DOI: 10.54083/ResBio/6.4.2024/161-166 *Res. Bio.*, 2024, 6(4):161-166

Research Biotica

e-ISSN: 2582-6743
October-December, 2024

Article ID: RB247 Review Article

Herbal Feed Additives with Feed Attractant and Stimulant Effect: The Potential New Avenue for Aquafeed

Annadurai Veeradharsan[1], Udipta Roy[2], Kamlesh Kumar[2], Barkha Asthana[2], Vikash Kumar[2] and MD Aklakur[2*]

[1]*Dept. of Fisheries Science, Alagappa University, Karaikudi, Tamil Nadu (630 003), India*
[2]*Regional Research & Training Centre (RRTC), ICAR-CIFE, Motipur, Muzaffarpur, Bihar (843 111), India*

Corresponding Author
MD Aklakur
✉: mdaklakur23@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Veeradharsan, A., Roy, U., Kumar, K., *et al*., 2024. Herbal Feed Additives with Feed Attractant and Stimulant Effect: The Potential New Avenue for Aquafeed. *Research Biotica* 6(4), 161-166. DOI: 10.54083/ResBio/6.4.2024/161-166.

Abstract

The global fish production is estimated at 178 million tonnes, out of which 88 million tonnes were from aquaculture. Capture fisheries have been stagnant in recent years. To fulfil the global demand, many countries are adopting advanced aquaculture practices to improve production. Fish feed is one of the essential and primary components in the aquaculture sector. To optimize the feeding performance of fish, various chemical additives are being incorporated. Despite its effectiveness, differential effects of additives are recorded. Consumers' concern for natural food has made an impact on the adoption of herbs as a preferable aquafeed additive. Using herbs as an efficient feed additive may help achieve the intended outcomes than other commercially sold chemical additives. Herbs are available at a low price and can act as effective additives and prophylactics in the aquafeed, with growth-supporting possibilities. Herbs are presumed to include several bioactive substances like phenolics, alkaloids, glycosides, flavonoids, terpenoids, saponins, tannins and steroids, which might assist in improving several physiological features, including feed intake, antioxidant capacity, growth, shelf life and raising the immunological activation. This article explains the current status of herbs and their inclusion in the aquaculture nutrition sector and their performance as an aquafeed additive. The use of herbs in aquafeed might assist in replacing chemical additions and fostering economical and sustainable production.

Keywords: Aquaculture, Aquafeed, Attractant, Feed additives, Herbals, Stimulant

Introduction

Aquaculture fish production accounted for 49% of 178 million tonnes of combined global fish production in 2020. Fish consumption per capita has increased to 20.5 kg in 2019 from 1961's 9 kg, with a growth rate of 1.4% annually. Fish, being a cheap and affordable source of protein, is easily digestible and highly nutritious, that contributes a prime share to the food basket globally. Aquaculture is a pivotal sector offering a major supply to global fish production, as the marine capture fishery has stagnated over the years. Aquaculture products provide essential nutrients and animal protein and their rapid increase in production in the last three decades has exhibited the demand and further growth of the sector is crucial to support the arising global population, which is by 2050 anticipated to achieve 9 billion (Awad and Awaad, 2017; Jana *et al.*, 2018). Herbs show more inherent biological activity than other compounds due to their rich source of secondary metabolites (SM) like essential oils, polypeptides and polysaccharides. Plants and herbs are naturally occurring compounds that are preferred over chemical compounds for the enhancement of overall animal health and to ensure the consumer's concerns as well. Herbs add flavour to animal feed and thereby affect the digestive fluid secretion, eating patterns, total feed intake of the animal and influence the digestion differently due to numerous active components (Tadese *et al.*, 2022). Bioactive components that exist in herbs are extensively used

Article History
RECEIVED on 20th August 2024 RECEIVED in revised form 06th December 2024 ACCEPTED in final form 13th December 2024

in drug development. In aquaculture, herbs don't play a role as chemotherapeutics alone, but also as an effective feed additive, since they contain various nutrients and chemical compounds. It offers enhanced growth and protection simultaneously. In the aquaculture industry, easy access and cheap price of plant and herbal products are the major supporting features for their preference and multi-scale use. They are being utilized either in extract, crude, or active compound forms, sometimes they may be incorporated with probiotics or animal products for better results (Awad and Awaad, 2017).

