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A Review on the Current Status and Emerging Trends in the Utilization of Fish Feed Additives for Sustainable Production of *Oreochromis Niloticus*

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ABSTRACT

Feed additives are regarded as an essential component of the fish diet during the production of fish feed. The addition of feed additives to fish feed is essential for enhancing the growth and immunity of farmed fish. The objective of the study was to conduct a comprehensive review on the current status and trends in the adoption of these fish feed additives for sustainable Tilapia production. In this study, an exploratory research design was used to review and comprehend numerous peer-reviewed papers published in national and international publications on issues related to fish feed additives currently used in Tilapia aquaculture production and the current and future prospects of essential fish feed additives. Feed additives are ingredients that are added in minor amounts to fish diets to increase nutrient content and prolong shelf life. Preservatives, binders, feeding stimulants, and food coloring are frequent feed additives. In order to optimize the production of farmed fish, it is necessary to encourage the use of additives as aquaculture expands. The purpose of feed additives in fish feed is to promote healthier and more rapid fish growth in aquaculture. As a result, fish diets must include the proper amounts of feed additives. The findings imply that fish feed without feed additives is analogous to "a vehicle without fuel" and should be regarded as poor fish feed when fed to fish in an aquaculture system. The end consequence will be a low growth rate for fish, decreased disease resistance, and consequently low productivity in an aquaculture production system.

INTRODUCTION

The world's most varied intensively farmed fish species, Tilapia, has lately reached productivity heights never before achieved. According to FAO (2020), the output of Tilapia is projected to be around 10.8 million metric tons in 2030. The Tilapia industry is currently expanding at a rate of 4% per year (Oglend, 2020). Production of Tilapia is seriously threatened by disease outbreaks, particularly Streptococcus infection in Red Tilapia and poor growth (Hernández *et al.*, 2009). The industry has created specialized commercial fish meals with various feed additives that are both necessary and optional for Tilapia's development rate and level of disease resistance in order to meet these growing problems. Similar to this, numerous innovative Red Tilapia strains (Behrends *et al.*, 1982) and genetically altered farmed Tilapia (GIFT) (Oliveira *et al.*, 2021) have been introduced. The novel red Tilapia strains feature vibrant hues, strong growth rates, and great market demand (Fitzgerald, 1979).

For the Tilapia farming business to experience the anticipated growth, it will be essential to have access to premium feeds with all-inclusive feed additives. In order to improve or preserve a fish diet or the feed materials, substances called feed additives are added. Common feed additives include binders, feeding stimulants, preservatives, and food colorings. According to Désiré *et al.* (2022), an ingredient or combination is gradually added to the basic fish feed mix in order to satisfy particular criteria for fish feeds. To make the fish meal more enticing, appetizing, and digestible for the cultured fish, attractants, tastes, and digestive aids are added to specially made fish feeds. Fish feed is bound with ingredients to prevent it from breaking down in the surrounding culture system (Yamazaki, 1976).

Additives given to diets for purposes other than providing nutrients are known as feed free of nutritional components (Hossain *et al.*, 2019). These ingredients are crucial to fish feeds because they increase pellet durability, diet safety, diet flavor, fish health status, and their impact on the final feed quality even though they mostly have little to no nutritional value. According to Tacon & Metian (2014), non-nutritive feed components added to fish meals include feed binders, carotenoid supplementation, medications and antibiotics, hormones, antifungals, antioxidants, fiber, flavorings, and water. The basic goal of feed additives in fish feeds is to enable healthier and faster fish growth, which increases productivity, in proportion to (Adéyèmi *et al.*, 2020). As a result, feed additives should be added to fish meals in the appropriate amounts. The various types of additives used in the creation of fish meals can be divided into three categories: supplementary additives, non-essential additives, and additives that do not promote growth. In order to produce sustainable Tilapia aquaculture, this study set out to make a thorough analysis of the current status and trend in the adoption of various fish feed additives.

