Integration of Plant-Based Proteins into Aquaculture Diets for Sustainable Fish Growth and Wellness

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SUMMARY

Aquaculture, the fastest-growing sector of aquatic animal production, plays an essential role in addressing global food security and nutritional needs. However, traditional aquaculture diets frequently use fishmeal and fish oil from marine species that caught in wild environments, creating problems from an ecological, moral, and financial standpoint. In this chapter, we look at how plant-based proteins from sources like soybeans, maize, rice, and many others are used and how they are incorporated into the formulations of aqua-feed. Considering the dietary protein content, amino acid profiles, and essential nutrients, we assess the growth performance, feed conversion efficiency, and health parameters of fish species fed plant-based diets. It also shows that diverse fish species, including tilapia, catfish, and salmon, can grow and stay healthy when fed well-balanced plant-based diets. While difficulties like antinutritional elements and palatability problems have been reported, ongoing research and technological advancements present encouraging solutions. Importantly, the use of plant-based proteins in aquaculture has the potential to support the sustainability of the sector by minimizing dependence on limited marine resources and reducing ecological footprint. This chapter emphasizes the significance of shifting towards plant-based diets for farmed fish as a crucial step in ensuring a secure and environmentally responsible future for aquaculture as the demand for seafood continues to rise globally.

INTRODUCTION

To make up for the shortage of aquatic products, aquaculture is currently experiencing sustained global growth (Okechi, 2004). Nutrition is defined as the interaction of a nutrient with living organisms which includes feed composition, ingestion, digestion or energy liberation, waste elimination, and nutrition required for maintenance, growth, and reproduction. Energy from food and feedstuffs is necessary for the growth, reproduction, and general health of aquatic organisms. Insufficient amount of diet can cause diseases and stunted growth (Helfrich & Smith 2004). Fish require a healthy diet for metabolism and other physiological activities. For appropriate growth rates, tissue development, and skeletal formation, certain amounts of nutrients such as proteins, lipids, carbohydrates, vitamins, and minerals are needed. Fish need energy from several physiological processes, such as swimming, reproducing, regulating their body temperature, and general metabolism. Fish require essential nutrients to maintain regular bodily processes. Without proper nutrition, deficiencies can occur, leading to impaired physiological processes and compromised health. Proper nutrition enhances gonadal development, hormone synthesis, and sperm/egg quality, leading to higher fertilization rates and increased reproductive success. Additionally, proper nutrition during early larval stages is crucial for the survival, growth, and development of fish fry. Nutrition strengthens the immune system of fish, enabling them to resist diseases and infections. Certain nutrients, like omega-3 fatty acids, can increase fish's resistance to environmental stressors like temperature changes and salinity fluctuations.

How to Cite: Jamil R, CR Wei, MRJ Khan, AMA Khan, M Faisal, M Awais, MI Asghar & UB Tahir, 2023. Integration of plant-based proteins into aquaculture diets for sustainable fish growth and wellness. In: Complementary and Alternative Medicine: One Health Perspective (Sindhu ZuD, B Aslam, U Uslu & M Mohsin, eds): FahumSci, Lahore, Pakistan, pp: 204-214. ISBN: 978-627-7745-01-1. https://doi.org/10.61748/CAM.2023/028

Efficient and sustainable feed utilization is a crucial aspect of fish nutrition (Halver & Hardy 2003).

Aquaculture produces about 50 million tonnes of fish annually and is constantly expanding and growing at a rate of over 8% per year, which is significantly higher than the average growth rate of terrestrial animals. This growth rate is due to the production of finfish and prawns because of their growing demand. Approximately 620 million tons of animal feed is produced worldwide. As a result, compared to conventional animal feeds, aquaculture feeds typically contain higher levels of total protein (> 35% of dry matter) and fat (> 10%). In intensive farming, fish meals and oils serve as the primary sources of proteins and lipids. The health and well-being of farmed fish are crucial for the sustainability and profitability of aquaculture operations. Farmers are turning to alternative sources of protein as fishmeal is very expensive. Essential oils, herbs, and the usage of botanical and herbal supplements are the most significant and readily accessible protein supplements. These substitutes have grown in favor recently and are crucial for enhancing fish health and performance (Kaushik & Hemre 2008).

EFFECT OF DIETARY COMPONENTS ON FISH HEALTH

The importance of proper nutrition in maintaining fish health and normal growth has long been acknowledged. In intensive culture, artificial diets made from different feedstuffs serve as the main source of nutrition. Prepared diets can expose fish to additional substances that could either have a positive or negative impact on their health in addition to providing the essential nutrients needed for normal physiological function (Hardy & Kaushik 2021).