History of Herbs

Plants have been employed as conventional drugs for centuries, initially in crude form preparations and later evolved as pure active principles (Asimi and Sahu, 2013). The medicinal use of plants was discovered thousands of years ago. The knowledge of herbs steadily spread to Mesopotamia, Persia, India, Egypt and the Eastern Mediterranean, then to Greece and Europe (Jones, 1996). India is the thriving origin for conventional medicines, which are predominantly from plants. India has a plant species of around 45,000 that possess therapeutic effects (Parkash *et al.*, 2018). Nearly 6000 plant varieties in India were used in traditional, folk and herbal medicine (Parkash *et al.*, 2018). Most herbal medicines have active components that are responsible for diverse biological activities (Asimi and Sahu, 2013). India holds a prosperous diversity of herbs, which makes it an efficient platform for herb-involved aquaculture practices (Anne Rebecca, 2014). Herbs are integrated into aquaculture systems as an effective chemotherapeutics and feed additives (Van Hai, 2015). Their potential use as a feed attractant is yet to be explored as an option for immunity and disease resistance in fish species reared under aquaculture.

Herbs in Aquaculture

Among the phytobiotics, Rotenone is a medicinal herb that has been predominantly used to kill fish in shrimp ponds, due to its highly toxic effect on fish; even a mild concentration is enough to kill a fish (Direkbusarakom, 2004). Saini *et al.* (2018) reported that clove oil of 0.02 ppm appeared to be an operative and risk-free anaesthetic for safer use on food fishes. The World Health Organisation encourages the incorporation of medicinal herbs in the aquaculture industry to minimize chemical usage (Dada, 2019). Due to the chances of drug resistance, environmental effects and consumer preferences, the employment of antibiotics and numerous other synthetic drugs is increasingly limited in the aquaculture industry, which has eventually increased the dependence on phytobiotics as alternatives in commercial use (Anne Rebecca, 2014). Herbs have several beneficial properties as they help in inducing protein synthesis in fish, which occurs during the transcription process due to their growth-promoting character (Radhakrishnan *et al.*, 2015). Plants or their residual products contain phenolic compounds, which can effectively substitute antibiotics, vaccines and several other compounds that were being incorporated in the aquaculture sector. These can be included in the diet as a whole plant or as extract compounds, feed attractants, or as a prebiotic blend, or as diverse immunostimulants (Van Hai, 2015). Herbs having low prices and beneficial effects with fewer side effects compared to synthetic or chemical additives influenced the aquafarmers and aqua-entrepreneurs to supplement herbal products in aquaculture systems to promote animal health and production.

Herbs as Aquafeed Additive

Additives are the compounds that can be included in the feed to elevate the effectiveness and intestinal nutrient assimilation, along with other physiological benefits to the experimental animal (Ahmadifar *et al.*, 2021). There is a further requirement for research to understand the novel feed additives and their inclusion in fish feeds (Ogunkalu, 2019). Natural feed additives are found to be beneficial compared to other classical chemicals and synthetic feed additives due to their non-accumulative nature (El-Dakar *et al.*, 2008). Hence, natural additives incorporation in the aquaculture sector has significantly increased and among them, herbal plants are consistently preferred as a risk-free and environment-friendly alternative to chemical additives. They have been used extensively in aquaculture due to their affordable cost and simple use. Mint oil extract improves health and the length of the intestine and intestinal villi, respectively (Mathew *et al.*, 2025). The presence of various bioactive compounds in herbs might be mirrored in the biological activities of the dietary supplements that contain herbs (Orso *et al.*, 2022). Herbs commonly known as phytobiotics, are plant-based products that can be incorporated into the feed to enhance the performance of animals (Kumar *et al.*, 2020). Dada (2019) indicated the promising potential of herbs and their derivatives in the aqua diet, which influenced the aqua feed manufacturers to supplement the herbs and herbal extracts in the aqua diet and also reported that herbs in the diet promote the growth, feed intake and survival rate of fingerlings of *Oreochromis niloticus*. The inclusion of feed additives in aquafeed at optimal doses and oral administration to the aquatic animals is an appropriate strategy to be followed in the aquaculture industry. Aquafeed can be provided with additives such as herbal substances, probiotics and prebiotics, which support the overall wellness of aquatic animals (Wei *et al.*, 2022; Barad *et al.*, 2024). The medicinal plants and their essences in aquafeed eventually lead to the involvement of multiple functions related to active metabolites and compounds. Extracts of plants contribute a significant role as appetite stimulators, growth enhancers and immuno-stimulators for aquatic animals (Dawood *et al.*, 2022); thus, phytobiotics can be used as a good feed stimulant. Parts of the plant have been incorporated as whole feed additives for a long time. Different parts of the herb, such as leaf, flower and rhizome, can be used in multiple forms, which helps to regulate the biological function of an animal (*e.g.*, growth enhancer, anti-stress agent, immunostimulant, appetite stimulator and antibiotic properties) (Ivanova *et al.*, 2024; Wang *et al.*, 2024). They help to protect the animals from extrinsic stressors such as degraded water quality, high ambient