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MATERIALS AND METHODS

This article review used an exploratory research design to evaluate and understand different peer-reviewed papers published in national and international journals about fish feed additives used in aquaculture production around the world and the current and future status of the most important fish feed additives on a commercial scale. The reviewed article talks about fish feed additives that are widely used in aquaculture around the world from 1980 to 2023. For this study, 70 peer-reviewed journal pieces were used as sources of literature. Based on the journals and papers put together here, the authors' contributions were judged using a comparative critical exploratory method.

RESULTS

Current Emerging Trend on the Use of Additives in Fish Feed in Aquaculture

In various aquaculture fish production systems, depending on whether finfish or shellfish species are being cultured, the use of fish feed additives has increased. Diverse authors have reviewed these issues and conducted research on the current utilization scale of additives in fish feed production as well as their impact on the market quality of aquaculture products. Based on the research conducted by Lin & Shiau (2007) and Liu *et al.* (2019), the incorporation of novel elements such as benzyl paraben into fish diets as additives promoted growth and acted as an antioxidant for the Nile Tilapia (*Oreochromis niloticus*) lipid metabolism. This indicates that certain essential compounds can be added to fish feed formulations as feed additives to reduce toxicity in farmed fish. Similarly, fin fishes are valued and inexpensive sources of omega-3 fatty acids and essential mineral elements for the human body (Shenouda, 1980). There is an urgent need to conduct additional research on novel fish feed additives, such as the inclusion of herbs in fish feeds, which reduce feed costs, increase nutrient utilization, and prevent the residual effects of hormones and antibiotics on fish tissues, which have consequences for humans who consume them. Neuropeptide Y used as a feed additive has a significant influence on stimulating and promoting the growth of Tilapia (*Oreochromis niloticus*), particularly when fed a low fish meal diet. This is evidence that the presence of feed additives in fish meals promotes Tilapia growth, increases their disease resistance, and provides therapeutic benefits in comparison to standard diets.

The most effective feed additives currently used in aquaculture are probiotics, prebiotics, phytogenic constituents, immunological stimulants, enzymes, hormones, mycotoxin binders, organic acids, and others (Cano-Lozano, 2022; de Araújo, 2018). The authors observed that these compounds affect the growth of Tilapia fish and recommended their use in aquaculture for fish-formulated diets. In developing nations such as Kenya, Tanzania, Thailand, and India, among others, the aquaculture industry is expanding significantly (Basavaraja, 2015, Hishamunda & Ridler, 2005). Demand for fish feed is escalating at a comparable rate, and feed additives are mandatory for improving the grade of fish feed produced locally for aquaculture. The use of feed additives in aquaculture is intended to enhance the palatability, efficiency, and profitability of fish feed. Due to the loss of biodiversity of most organisms that can be used as essential additives in fish feeds during formulation, environmental degradation, and the discharge of feed additive residues into the environment, a moral judgement option on feed additives is now required by law. Additional research into enhancing fish production with additives will permit the development of the optimal fish food. According to Gabriel (2019) and Poolsawat (2021), a number of studies on enzymes, medicinal feed additives, and probiotics used as fish feed additives have been reviewed. These feed additives improve feed flavor and texture, feed pigmentation, feed nutritional value, feed digestibility, and, ultimately, production efficiency.