Carbohydrates

Due to their abundance and low cost, carbohydrates are an excellent source of energy. The FAO reports that the combined global production of the three main cereal grains in 2013 was 2.5 billion tons and these grains contain roughly 2.1 and 1.75 billion tons of total carbohydrates and digestible portions of starch and sugar respectively. The cost of carbohydrates is lower than proteins and lipids therefore the insertion levels of carbohydrates in commercial fish feed undertake direct economic significance i.e. in terms of lower feed cost per unit weight gain (Jones et al., 2015). The presence of carbohydrates in aquaculture feed during the process of feed formulation helps in the stability and palatability of feed. It also minimizes nutrient leaching and feed wastage. In fish, carbohydrates are stored in the form of glycogen. Carbohydrates are a significant source of energy for mammals, but fish can use them effectively. Fish only get 1.6 calories from the same amount of carbohydrates as mammals can get 4 calories from one gram of carbohydrates. Fishes are also responsible for the digestion of cellulose because of the presence of cellulase enzyme present in them. In another study, it was investigated that cellulase enzyme is present in the intestine and hepatopancreas (Jones et al., 2015).

Protein

The most expensive component of fish feed is protein. It is essential to accurately determine each species' protein need. Although there are more than 200 amino acids in nature, only 20 are commonly found. Of these 10 are indispensable (essential) that cannot be synthesized by fish and must be present in the diet. These are arginine, methionine, histidine, tryptophan, threonine, leucine, isoleucine, lysine, valine, and phenylalanine. The deficiency of essential amino acids leads to poor utilization of dietary protein and may result in growth retardation, less weight gain, and low feed efficiency. Understanding and meeting the unique dietary protein and amino acid requirements of each fish species is essential for achieving optimum growth and health. Carnivore fish species need higher protein requirements compared to herbivore fish (Craig et al., 2017).

Lipids

Lipids are high-energy nutrients that can replace some of the proteins in aquaculture feeds. The energy density of proteins and carbohydrates is roughly half that of lipids. Lipids, which serve as carriers for fat-soluble vitamins and provide essential fatty acids, are typically present in fish diets in amounts ranging from 7 to 15%. A recent development in fish feeds is the addition of more lipids to the diet. By partially sparing protein, increasing dietary lipids can reduce feed costs. Lipid deficiency leads to impaired fish growth, reproductive issues (reduced fertility, poor egg quality, reproductive abnormalities), weak immune system, reduced survival rate, abnormalities in organ function, and changes in fish behavior. Fish typically contains omega 3 and omega 6 families of fatty acids. Omega 3 fatty acids are essential for the growth and health of marine fish. The two primary essential fatty acids are Eicosapentaenoic acid (EPA: 20:5n:3) and docosahexaenoic acid (DHA: 22:6n:3). However, freshwater fish frequently require linolenic acid (an 18 carbon n-3 fatty acid), in amounts ranging from 0.5 to 1.5% of their dry diet. Since freshwater fish cannot produce this fatty acid, it must be consumed in the diet. Freshwater fish do not need long-chain, highly unsaturated fatty acids (Craig et al., 2017).

Vitamins

Vitamins are necessary for a balanced diet and healthy fish growth. Because they are frequently not synthesized by fish, they must be added to the diet. The two types of vitamins are fat-soluble and water-soluble. Vitamin B (thiamin, niacin, riboflavin, pantothenic acid, pyridoxine, biotin, folic acid, and cobalamins) and vitamin C (ascorbic acid) are examples of water-soluble vitamins. The most important of these nutrients, vitamin C is a strong antioxidant that supports the immune systems of fish and prawns. Vitamins A, D, E, and K are also fat-soluble vitamins, but vitamin E gets the most attention for its crucial antioxidant function. Vitamin C and E act as feed ingredients that also prevent lipid oxidation, extending shelf life. Each vitamin deficiency has unique symptoms but the most prevalent one for all vitamins is the stunned growth of fish. Ascorbic acid and folic acid deficiencies may cause scoliosis as well as dark coloration. Vitamin deficiencies in fish can lead to various health issues including stunted growth, weakened immune system, bone deformities, visual impairment, nervous system, and reproductive problems (Craig et al., 2017).

Minerals

Minerals are inorganic nutrients that must be consumed for a healthy body to function. Minerals can be divided into micro minerals which are required in very small amounts and macro minerals which are required in large amounts. Calcium, sodium, potassium. Chlorine, sulfur, phosphorus, and magnesium are among the common macro-minerals found in food. These minerals support the formation of bones and the regulation of osmotic balance. Small amounts of these trace minerals, such as iron, copper, chromium, iodine, manganese, zinc, and selenium, are required by the hormone and enzyme systems, Mineral deficiencies in fish can have significant effects on their health like bone and skeletal issues, electrolyte imbalance, reproductive problems, impaired growth, weakened immune system, reduced vitality and overall health (Craig et al., 2017).