temperature and overstocking (Tadese *et al.*, 2022). Lately, medicinal herbs have become more prominent as natural additives in health management and growth promotion in fish (Sonmez *et al.*, 2015). Plant-based feed additives incorporation in the diet of *C. carpio* is a new potential avenue for improving feed and nutrient utilization, leading to enhanced growth and immunity (Kuebutornye *et al.*, 2024). The plant-based additives' effect improves the feed efficiency, which enables aquafarmers to attain maximum possible performance in health, growth, reproduction and feeding efficiency (Dada and Sonibare, 2015; Hossain *et al.*, 2024; Kuebutornye *et al.*, 2024). Ogunkalu (2019) indicated a positive increase in specific growth rate when garlic was included in the *Oreochromis niloticus* diet. Black cumin oil inclusion in the diet of rainbow trout didn't affect the shelf life of fish negatively and also inhibited the microbial spoilage (Öz *et al.*, 2017). A combination of medicinal plant supplementation in aquafeed is found to be effective in combating immunological issues, supplementing nutrient insufficiency and adding phytochemicals to the diet (Ogunkalu, 2019). Though, further researches need to be conducted to standardize the dosage and understand the effects related to anti-nutritional factors of herbs and their associated toxicity in fish.

Herb as a Feed Attractant

Feed attractants help in quick feed consumption, therefore stimulating growth and survival. Several plant materials were used for exciting or attracting fish while angling and harvesting by traditional farmers in India (Venkateshwarlu *et al.*, 2009). Locally available herbs that were used in Venkateshwarlu *et al.* (2009) experiment listed as Ekangi, Jatamansi, Latkhandhana, Jayatri, Lataka, Kakla, Sturi, Bhuski, Aobel, Kharbar and Tambal. Each herb was powdered at 1% and made dough with starch then placed in compartments for evaluation against the control group and betaine (commercial attractant) group on *M. rosenbergii* and IMCs, which were procured and acclimatized for 20 days. The result of the study showed high feed attractant activity of herbs.

Table 1: Attractant activity of different herbs on *M. rosenbergii* (Venkateshwarlu *et al*., 2009)

Sl. No.	Herbs		Percentage of the attractant activity of animals on various herbs
	Local name	Scientific name	
1	Control	-	6±1.14
2	Betaine	-	14±2.86
3	Aobel	Unknown	11±2.37
4	Bhuski	Unknown	36±2.88
5	Ekangi	*Kaempferia galanga*	33±2.88
6	Jatamansi	*Nardostachys jatamansi*	11±2.37
7	Kakla	*Piper cubeba*	26±2.88
8	Lataka	*Abelmoschus moschatus*	13±2.88
9	Tambel	Unknown	16±2.88