Researchers such as (Dang & Kienzler, 2021; Mamdouh, 2021) investigated whether feed additives in Tilapia fish diets can function as chemo preventive agents, reducing the toxicity risk of various contaminants and detoxifying some active toxic substances in the fish feed. In light of this, having a comprehensive understanding of the internal action pathways of various protective feed additives may facilitate the development of novel alternatives for treating feeds during storage. Similarly, the study of fish nutritional requirements should be conducted with great care, and there is a consequent need to seek out innovative feed additives and supplements that ensure low feed costs, optimum digestibility, and few negative effects on fish and the environment (Désiré, 2022; Syed *et al.*, 2021). Similarly, Genschick (2021) evaluated the preparation of high-quality feed from acceptable and readily accessible feed additives in their research. Beneficial feed additives enhance not only the fish's growth and yield, but also their health. Beneficial feed additives include prebiotics, probiotics, seaweeds, microalgae, enzymes, organic acids, mycotoxin binders, phytobiotics, and yeast. Similarly, Yu *et al.*, (2021) evaluated the use of antibiotics in Tilapia fish farming feeds to prevent viral diseases and improve growth performance, a prevalent practice. Recently, the precautionary use of antibiotics and chemotherapeutic agents has been criticized, resulting in their global prohibition in fish markets. The majority of fish producers (Romero, 2012) are encouraging the use of beneficial feed additives as an alternative to antibiotics in aquaculture diets. The current study provides a comprehensive and practical summary of previous research on various feed additives used in aquaculture, particularly for Tilapia fish production, with examples such as probiotics, prebiotics, Synbiotics, immunostimulants, organic acids, nucleotides, and medicinal plants.

According to El-Kady *et al.*, (2021), the use of probiotics, prebiotics, and Synbiotics for the sustainable growth of Tilapia fish species has been evaluated. The authors explore the effects of probiotic, prebiotic, and synbiotic administration on growth performance, stress tolerance, intestinal microbiota, immune response, and health of Nile

Tilapia (*Oreochromis niloticus*). Furthermore, Harikrishnan *et al*., (2020) investigated how a diet abundant in dried lemon peel enhances the antioxidant activity, growth, and metabolism of *Labeo rohita*. Therefore, dried lemon peels can also be utilized to modulate the immune antioxidant capacity of Tilapia. Nile Tilapia, *Oreochromis niloticus* (Linnaeus, 1758), fed on varying concentrations of Aloe Vera extract as feed additives in a confined aquaculture system exhibited improved growth (Syed *et al*., 2022). A diet containing Aloe Vera (Liliaceae) as feed additives genetically promotes sex reversal in Farmed Nile Tilapia Fingerlings (Gabriel, 2017).

The use of Aloe Vera in fish supplies has no negative impact on the health of the fish, the farmer, or the environment. This study therefore recommends the use of Aloe vera in sex reversal and growth promoters in the production of all male Tilapia fish species in order to control the fish's prodigious breeding behavior for sustainable aquaculture production. Utilizing plant compounds as a fundamental feed additive in aquaculture proves to be environmentally and user-friendly. In addition, plant extract additives are readily accessible and inexpensive for the average fish farmer, which reduces the cost of feed production and, consequently, the price of feeds. Based on the findings of the study, the addition of 400g/kg of Aloe Vera to the diet of Nile Tilapia (*Oreochromis niloticus*) is essential for enhancing growth performance and metabolism (Syed *et al*., 2022). Another study by Ojha (2014) investigated how the fish feed worked in conjunction with Pedalium murex as an additive to enhance the survival, metabolism, and immunity of *Labeo rohita* (Hamilton, 1822) fingerlings. In addition to enhancing the fish's metabolism and disease resistance, their research indicates that Pedalium murex extracts have a significant impact on the growth performance of *Labeo rohita* fingerlings. Consequently, the authors recommended a dosage of (0.08 g/100 g diet) in the *Labeo rohita* diet feed formulation. This Review study makes a strong recommendation for the use of Pedalium murex growth promoter feed additives for Tilapia fish farming and may even be recommended for global commercial aquaculture production.