Probiotics and prebiotics

Probiotics are beneficial live microorganisms that, when consumed, confer health benefits to the host. They can enhance digestion, improve nutrient absorption, and support a healthy gut microbiota. Prebiotics, on the other hand, are non-digestible compounds that selectively promote the growth of beneficial bacteria in the gut. Probiotics and prebiotics are often used in aquaculture to enhance gut health and improve disease resistance (Hai, 2015).

Enzymes

Enzymes are protein molecules that facilitate biochemical reactions in the digestive system. In aquaculture, enzymes are often added to feed to improve nutrient digestibility, particularly in feeds with high levels of plant ingredients. Alternatives are required to replace fish feed with other raw materials because modern aquaculture must be sustainable in terms of energy use, raw material use, and environmental impact. Enhancing the digestibility and absorption of ingredients derived from both plants and animals through the addition of enzymes to fish feed can increase the growth parameters of aquaculture animals. There are two types of enzymes; digestive and non-digestive enzymes. Digestive enzymes include (amylase, protease, hemicellulose, cellulose, and lipase) while nondigestive enzymes include (glucose oxidase, lysozyme, and phytases) in fish feed (Liang et al., 2022). For instance, weight gain increased by over 90% in salmon-fed diets containing low levels (1 mg/kg) of 17-methyltestosterone. Some species, like chinook salmon, do not react to dietary hormone supplementation as dramatically. But when testosterone was added to the diet for autumn chinook salmon, growth increased by 26%. Numerous studies have demonstrated that thyroid hormones help teleost fish grow. However, their ability to work in concert with endogenous pituitary hormones, particularly growth hormones, is necessary for their growth-promoting effects (Donaldson, 2000).

HERBAL AND BOTANICAL SUPPLEMENTS FOR AQUACULTURE

In addition to being used to treat illnesses, herbal and botanical supplements are also used to promote growth, build stress resistance, and fight against infection. Herbal ingredients such as flavonoids, alkaloids, and tannins may have antimicrobial properties, and they can also stimulate the immune system, giving fish non-specific immune defenses and boosting those that are specific (Pandey et al., 2012 a and b). Herbal and botanical treatments are economical, eco-friendly, and have few side effects. Herbal supplements can be used in place of antibiotics to control fish health, and traditional herbal and botanical remedies may boost the immune system..

As the fish meal is expensive the use of non-conventional feedstuffs has been reported with good growth and better cost-benefit values. The use of non-conventional feed materials of botanical origin has been restricted because of the presence of alkaloids, glycosides, oxalic acids, phytates, protease inhibitors, haematoglutinin, momosine, saponegin, cyanoglycosides, and linamarin. They are very cheap, byproducts or waste products from agriculture farm-made feeds, and processing industries and can serve as a form of waste management in enhancing good sanitation. These include all varieties of animal feed materials, such as silkworms, termites, grub, earthworms, tadpoles, snails, etc. Jack beans, cottonseed meal, soybean meal, cajanus, chaya, maize bran, palm kernel cake, duckweed, rice bran, and groundnut cake are examples of plant waste. Animal waste includes things like dung, offal, viscera, feathers, fish silage, bone, and blood. (Abowei & Ekubo 2011; Pandey, 2013).

The feeds for fry and fingerlings typically contain more crude protein than 50%. As fish get older, their growth rate slows down and protein requirements decrease accordingly. In fish feeds, fishmeal should be a major protein source (Abowei & Ekubo 2011). In aquaculture, various botanical supplements are used to enhance fish health, growth, and overall performance. These botanical supplements are derived from plants and can provide additional nutrients to aquatic organisms. Detail of various plants with proven biological activity in aquaculture has been presented in Tab 1.