According to Venkateshwarlu *et al.* (2009) attractant activity of herbs is species-specific and among IMC, Catla is highly attracted to Latkhandara, Rohu is highly attracted to Kakla and Mrigal is highly attracted to Kharbaz. In conclusion, freshwater prawns (*M. rosenbergii*) are highly attracted to Bhuski at a rate of 36% and to Ekangi at a rate of 33%, respectively when compared to the betaine (commercial attractant) and Control groups (Table 1). In another species, Paul *et al.* (2014) experimented on *Cirrhinus mrigala* fingerlings for 60 days with plant-based feed attractants. *Cuscuta reflexa*, Awbel, Kharboj, Tambul, *Cucumis melo*, *Zanthoxylum acanthopodium*, *Piper cubeba*, Chotokakla, *Myristica fragrans and* Jayatri, were incorporated at 1% inclusion level in the diet. The result concluded that the inclusion of 1% of Awbel, *Cuscuta reflexa* can be used as a good attractant due to the better performance in growth and consumption of feed. Similarly, El-Dakar *et al.* (2008) reported a study of the attractant effect on *Oreochromis niloticus × Oreochromis aureus*, hybrid tilapia supplemented with dried basil leaves. Basil leaves inclusion is at the levels 0, 0.5, 1 and 2% and fed to the hybrid tilapia for 112 days (6 days a week) which resulted, increased basil leaf levels found to reduce the feed waste percent, which is around 33.48% in the control diet whereas in the 2% dried basil leave diet it was around 8.43%.

Herbs as a Feed Stimulant

Medicinal plants are involved in various biological activities, including feed stimulation such as growth stimulation, immune stimulation, antioxidant stimulation, appetite stimulation, anti-stress and antimicrobial activity in fish. Alkaloids, phenolics, steroids, terpenoids, saponins, glycosides, tannins and flavonoids are principal active components that help the herb to achieve these modes of activity (Awad and Awaad, 2017).

Growth Stimulation

Growth performance, nutrient utilization, protein efficiency, physiological parameters and feed conversion were improved when tilapia were fed with fresh fenugreek meal (*T. foenum-graecum*), Fenugreek sprouts (*Trigonella foenum-graecum*), Chamomile flowers (*Matricaria recutita Lat*), Eucalyptus (*Eucalyptus citriodora*), hot pepper meal (*Capsicum frutescens L.* var. *abbreviatum*) and Thyme seeds (*Thymus vulgaris*) meal. Administering dosage, mode and

route are key factors that affect medicinal plant efficiency (Kuebutoryne and Abarike, 2020). Rainbow trout showed the best growth performance when fed with thyme essential oil diet at different dose concentration levels (0.05, 0.1 and 0.2%), which helped in improving specific growth rate, weight gain and feed intake at a minimum (0.05%) dosage. Rosemary leaf powder positively increased the growth, feed intake and conversion in a dose-dependent manner in Common carp fingerlings. Supplementation of thyme improved the Sturgeon growth at a concentration of 2% inclusion (Orso *et al.*, 2022). In another interesting work, Kuebutoryne and Abarike (2020) stated a significant increase in specific growth rate and weight gain after feeding tilapia with an *Echinacea purpurea* included diet in Tilapia. He also reported improved growth and feed intake of Nile tilapia when the diet was incorporated with *Aloe vera*. In another study, a 1% garlic-enriched diet significantly increased weight gain, while those fed with a 0.5% *Ocimum gratissimum* supplemented diet exhibited improved feed conversion ratio of Tilapia. Garlic added to a Nile tilapia (*Oreochromis niloticus*) feed raised both feed intake and specific growth rate. Ogunkalu (2019) reported that the inclusion of 2.5% kg^{-1} garlic in the diet exhibited high growth performance in *Oreochromis niloticus*. Therefore, it is understood that the incorporation of fenugreek, thyme, *Aloe vera*, garlic, eucalyptus, hot pepper meal, chamomile flower, *etc.*, herbs in the diet assist in significant growth improvement on various fish species. The supplementation also improves physiological parameters, nutrient utilization and feed uptake, thus providing suitable aquaculture outcomes.