The effect of an ethanolic extract of *Mucuna pruriens* on the growth, biochemistry, and sex reversal of Nile Tilapia (*Oreochromis niloticus*), as well as the spermatogenic effect of ethanol extract *Mucuna pruriens* (Etta, 2009; Mukherjee, 2015). Fingerlings of Nile Tilapia (*Oreochromis niloticus*) exhibited a significant influence on growth, metabolism, and haematological parameters. Dietary *Mucuna supp.* supplements also improved the male population. This provides conclusive evidence that *Mucuna pruriens* is the optimal feed additive for commercial aquaculture production. Additionally, it may improve the fish's digestion and resistance. Furthermore, the effects of different amounts of *Moringa oleifera* leaf meal diet on the growth performance of African catfish *Clarias gariepinus*, haematological indices, and biochemical enzymes that the growth performance of juvenile *Clarias gariepinus* improved significantly when fed feeds containing *Moringa oleifera* leaf additives (Nuhu, 2013). The effects of *Moringa oleifera* on growth performance, haematological effects, and biochemical activities in the bodies of various Tilapia species, including Red Tilapia, Nile Tilapia, Tilapia Zilli, *Oreochromis mozambique,* and other Tilapia strains, should be investigated and documented. Evaluation of the nutritive Value of Water Hyacinth (*Eichhornia crassipes*) Leaf Meal in Compound Diets for Rohu, *Labeo rohita*. Fingerling diets after fermentation with two microbial isolates derived from the gut microbiome was conducted by Saha *et al*., (2011) and yielded a similar result. Their findings support the recommendation that 40% of fish meal can be substituted with Water hyacinth leaf meal fermented with fish gut microbes as a feed additive that has no negative effect on various fish species. This discovery, when effectively implemented, will produce nutritionally dense fish feed formulations that are cost-effective. The health and nutritional properties of Mucuna seed meal, as well as its inclusion in the diet of *Clarias gariepinus* feed additives, are quite encouraging. Both (Afolabi, 1985; Okomoda, 2017) and Oliveira *et al*., (2021) concluded that toasting Mucuna seed meal considerably improved the nutritional quality and palatability of fish feeds, allowing the African catfish *C. gariepinus* to consume more of the feed at an inclusion rate of 200g/kg. This review paper recommends the use of toasted Mucuna seed meal in Tilapia fish aquaculture to improve the nutritional value of the fish feeds in light of these studies.

Dietary cooperation of Carrots (*Daucus carota*) used as colorant pigmentation in Swordtail (*Xiphophorus helleri*) considerably improved the orange coloration of the body, particularly when supplemented with dietary Spinach at 1.3g/100g of the fish diet (Mukhopadhyay, 2021).

According to the findings of this author's study, natural carotenoid sources such as Carrots and Spinach can be added to the diet of Red Tilapia and *O. mozambique* to enhance their body coloration. It has also been investigated (Mukhopadhyay, 1996; Roopma, 2015) how substituting Sunflower oil for fish oil in the diet of juvenile *Catla catla* (Ham) affects growth performance and feed utilization. The results of the authors demonstrate conclusively that Sunflower oil may be substituted for 50% of the diet of Indian Carp (*Catla catla*) without impairing its growth performance. This study recommends that similar research be conducted on various species of Tilapia in order to optimize the formulation dosage for Sunflower oil as additives in Tilapia fish feed production. Similarly, Liu *et al*., (2019) assessed the impact of oils on the nutritional value of Nile Tilapia fillets and determined that oils are economical sources of essential fatty acids. Utilization of food oils in precise quantities as required by various fish species, including crustaceans, for optimal growth and development of muscle and body mass index. Due to their antibacterial, anti-oxidative, and growth-promoting properties, as well as their potential to enhance feed palatability, digestibility, and binding capacity, these oils in fish diets are beneficial to fish. This study strongly recommends the incorporation of lipids and fats into fish

feed formulation for sustainable aquaculture production.

Fish Feed Additives Used in Tilapia Feed Production
Essential Fish Feed Additives

To enhance the nutritional value of the fish diet and promote healthy growth, essential feed additives are added in smaller quantities. Their extended absence from fish diets may lead to nutritional deficiency diseases, particularly in Red Tilapia (Hernández, 2009; Wangkahart, 2022). Vitamins, minerals, and other nutrients are equally important for fish nutrition. In the production of *Oreochromis niloticus*, for instance, some fish farmers use prepared fish feeds with the appropriate quantities of fish additives such as calcium and vitamin premix, as well as probiotics (Opiyo 2018; Syanya & Munala, 2022). These practices are worthy of imitation. The fundamental fish feed additives discussed below are not the only ones utilized frequently in aquaculture.