MEDICINAL PLANTS IN AQUACULTURE

Medicinal plants have emerged as a promising and effective alternative method for the control of fish diseases due to the negative impacts of the environment humans, and drugs used in aquaculture. Medicinal plants are used in aquaculture as feed additives as well as chemotherapeutics (Chang, 2000) because they contain a wide variety of chemical compounds (Plant & Lapatra 2011). Fish growth, appetite stimulation, antimicrobial activity, and stress reduction have all been linked to medicinal plants (Chakraborty & Hancz, 2011; Citarasu, 2010). Additionally, the presence of numerous active principal components including alkaloids, steroids, phenolics, tannins, terpenoids, saponins, glycosides, and flavonoids, are thought to be the cause of those plants' and their derivatives' actions (Sivaram et al., 2004; Harikrishnan et al., 2011). Many plants are accessible and inexpensive, which encourages their widespread use in aquaculture to simultaneously improve growth and protection. They have been used in a variety of ways, including as crude, plant extracts, or active compounds (Bahi et al., 2017). Van Hai, (2015) reported that medicinal herbs have been used as immunostimulants. Aquaculture may benefit from the use of medicinal herbs as safe, natural alternatives to antibiotics and immunoprophylactics. These plants are becoming more and more popular all around the world because they are inexpensive, simple to prepare, and don't harm animals or the environment too much. Many aquatic animals have been researched in relation to a broad spectrum of medicinal plants, including herbs, spices, seaweeds, herbal medications, herbal extracted chemicals, traditional Chinese medicines, and commercial plant-derived goods.

PLANT-BASED PROTEIN SOURCES IN AQUACULTURE

Aquaculture often relies on various plant-based protein sources as alternatives to fishmeal, which can be expensive and environmentally unsustainable. These plant-based protein sources provide essential amino acids and serve as a crucial component of balanced fish diets. Here are some common types of plant-based protein sources used in aquaculture.

Soybean meal

The vegetable-protein source that replaces fish meal most frequently in practical diets is soybean meal. Soybean meal (SBM), which has a high protein content, high digestibility, and a generally well-balanced amino acid profile, is a common feed ingredient for many aquaculture species (Storebakken, 2000). In fish feed, soybean products have largely replaced fishmeal due to their advantages in terms of nutrition, the environment, and the economy. Due to its high nutrient content, soybean meal (SBM), according to Storebakken (2000), has been reported to have the ability to replace fishmeal components without having any negative effects on the fish. The growing demand for food for human consumption and other livestock industries places restrictions on how much of this conventional source of protein can be used and available for fish feed, making it unsustainable for the aquaculture industry (Fadel et al., 2017).

Soybeans are high in protein (44-50%), and they include all the necessary amino acids that fish need. Feeds for many different fish species, such as salmon, trout, tilapia, and catfish, frequently contain soybean meal. Since it has a balanced profile of essential amino acids, it is regarded as a healthy source of protein for fish. But in comparison to the needs of some fish species, soybeans may not contain as much methionine or lysine as other amino acids. Therefore, to meet the fish's nutritional needs, further amino acid supplementation might be required. The processing method and the existence of anti-nutritional substances are two examples of factors that can affect how easily soybean protein is digested. Heat treatment and other processing techniques are commonly used to increase the digestibility of soybean protein for fish (Arriaga et al., 2021).

Anti-nutritional elements found in soybeans, such as phytic acid and trypsin inhibitors, can obstruct fish's ability to digest and absorb nutrients. Due to its widespread cultivation and easy accessibility, it is an affordable source of protein for fish meals. Its versatility in forms (meals or pellets) makes it simple to use into fish diet formulations. It's crucial to remember that different fish species have different nutritional needs, therefore soybeans may not be the best choice as a source of protein in every case. It's possible that some species are more tolerant to soybean-based foods than others and that they use them more effectively (Lim et al., 2023).

Corn gluten meal

As a byproduct of processing corn, corn gluten meal has a high protein content. This is especially beneficial for fish species that are herbivorous and omnivorous in their diets. Certain fish species can use it as a source of protein. Corn gluten meal has between 60% and 70% protein (Doughty et al., 2019). It is crucial to take into account the unique nutritional needs of the fish species you are feeding when utilizing it in fish feed. Certain fish species, such as catfish and tilapia, are comparatively good at tolerating and digesting plant-based proteins like maize gluten meal. Carnivorous fish species, like trout and salmon, on the other hand, may not be as adept at using plant-based proteins and instead have a greater need for animal-based proteins (Preira & Oliva-Tales 2003).

Due to its high protein content and excellent digestibility for a variety of fish species, maize gluten meal can help fish grow at healthy rates by facilitating effective nutrient absorption and utilization. A healthy supply of amino acids, like as methionine and lysine, which are vital for fish growth and development, can be found in maize gluten meal (Lewis & Kohler 2008). On the other hand, it lacks some important amino acids, such as histidine and tryptophan. Thus, while utilizing protein derived from maize gluten meal. It's crucial to remember, nevertheless, that compared to other protein sources like fish meal or soybean meal, maize gluten meal has a very high carbohydrate content. Depending on the specific needs of the various fish species, it could be essential to adjust the formulation and account for the overall amount of carbohydrates in the fish feed (Nandakumar et al., 2017).