Immune Stimulation

Immunity is a very important factor for determining feeding behaviours in fish. Astragalus polysaccharides extracted from *Astragalus membranaceus* demonstrated enhanced immune responses, *i.e.*, respiratory burst activity, glutathione peroxidase, lysozyme activity, superoxide dismutase, amylase and phagocytes of Nile tilapia (Kuebutoryne and Abarike, 2020). Orso *et al.* (2022) found that oral administration of rosemary leaf powder significantly increased immune-related gene expressions, including innate and adaptive immune responses, in Nile tilapia fingerlings. They also found that immunomodulation occurred in beluga juveniles when sage ethanolic extract was added to the feed, which increased serum immunoglobulin and lysozyme levels. Kuebutoryne and Abarike (2020) mentioned that the diet supplemented with citrus oil extract significantly enhanced haematocrit levels, globulin, haemoglobin, albumin, serum total protein, lysozyme and myeloperoxidase activity in tilapia, *Oreochromis mossambicus*. The production of Serum lysozyme activity and ROS (Reactive Oxygen Species) was significantly enhanced when the diet was supplemented with *Solanum trilobatum* in tilapia. Thyme essential oil at a 1% inclusion level in rainbow trout juvenile diet helped to protect against immune suppression and inflammation in the intestine, triggered by Aflatoxin B1. Dried mint powder included in the diet at levels 1, 2 and 3% improved the immunological parameters in fish. Total Immunoglobulin (Ig) level, along with lysozyme activity in common carp juveniles, was reported when they were fed with rosemary leaf powder in various dose concentrations (Orso *et al.*, 2022). Therefore, it is evident that supplementation of essential herbs potentially improves immune status for various commercially important fish species.

Antioxidant Stimulation

Kuebutoryne and Abarike (2020) reported that the inclusion of *Astragalus radix* on Nile tilapia improved the lysozyme activity and the diet containing *Scutellaria radix* reduced the superoxide anion production outside the cell and also stated that the incorporation of garlic in any form in the fish diet is found to boost the antioxidant activity. Orso *et al.* (2022) stated the significant increase of glutathione peroxidase (GPx), SOD and glucose-6-phosphate dehydrogenase (G6PD) activities when the diet was supplemented with sage oil for rainbow trout juvenile at different concentrations (0.05, 0.1 and 0.15%) which indicates enhanced antioxidant protection for the experimental animal. 0.25% menthol inclusion enhanced the anti-oxidative status in juvenile common carps. It is also reported that 0.5 and 1% rosemary leaf powder incorporation in Nile Tilapia diet demonstrated a significant increase in the CAT (Catalase) activity. Therefore, herb-induced antioxidant stimulation is evident in several fish species, which might help in ameliorating stress and its associated mortality.

Appetite Stimulation

Medicinal herbs are great at improving digestion and have broad stimulatory influences, especially on pancreatic enzyme activity and bile secretion (Dada, 2019). Herbs like mint, ginger and garlic are identified as basic digestive stimulants for animals (Venkatramalingam *et al.*, 2007). Citarasu (2010) mentioned that numerous plant essences from spices and herbs have bactericidal properties, which affect gut microflora and intensify animal performance by activating gut secretions. Livol (IHF-1000), being a commercial growth enhancer having herbal as base, includes several plant constituents, namely *Terminalia arjuna*, *Solanum nigrum*, Colocynth, *Boerhavia diffusa* and black salt, which promote feed intake in fish species. Papaya leaf meal with papain has been found to increase protein digestion in the post-larvae of *P. monodon* (Venkatramalingam *et al.*, 2007). Dietary inclusion of herbs or spices triggers digestive enzyme secretion and boosting the appetite, therefore resulting in the enhanced food consumption (Citarasu, 2010). Venkatramalingam *et al.* (2007) incorporated the artemia that fed with *Zingiber officinalis* to the *P. monodon* post-larvae at various concentrations, which stimulated digestive enzyme activities due to the presence of zingiberene, gingerol, camphene, *etc.*, compounds. These substances also boost feed absorption and enzyme activity, thereby supporting FCR, SGR and amylase and protease activity of fish. Fish salivation, or the production of amylase, has been induced by the use of spices like pepper and essential oils like cinnamon aldehyde. A rise in such enzyme production may lead to an improvement in digestibility and nutrient availability from the diet (Citarasu, 2010). In the current era, consumer concern and awareness about food safety

paved the way for the need for alternative appetizers derived from nature. Herbs are a kind of appetizers that help in increasing feed intake and enhancing digestion, thereby promoting growth and production. Among commercial products, Nutripro-aqua is a commercial herbal growth enhancer, mainly soya-based, that stimulates digestion and promotes weight gain in *M. rosenbergii* (Venkatramalingam *et al.*, 2007). These appetizing plant-derived compounds or herbs can be explored as an alternative feeding stimulant in eco-friendly farming.

