicinal plants, including *A. marmelos, C. dactylon, L. camara, M. charantia*, and *P. amarus* (Balasubramanian *et al.*, 2007).At a concentration of 100 mg kg-1 of animal body, the aqueous extract of *C. dactylon* demonstrated the strongest antiviral activity among the plants (Balasubramanian *et al.*, 2007).

**Harnessing Herbal Power: Antiviral Properties against Fish and Shrimp Viruses**

Herbal drugs emerge as potent antiviral agents combating fish and shrimp viruses. Methanol extracts from five medicinal plants*,C. dactylon, A. marmelos, Tinospora cordifolia, Picrorhiza kurroa, and Eclipta alba*were integrated into the diet of WSSV-infected shrimp, showcasing significant antiviral activity. Notably, P. monodon treated with an aqueous Bermuda grass (*C. dactylon*) extract, either orally or intramuscularly, exhibited zero mortality against WSSV, in stark contrast to the 100% mortality in the control group (Balasubramanian *et al.*, 2007). Traditional Indian medicinal plants, including *A. marmelos, C. dactylon, L. camara, M. charantia, and P. amarus,* displayed robust antiviral activity against WSSV in *P. monodon*. The aqueous extract of *C. dactylon*, at a concentration of 100 mg kg-1 of animal body, demonstrated the highest antiviral efficacy among the tested plants (Balasubramanian *et al.*, 2007).

The active compounds found in herbs have the potential to inhibit or block the transcription of the virus, thereby reducing its replication in host cells and boosting non-specific immunity. They boost the host immune system's capacity. Numerous bioactive compounds found in various ethanolic and methanolic herbal extracts have the ability to inhibit or block the synthesis of viral mRNA, thereby reducing viral replication in host cells and enhancing non-specific immunity. Harikrishnan *et al.* (2010a) showed that the herbal leaf extract of *Punica granatum* improved innate immune responses and disease resistance against lymphocystis viruses in Olive flounder, *Paralichthys olivaceus*.Active ingredients in medicinal plants prevent virus transcription, lessen its ability to replicate in host cells and boost the host's innate immune response (Syahidah *et al.*, 2015).Tiger grouper, *Epinephelus fuscoguttatus*, is protected from iridovirus infection by immersion of herbal solution (AquaHerb©) at 20 mg/l (Novriadi and Haw, 2015).The plant's antiviral activity was assessed in the literature using extract, fraction, and compound forms (Zitterl *et al.*, 2020).

**Herbal Guardians: Unleashing Antifungal Powers**

Herbal drugs exhibit remarkable antifungal activity, disrupting fungal cell walls, modifying membrane permeability, influencing metabolism, and inhibiting protein synthesis, ultimately leading to fungal cell death. Hashemi *et al.* (2011) highlighted the inhibitory effect of ethanol extracts from common rue (*Ruta graveolens*) on Saprolegnia sp., underscoring its potent antifungal properties. Investigating the phytochemical composition, antifungal, anti-aflatoxigenic, antioxidant, and anticancer properties, Ali (2013) explored essential oils from *Glycyrrhiza glabra* and *Matricaria chamomilla* Ten traditional Chinese medicinal plants, including *Cnidium monnieri, Magnolia officinalis, and Aucklandia lappa*, exhibited robust inhibitory effects on fungal species, particularly Saprolegnia and *Achlya klebsiana* (Xue *et al.*, 2017). Noteworthy antifungal activity was observed in petroleum ether extracts from *Cnidium monnieri, Magnolia officinalis, and Aucklandia lappa* bark (Wu *et al.*, 2011). Red algae *Asparagopsis taxiformis* demonstrated antifungal prowess against Aspergillus species (Wu *et al.*, 2011). Additionally, the use of Euphorbiaceae (*Euphorbia fischeriana*) and *Magnolia officinalis* produced a potent antifungal effect against Saprolegnia sp. (Huang *et al.*, 2015).

**Unveiling Nature's Elixir: Herbal Aphrodisiacs for Enhanced Reproduction**

Herbal drugs, recognized for their diverse therapeutic properties, also wield the power to act as potent aphrodisiacs, influencing reproductive processes and hormonal balance. Babu (1999) discovered that a maturation diet enriched with extracts from *W. somnifera, Mucuna pruita, Ferula asafoetida,* and *Piper longum* significantly increased fecundity and gonadal weight in black tiger shrimp, reducing intermolt periods compared to controls. *Asparagus racemosus, i*n conjunction with 5% rice bran, was observed to promote reproduction and enhance sexual parameters in *A. franciscana* (Devi 1995). Furthermore, Lin-Cabello *et al.* (2004) reported accelerated maturation in crayfish (*Cherax quadrucarinatus*) when fed a diet containing plant carotenoids, vegetable oils, and vitamin A.

Citarasu T. (2010) highlighted the efficacy of a herbal product, reprotism, in enhancing reproductive performance in Artemia franciscana. The addition of retinol palmitate exhibited a profound inductive effect on the primary vitellogenic phase and indicators of ontogenic oocyte development. These findings underscore the potential of herbal interventions in fostering reproductive vitality across various aquatic species.

**Empowering Aquaculture through Indigenous Wisdom**

Harnessing the potential of herbal biomedicines in aquaculture necessitates the incorporation of indigenous technical knowledge from local communities. Future research should prioritize collaborative endeavors with these communities to document traditional practices and remedies. Integrating indigenous knowledge ensures a contextual understanding of the environment, species, and practices, offering valuable insights into effective herbal solutions. Collaborative research projects should engage local practitioners, combining their wisdom with scientific methodologies to identify, validate, and optimize herbal interventions. This approach not only respects cultural diversity but also promotes sustainable practices rooted in local traditions. By embracing indigenous technical knowledge, research can bridge the gap between traditional wisdom and modern aquaculture, fostering a harmonious coexistence that benefits both ecosystems and local communities. This inclusive approach holds the key to unlocking the full potential of herbal biomedicines while fostering community-led sustainable aquaculture practices.

**Conclusion**

The diverse array of active ingredients found in herbal biomedicines, encompassing alkaloids, flavonoids, pigments, phenolics, terpenoids, starch, steroids, and essential oils, embodies a rich source of biomedical properties that significantly benefit aquaculture. These inherent properties, including growth promotion, immune system tonicity, appetite stimulation, and antistress effects, present a holistic approach to enhancing the overall health and performance of aquatic species. Harnessing the potential of herbal biomedicines in aquaculture not only addresses concerns related to the cost and adverse effects associated with synthetic compounds but also contributes to the broader goal of fostering environmental sustainability.

The use of alternative herbal biomedicines emerges as a promising strategy, showcasing remarkable efficacy in aquaculture applications. Beyond their therapeutic potential, herbal extracts play a pivotal role in disease prevention and growth optimization. The multifaceted benefits offered by herbal biomedicines underscore their significance in promoting a balanced and resilient aquaculture ecosystem.

As we look ahead, further research into the optimal utilization of these herbal remedies, coupled with the integration of indigenous technical knowledge from local communities, holds the key to unlocking even greater potential. Embracing herbal biomedicines in aquaculture not only aligns with the principles of sustainable practices but also marks a progressive stride toward healthier and more environmentally conscious aquatic farming methodologies.

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