Wheat gluten

Wheat gluten is made from wheat and has a high-grade protein content. It serves as a source of vital amino acids for aquaculture feeds. Many fish species, such as carp, tilapia, and marine finfish, can be fed wheat gluten. Like maize gluten meal, wheat gluten can also be utilized as a source of protein for fish (Apper-Bossard et al., 2013). Gluten proteins make up the majority of wheat gluten, which is a byproduct of processing wheat. It is well-known for having a high protein level, usually between 70% and 80%. It is crucial to keep in mind that different fish species have varying nutritional needs and capacities for metabolizing plant-based proteins when thinking about using wheat gluten as a source of protein for fish (Zaretabar et al., 2021).

Certain fish, like carp and tilapia, can use wheat gluten as a useful source of protein and have a comparatively high tolerance for plant-based proteins. However, carnivorous fish species, such as salmon or trout, may not gain as much from plant-based protein sources and instead have a greater need for animal-based proteins. Wheat gluten meal has a high protein content, is rich in nutrients that support fish health, and is highly digestible. Like maize gluten meal, wheat gluten has comparatively low levels of some important amino acids, like methionine and lysine. To guarantee a balanced diet, it is crucial to combine wheat gluten with additional protein sources that have complementary amino acid profiles (Draganovic et al., 2011).

Canola meal

A byproduct of extracting oil from canola seeds is canola meal. It is a valuable source of protein and replaces fishmeal in aquaculture feeds. Canola meal has been successfully fed to salmonids, tilapia, and other fish species (Enami, 2011). Among the necessary amino acids that are plentiful in canola meal and are vital to fish growth and development are methionine, lysine, and cysteine. Protein content in canola meal is normally between 36% and 40%. Canola meal has a well-balanced amino acid profile, while possibly having less tryptophan and threonine than other meals (Webster et al., 2000).

Canola meal is an important source of protein because it provides vitamins, minerals, and fatty acids that are important for fish growth and development. Fish health and vitality are also enhanced by the presence of these nutrients. Canola meal also includes lipids, carbs, and other elements that increase the caloric value of the diet. Canola meal is appropriate for use in fish diets due to its mild carbohydrate content.

Sunflower meal

A substance high in protein that can be utilized in aquaculture is sunflower meal. It may, however, contain less protein (28% to 35%) than some other plant-based protein sources (Lozano et al., 2007). Sunflower meal is a possible source of protein for fish feeds; nevertheless, its usefulness will vary depending on the type of fish and their specific dietary requirements. Sunflower meal is beneficial as a protein source for fish species like tilapia and carp that can digest and use plant-based proteins. Carnivore fish species need a greater need for animal-based (Rahmdel et al., 2018). There are comparatively few important amino acids, such as lysine and methionine, in sunflower meal (Iqbal et al., 2022). All things considered, some fish species, especially those that have a greater tolerance for plant-based proteins, can use sunflower meal as a source of protein. To encourage the best possible growth and health, it is essential to balance the diet with different protein sources and nutrients and to take into account the unique nutritional requirements of the fish (Rehman et al., 2013).

Cottonseed meal

It is inexpensive, high-digestible, high in protein, and promotes the growth of fish species. Nonetheless, the presence of certain anti-nutritional components might limit its application in fish diets (El-Saidy & Gaber 2004). To mitigate these variables and guarantee the acceptability of cottonseed meal as a source of protein, appropriate processing methods must be employed. Cottonseed meal is rather an acceptable source of protein for fish because it normally includes 40% to 50% protein (Lim & Lee 2009).

It is imperative to acknowledge that the caliber of cottonseed meal is subject to fluctuations owing to variables such as the caliber of cottonseed utilised, techniques of processing, and the existence of gossypol, a naturally occurring component in cottonseed that possesses hazardous properties for certain animals, including fish (Li & Robinson 2006). Cottonseed meal can be beneficial as a protein source for fish species like carp or tilapia that can handle and digest plant-based proteins well (Jabeen et al., 2004). Gossypol levels can be harmful to fish health, so it is important to choose premium cottonseed meal with minimal amounts. Cottonseed meal also contains dietary fiber, which is advantageous for fish digestion (Lee et al., 2002).

Rice polish

Fish can be fed rice polish, sometimes called rice bran, as a source of protein. A byproduct of milling rice, rice polish is packed with nutrients such as proteins, carbs, lipids, vitamins, and minerals. Typically, rice polish has a protein content of 12% to 18% (Ge et al., 2020). It is crucial to remember that rice polish could not have the same level of protein quality or balanced amino acid profile as other protein sources like fish or soybean meal. Moreover, rice polish has lipids, carbs, and other elements that can raise the energy level of fish meals. It also contains nutritional fiber, which is beneficial to fish's digestive system. Thus, even though rice polish can provide some fish species with protein, it's vital to take into account its drawbacks and possible nutrient imbalances (Hussain et al., 2011).