Conclusion

Fish is a prominent source of animal protein, with the rising demand globally, but the limited yield of fish sources from catch fisheries has shifted the burden to aquaculture. Aquaculture uses chemical-dependent feed stimulants and attractants to boost growth and production; nonetheless, they have negative effects, including chemical build-up in the human body and resistance to microorganisms. Medical herbs have been found by the World Health Organisation (WHO) as a possible substitute for synthetic ones since they are inexpensive, easy to use and have no negative consequences. Herbs can be added to fish diets to improve development, feed intake, immunity and digestive capacity, leading to increased production using eco-friendly and sustainable practices. Therefore, further research will assist in a better understanding of herbs' full potential and use in the aquaculture industry.

Acknowledgements

The authors are thankful to Director & Vice-Chancellor, of ICAR-CIFE, Mumbai, has consistently provided facilitation and support at RRTC Motipur, ICAR-CIFE, which has been instrumental in the timely completion of this work.

References

Ahmadifar, E., Fallah, H.P., Yousefi, M., Dawood, M.A.O., Hoseinifar, S.H., Adineh, H., Yilmaz, S., Paolucci, M., Doan, H.V., 2021. The gene regulatory roles of herbal extracts on the growth, immune system and reproduction of fish. *Animals* 11(8), 2167. DOI: https://doi.org/10.3390/ani11082167.

Anne Rebecca, A., 2014. Herb based aquaculture: A suitable practice for India. *International Journal of Advanced Scientific and Technical Research* 4(4), 711-734.

Asimi, O.A., Sahu, N.P., 2013. Herbs/spices as feed additive in aquaculture. *Scientific Journal of Pure and Applied Sciences* 2(8), 284-292..

Awad, E., Awaad, A., 2017. Role of medicinal plants on growth performance and immune status in fish. *Fish & Shellfish Immunology* 67, 40-54. DOI: https://doi.org/10.1016/j.fsi.2017.05.034.

Barad, R.R., Verma, D.K., Yusufzai, S.I., Shrivastava, V., Ram, A.R., 2024. Herbal feed additives: Natural boost for aquatic health and growth. In: *Sustainable Feed Ingredients and Additives for Aquaculture Farming: Perspectives from Africa and Asia*. (Eds.) Gabriel, N.N., Abasubong, K.P., Erasmus, V.N. and Kamble, M.T. Springer Nature, Singapore. pp. 405-431. DOI: https://doi.org/10.1007/978-981-97-4279-0_18.

Citarasu, T., 2010. Herbal biomedicines: A new opportunity for aquaculture industry. *Aquaculture International* 18(3), 403-414. DOI: https://doi.org/10.1007/s10499-009-9253-7.

Costacurta de Aguiar, G.A.C., Carneiro, C.L.S., Campelo, D.A.V., Rusth, R.C.T., Maciel, J.F.R., Baldisserotto, B., Zuanon, J.A.S., de Oliveira, A.V., Oliveira, M.G.A., de Freitas, M.B.D., Furuya, W.M., Salaro, A.L., 2023. Effects of dietary peppermint (*Mentha piperita*) essential oil on growth performance, plasma biochemistry, digestive enzyme activity, and oxidative stress responses in juvenile Nile tilapia (*Oreochromis niloticus*). *Fishes* 8(7), 374. DOI: https://doi.org/10.3390/fishes8070374.

Dada, A.A., 2019. Effects of herbal growth promoter feed additive in fish meal on the performance of Nile tilapia (*Oreochromis niloticus* (L.)). *Egyptian Academic Journal of Biological Sciences (B. Zoology)* 4(1), 111-117. DOI: https://doi.org/10.21608/EAJBSZ.2012.13877.

Dada, A.A., Sonibare, O.F., 2015. Effect of dietary administration of the herbal additive siamweed (*Chromolaena odorata*) on growth performance and haematological changes in *Clarias gariepinus* fingerlings. *Journal of Fisheries* 3(1), 221-226. DOI: https://doi.org/10.17017/j.fish.95.