BENEFITS OF USING BOTANICAL SUPPLEMENTS IN FISH

The use of botanical supplements in aquaculture can provide several benefits that contribute to the overall health. Here are some of the key benefits of using these supplements

Improved growth and digestion

By offering vital nutrients, amino acids, and bioactive substances that support ideal development and tissue formation, botanical supplements can speed up fish growth and digestive health. These additives can help increase growth potential and boost feed conversion efficiency, which will boost the financial performance of aquaculture operations (Daniel, 2018).

Enhanced immune function

Fish immune systems are supported by a variety of botanical supplements that have immuno-stimulatory qualities. They can boost illness resistance, fortify the fish's defenses, and enhance general health. In aquaculture systems, this lowers the frequency and intensity of infections, improving survival rates and lowering mortality rates (Daniel, 2018).

Anti-inflammatory properties

Fish inflammation can be decreased by the anti-inflammatory qualities of many herbs and botanicals. Stress, illness, and injuries frequently cause inflammation. By taking anti-inflammatory vitamins, can help reduce inflammation and encourage a quicker recovery (Daniel, 2018).

Parasite control and color enhancement

Some plants and herbs have inherent anti-parasitic qualities. By adding these nutrients to the fish's diet, parasite illnesses may be avoided or controlled, lowering the need for harsh chemical treatments. Certain pigments or chemicals found in certain botanical supplements may increase the attention of fish toward feed (Daniel, 2018).

Stress reduction and disease prevention

Certain herbal supplements include antifungal, antibacterial, and antiparasitic qualities. Supplements containing botanicals like ginger, garlic, and turmeric may help reduce stress. They can lessen the harmful consequences of stressors including handling, moving, and alterations in the surroundings. Aquaculturists can help prevent and control the onset of illnesses and disorders by adding these additives to fish meals (Daniel, 2018).

Drawbacks

It is crucial to remember that the choice and application of botanical supplements ought to be supported by scientific investigation, knowledge of the needs unique to each species, and appropriate formulation. Careful consideration should be given to the timing and dose of supplements to achieve the best possible outcomes and prevent negative impacts on fish health and the environment. Although there are advantages to using botanical supplements in aquaculture, there are certain disadvantages as well as things to keep in mind. The following are some possible disadvantages of these additives in aquaculture.

Variable quality, availability, and cost

There is variation in the availability and quality of botanical supplements. Supplement composition, potency, and effectiveness can vary depending on the source, processing techniques, and storage environment. Supplements containing botanicals may raise the total cost of aquaculture production.