Dawood, M.A.O., El Basuini, M.F., Yilmaz, S., Abdel-Latif, H.M.R., Alagawany, M., Kari, Z.A., Abdul Razab, M.K.A., Hamid, N.K.A., Moonmanee, T., Van Doan, H., 2022. Exploring the roles of dietary herbal essential oils in aquaculture: A review. *Animals* 12(7), 823. DOI: https://doi.org/10.3390/ani12070823.

Direkbusarakom, S., 2004. Application of medicinal herbs to aquaculture in Asia. *Walailak Journal of Science and Technology (WJST)* 1(1), 7-14.

El-Dakar, A., Hassanien, G., Gad, S., Sakr, S., 2008. Use of dried basil leaves as a feeding attractant for hybrid tilapia, *Oreochromis niloticus* × *Oreochromis aureus*, fingerlings. *Mediterranean Aquaculture Journal* 1(1), 35-44. DOI: https://doi.org/10.21608/maj.2008.2662.

Hossain, M.S., Small, B.C., Kumar, V., Hardy, R., 2024. Utilization of functional feed additives to produce cost-effective, ecofriendly aquafeeds high in plant-based ingredients. *Reviews in Aquaculture* 16(1), 121-153. DOI: https://doi.org/10.1111/raq.12824.

Ivanova, S., Sukhikh, S., Popov, A., Shishko, O., Nikonov, I., Kapitonova, E., Krol, O., Larina, V., Noskova, S., Babich, O., 2024. Medicinal plants: a source of phytobiotics for the feed additives. *Journal of Agriculture and Food Research* 16, 101172. DOI: https://doi.org/10.1016/j.jafr.2024.101172.

Jana, P., Karmakar, S., Roy, U., Paul, M., Singh, A.K., Bera, K.K., 2018. Phytobiotics in aquaculture health management: A review. *Journal of Entomology and Zoology Studies* 6(4), 1422-1429.

Jones, F.A., 1996. Herbs - useful plants. Their role in history and today. *European Journal of Gastroenterology & Hepatology* 8(12), 1227-1231. DOI: https://doi.

org/10.1097/00042737-199612000-00018.

Kuebutornye, F.K.A., Abarike, E.D., 2020. The contribution of medicinal plants to tilapia aquaculture: A review. *Aquaculture International* 28, 965-983. DOI: https://doi.org/10.1007/s10499-020-00506-3.

Kuebutornye, F.K.A., Roy, K., Folorunso, E.A., Mraz, J., 2024. Plant-based feed additives in *Cyprinus carpio* aquaculture. *Reviews in Aquaculture* 16(1), 309-336. DOI: https://doi.org/10.1111/raq.12840.

Kumar, R.M., Naik, M.R., Kota, S.K., Prasad, G.S., 2020. Role of phytobiotics in aquaculture. *Agriallis* 2(12), 24-27.

Ogunkalu, O., 2019. Effects of feed additives in fish feed for improvement of aquaculture. *Eurasian Journal of Food Science and Technology* 3(2), 49-57.

Orso, G., Imperatore, R., Coccia, E., Ashouri, G., Paolucci, M., 2022. *Lamiaceae* as feed additives in fish aquaculture. *Fishes* 7(6), 349. DOI: https://doi.org/10.3390/fishes7060349.

Öz, M., Dikel, S., Durmuş, M., Özoğul, Y., 2017. Effects of black cumin oil (Nigella sativa) on sensory, chemical and microbiological properties of rainbow trout during 23 days of storage at 2±1 °C. *Journal of Aquatic Food Product Technology* 26(6), 665-674. DOI: https://doi.org/10.1080/10498850.2016.1253631.

Öz, M., 2018. Effects of black cumin (*Nigella sativa*) oil on ammonia and biogenic amine production in rainbow trout. *Indian Journal of Animal Research* 52(2), 265-269. DOI: https://doi.org/10.18805/ijar.v0iOF.8474.