Tab 1. Therapeutic Properties of Medicinal Plants and Herbs in Aquaculture

Scientific name	English name	Plant part	Active compound	Biological activity	References
Allium cepa	Onion	Bulbs	Flavonoids, vitamins, Sulphur	antioxidant, antibacterial, anticancer activities	Akrami et al., 2015
Allium tuberosum	Garlic	Bulb	Allicin	Digestion stimulant, antiseptic	Ghehdarijani et al., 2016
Aniba rosaeodoral	Rosemary	Leaves	Cineole	Digestion stimulant, antiseptic, antioxidant	Cristea et al., 2012
Apium graveolens	Celery	Fruit, leaves	Phtalides	Appetite and digestion stimulant	Cristea et al., 2012
Artemisia annua	Artemisia	Leaves	Artemisin	Anticoccidial	Cristea et al., 2012
Azadirachta indica	Neem	Leaves, bark	Azadirachtin, salanin, numbin	Antiviral, antiseptic, fungicidal	Nya & Austin 2009
Brassica spp.	Mustard	Seed	Allyl isothiocyanate	Digestion stimulant	Cristea et al., 2012
Capsicum annum longum	Capsicum	Fruit	Capsaicin	Antidiarrhoic, stimulant tonic, anti-inflammatory	Cristea et al., 2012
Cinnamomum zeylanicum	Cinnamon	Bark	Ammameldehyde	Appetite and digestion stimulant, antiseptic	Cristea et al., 2012
Cochlearia armoracia	Horseradish	Root	Allyl isothiocyanate	Appetite stimulant	Cristea et al., 2012
Coriandum sativum L.	Coriander	Leaves	Unalol	Digestion stimulant	Cristea et al., 2012
Cuminum cyminum	Cumin	Seed	Cuminaldehyde	Digestive, galactagauge	Cristea et al., 2012
Curcuma longa	Turmeric	Bulb	Curcumin	antioxidant, anti-inflammatory, antimicrobial	Turker et al., 2009
Elettaria caramomum	Caradamon	Seed	Cinook	Appetite and digestion stimulant	Cristea et al., 2012
Illicum verum	Anise	Fruit	Anethole	Digestive stimulant, galactagauge	Cristea et al., 2012
Laurus nobilis	Bay laurel	Leaves	Cineole	Appetite and digestion stimulant, antiseptic	Cristea et al., 2012
Mentha piperital	Peppermint	Leaves	Menthol	Appetite and digestion stimulant, antiseptic	Cristea et al., 2012
Myristica flagrans	Nutmeg	Seed	Sabinene	Digestion stimulant, antidiarrheal	Cristea et al., 2012
Origanum vulgare	Oregano	Whole plant	Carvacrol, Thymol	digestive health, control pathogenic bacteria, enhance growth	Cristea et al., 2012
Panax spp.	Ginseng	Roots and rhizome	Ginsenosides	improve fish growth, enhance immune function, and reduce stress	Immanuel et al., 2009
Pelroselinum crispum	Parsley	Leaves	Apiol	Appetite and digestion stimulant, antiseptic	Cristea et al., 2012
Piper nigrum	Pepper	Fruit	Piperine	Digestion stimulant	Cristea et al., 2012
Salvia apiana	Sage	Leaves	*Cineole*	Digestion stimulant, antiseptic, carminative	Cristea et al., 2012
Syzygium aromaticum	Clove	Cloves	Eugenol	Appetite and digestion stimulant, antiseptic	Cristea et al., 2012
Thymus vulgaris	Thyme	Whole plant	Thymol	Digestion stimulant, antiseptic, antioxidant	Cristea et al., 2012
Trigonella foenumgraecum	Fenugreek	Seed	Trigonelline	Appetite stimulant	Cristea et al., 2012
Urtica dioica L.	Stinging nettle	Leaves	Vitamins, iron, flavonoids, sterols, salicylic acid and carotenoids	possesses anti-inflammatory, antiviral, immunostimulation, antianalgesic, anticarcinogenic, antibacterial, antioxidant, antiulcer, antifungal activities	Ngugi et al., 2015
Zingiber officinale	Ginger	Rhizome	Zingerole	Gastric stimulant	Cristea et al., 2012

Certain supplements could be pricey, particularly those made from unique or exotic plant species. It is important to carefully weigh the possible benefits of taking supplements against their cost to determine whether or not they are cost-effective.

POTENTIAL INTERACTIONS AND REGULATORY CONSIDERATIONS

There is a chance that the active ingredients in different botanical supplements will interact or contradict one another. Some combinations can have negative effects or decreased efficacy. Local or regional authorities may impose rules and limitations on the use of botanical supplements in aquaculture. The permitted substances, maximum dosage ranges, withdrawal times, and labeling specifications may all be governed by these rules.

Environmental concerns

Certain botanical supplements may have an impact on the environment during production and sourcing. For instance, growing specific plant species for the manufacturing of supplements may need a large amount of energy, water, and land. Furthermore, if botanical materials are not harvested or extracted responsibly, it may harm natural ecosystems. The environmental impact of producing and using botanical supplements in aquaculture must be taken into account.

Overdosing and toxicity risks

If taken in excess, several herbal and botanical supplements might be poisonous or have negative effects. If the recommended dosage is not followed precisely or if supplements are combined carelessly, overdosing may result. To avoid potential toxicity, it is essential to closely adhere to dosage instructions and keep an eye on the fish's reaction.

Lack of long-term studies

The long-term consequences of adding herbal and botanical supplements to fish diets are unknown. Although studies conducted in the short term might yield favorable results, it's crucial to take long-term effects on fish health, growth, and reproduction into account. Extensive research is required to completely comprehend the effects of extended supplementation (Gutasi, 2021). Aquaculturists must carefully weigh the possible advantages and disadvantages of utilizing botanical supplements, taking into account aspects like cost-effectiveness, scientific validity, legal compliance, and environmental sustainability. The benefits of utilizing supplements in aquaculture can be maximized and any potential negative effects can be minimized with proper formulation, quality control, and adherence to best practices.