Parkash, J., Prasad, D.N., Shahnaz, M., Dev, D., 2018. Herbs as traditional medicines: A review. *Journal of Drug Delivery and Therapeutics* 8(5), 146-150. DOI: https://doi.org/10.22270/jddt.v8i5.1910.

Paul, B.N., Pandey, B.K., Giri, S.S., 2014. Effect of plant based feed attractants on growth of *Cirrhinus mrigala* fingerlings. *Animal Nutrition and Feed Technology* 14(2), 393-398. DOI: http://dx.doi.org/10.5958/0974-181X.2014.01338.9.

Radhakrishnan, S., Bhavan, P.S., Seenivasan, C., Muralisankar, T., Shanthi, R., 2015. Effects of native medicinal herbs (*Alternanthera sessilis*, *Eclipta alba* and *Cissus quadrangularis*) on growth performance, digestive enzymes and biochemical constituents of the monsoon river prawn *Macrobrachium malcolmsonii*. *Aquaculture Nutrition* 21(4), 496-506. DOI: https://doi.org/10.1111/anu.12180.

Saini, V.P., Kamble, A.D., Ojha, M.L., Raosaheb, S.S., 2018. Assessment of safe dose of clove oil for using as anesthetics in aquaculture operations. *International Journal of Pure & Applied Bioscience* 6(5), 797-802. DOI: http://dx.doi.org/10.18782/2320-7051.7018.

Sonmez, A.Y., Bilen, S., Albayrak, M., Yılmaz, S., Biswas, G., Hisar, O., Yanik, T., 2015. Effects of dietary supplementation of herbal oils containing 1,8-cineole, carvacrol or pulegone on growth performance, survival, fatty acid composition and liver and kidney histology of rainbow trout (*Oncorhynchus mykiss*) fingerlings=. *Turkish Journal of Fisheries and Aquatic Sciences* 15, 813-819. DOI: http://doi.org/10.4194/1303-2712-v15_4_04.

Tadese, D.A., Song, C., Sun, C., Liu, B., Liu, B., Zhou, Q., Xu, P., Ge, X., Liu, M., Xu, X., Tamiru, M., Zhou, Z., Lakew, A., Kevin, N.T., 2022. The role of currently used medicinal plants in aquaculture and their action mechanisms: A review. *Reviews in Aquaculture* 14(2), 816-847. DOI: https://doi.org/10.1111/raq.12626.

Valladão, G.M.R., Gallani, S.U., Pala, G., Jesus, R.B., Kotzent, S., Costa, J.C., Silva, T.F.A., Pilarski, F., 2017. Practical diets with essential oils of plants activate the complement system and alter the intestinal morphology of Nile tilapia. *Aquaculture Research* 48(11), 5640-5649. DOI: https://doi.org/10.1111/are.13386.

Van Hai, N., 2015. The use of medicinal plants as immunostimulants in aquaculture: A review. *Aquaculture* 446, 88-96. DOI: https://doi.org/10.1016/j.aquaculture.2015.03.014.

Venkateshwarlu, G., Muralidhar, A.P., Rathod, R., Pal, A.K., 2009. Plants traditionally used in fish harvest & angling potential feed attractants in aquaculture. *Indian Journal of Traditional Knowledge* 8(4), 539-542.

Venkatramalingam, K., Christopher, J.G., Citarasu, T., 2007. *Zingiber officinalis* an herbal appetizer in the tiger shrimp *Penaeus monodon* (Fabricius) larviculture. *Aquaculture Nutrition* 13(6), 439-443. DOI: https://doi.org/10.1111/j.1365-2095.2007.00495.x.

Wang, J., Deng, L., Chen, M., Che, Y., Li, L., Zhu, L., Chen, G., Feng, T., 2024. Phytogenic feed additives as natural antibiotic alternatives in animal health and production: A review of the literature of the last decade. *Animal Nutrition* 17, 244-264. DOI: https://doi.org/10.1016/j.aninu.2024.01.012.

Wei, L.S., Goh, K.W., Hamid, N.K.A., Kari, Z.A., Wee, W., Van Doan, H., 2022. A mini-review on co-supplementation of probiotics and medicinal herbs: Application in aquaculture. *Frontiers in Veterinary Science* 9, 869564. DOI: https://doi.org/10.3389/fvets.2022.869564.