VARIOUS RAW PLANTS TO PREPARE FISH DIET

Various plants have been used to nourish fishes for their growth and performance but the most common are gilthead sea bream (*Sparus aurata*), Atlantic salmon (*Salmo salar)*, Asian seabass (*Lates calcarifer*), etc. A study was carried out to assess if there would be any spoilage changes during ice storage if sustainable plant raw materials (plant meal and oils) were used in place of fish meal and fish oil (FO) in rainbow trout, gilthead sea bream, and common carp during long-term feeding. These three species were provided plant-based foods for the duration of their rearing cycles, and their results were compared to those of their counterparts who were on FM/FO-based diets or commercial diets. The freshness was assessed using sensory QIM techniques tailored for these species and the ATP breakdown products (-value and components). Rainbow trout, gilthead sea bream, and common carp were found to have sensory acceptability at 14, 15, and 12 days, respectively. This translated to roughly 80%, 35%, and 65% of -values for common carp, gilthead sea bream, and rainbow trout, respectively. For gilthead sea bream and common carp, there was no discernible change in postmortem shelf life based on feeding history; neither chemical nor sensory freshness demonstrated dietary effects. At the end of their shelf life, rainbow trout fed a plant-based diet showed a slightly lower level of sensory freshness than fish fed a diet based on FM/FO. These results suggest that FM and FO can be successfully replaced without significantly affecting the fish's shelf life.

Seaweed supplements in salmon aquaculture

In salmon aquaculture, seaweed-based supplements have been used to improve fish health and lessen the negative environmental effects of fish farming. Researchers in Norway found that adding seaweed extracts to salmon meal boosted the fish's immune system, digestive health, and decreased their need for antibiotics. Adding seaweed to the diet has also demonstrated the ability to lessen the amount of waste and nutrients that are released into the nearby seas (Kamunde et al., 2019).

Herbal extracts in tilapia farming

In tilapia farming, herbal extracts obtained from several plants have been utilized as dietary supplements. An investigation into the effects of a combination of herbal extracts in the diet of Nile tilapia (*Oreochromis niloticus*) was carried out in Brazil. The fish's intestinal health, feed utilization, and growth performance were all enhanced by the herbal supplement. Additionally, it showed antibacterial qualities that would lessen the likelihood of bacterial infections (Ogello et al., 2014).

Juvenile cobia (*Rachycentron canadum*)

One diet in which soybean meal protein was substituted for fishmeal protein to the extent of 20, 40, 60, and 80%. According to the study, there were no appreciable adverse impacts on the growth performance, feed utilization, or body composition of juvenile cobia when up to 40% of the fishmeal was replaced with soybean meal. However, growth performance and feed utilization efficiency showed a modest decline at substitution levels of 60 and 80%. Overall, the study found that juvenile cobia may safely substitute up to 40% of the protein in fishmeal with protein from soybean meal without sacrificing growth or feed efficiency. According to this research, soybean meal may be an appropriate botanical protein source for cobia aquaculture, lessening the need for fishmeal and improving the sustainability and economics of the diets.

Rainbow trout (*Oncorhynchus mykiss*)

Tusche et al. (2012) preferred wheat gluten meal instead of fish meal to rainbow trout and found it more effective. The experiment was conducted and various concentrations of wheat gluten (25, 50, 75, and 100%) were prepared and provided to trout. When fish meal was substituted with wheat gluten meal up to 50%, positive results like growth performance, feed utilization, and body composition were observed. However, growth performance, feed utilization efficiency, and protein retention decreased when the substitution level reached 75 and 100%.

Nile tilapia (*Oreochromis niloticus*)

Bell & Davies (2023) performed research in which soybean meal and corn gluten meal protein were prepared in different concentrations i.e. 0, 25, 50, 75, and 100%. According to the study, there were appreciable effects were observed when more than 50% concentration was used and no side effects have been observed.

CONCLUSION

Numerous benefits can be obtained from using botanical supplements, such as better immune system performance, increased growth performance, illness prevention, reduced stress, and improved general health and welfare of fish. With the help of these supplements, specific nutritional deficiencies may be addressed, nutrient utilization can be optimized, and the health and well-being of farmed fish are supported. Supplements made of botanicals, which are a natural and sustainable way to improve fish health, are obtained from a variety of plants and herbs. They frequently contain bioactive substances that have immune-stimulatory, antibacterial, anti-inflammatory, and antioxidant qualities. These substances have the potential to lessen the impact of stresses, strengthen the immune system, and increase resistance to infections, all of which can decrease the need for antibiotics and other medications. There are certain difficulties and things to think about while using botanical supplements in aquaculture. To protect fish welfare and avoid negative effects on the environment, safety measures like quality control, appropriate dose, and regulatory compliance are crucial. Furthermore, it is imperative to thoroughly assess the suitability of supplements with regard to feed formulations, processing techniques, and fish species in order to guarantee optimal effectiveness and appropriate supplement distribution. All things considered, botanical supplements provide encouraging chances to enhance fish health, lower the danger of illness, and support environmentally friendly aquaculture methods. Aquaculturists can realize the full potential of these supplements to improve the profitability, productivity, and environmental sustainability of their fish farming operations by putting appropriate protocols for formulation, administration, and monitoring into practice.

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