Inorganic Minerals

The calcium, phosphorus, sodium, molybdenum, chlorine, magnesium, iron, selenium, iodine, manganese, copper, cobalt, and zinc are considered essential for the physiological functioning of fish (Alfiansah *et al*., 2022). In the case of Tilapia fish, these mineral elements can be supplemented with fluoride and chromium, both of which have been identified as essential growth-promoting elements when added to feed. Accordance with Kord *et al*. (2022) Calcium, phosphorus, sodium, potassium, iron, manganese, magnesium, copper, chloride, iodine, cobalt, and zinc are considered essential minerals for inclusion in the diets of Tilapia larvae and fingerlings. Consequently, their inefficiency may cause outbreaks of nutritional deficiency diseases in the culture system. When trace minerals such as copper, zinc, cobalt, iodine, and manganese are supplied as additives in the diet of fish, fish growth is generally enhanced (Sørensen, 2012). Calcium and phosphorus are essential for bone and exoskeleton development in the majority of vertebrates and crustaceans, while sodium, potassium, magnesium, and chloride are involved in osmoregulation (Prabhu *et al*., 2016). Magnesium, manganese, and zinc are cofactors of biochemical enzymes (Yossa *et al*., 2021). According to the findings of the majority of these authors, when formulating fish feed for aquaculture production, it is necessary to include the majority of essential mineral elements as feed additives.

Fish Oils

Due to its high concentration of n-3 long-chain polyunsaturated fatty acids (n-3LC- PUFA) such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are essential for fish growth and immune booster during production (Peng *et al*., 2008), Fish Oil (FO) has traditionally been the primary lipid source that has been used as fish feed additives. Incorporating fish oil into fish diets provides the cultured fish, particularly Tilapia species, with dietary energy and the essential fatty acids they require. According to Lin *et al*. (2022), a combination of fish oil and maize oil in the diet of Grouper (*Epinephelus malabaricus*) has a significant impact on growth and non-specific immunological responses. In order to increase growth and food conversion ratio, as well as the palatability of the feeds for the fish, 2-3% fish oil is added as an additive to Tilapia fish feeds during feed formulation. Similarly, according to Karapanagiotidis (2022), fish oils rich in polyunsaturated fatty acids (PUFA) such as cod liver oil, sardine oil, squid oil, and clam oil are frequently used as feed additives in the aquaculture sector. The feeds containing fish oil as an additive are highly palatable to fish and increase the FCR and digestibility of the feeds in cultured fish.

Phospholipids as Fish Feed Additives

The phospholipids provide choline, phosphorus, and essential fatty acids for the growth of fish, which must be obtained through dietary sources. Dietary phospholipids enhance growth performance inferentially by increasing CCK levels, which stimulate pancreatic secretion by increasing chylomicron levels (Luo *et al*., 2010). Similarly, Phospholipids, such as phosphatidylcholine, are crucial for the development and long-term survival of fish. The addition of 1-2% Soybean lecithin to the diet of Common carp (*Cyprinus carpio*) promotes accelerated growth and improves the feed conversion ratio, according to study (Khorshidi *et al*., 2022). Likewise, this is feasible for Tilapia fish species. Physiologically significant phospholipids are involved in the transfer of lipids (Wohlfarth, 1990). Phospholipids are found in a variety of plant and animal sources, although not all of them contain substantial amounts of specific phospholipids. Vegetable phospholipids lack essential long-chain polyunsaturated fatty acids (LC- PUFAs) such as EPA and DHA, which are particularly important in Tilapia cultivation. As a result of this deficiency, Soya phospholipids are the most commonly used phospholipid source in Red Tilapia fish feed additives during fish feed formulation. This is due to their insufficient levels of omega-3 fatty acids and phosphatidylcholine (a type of phospholipid). Phospholipids are necessary in the fish diet for optimal growth, survival, and prevention of skeletal deformities. Insufficient dietary phospholipids limit lipoprotein synthesis in enterocytes, resulting in impaired lipid transport to the tissues in Carps (Khorshidi *et al*., 2022). Similarly, according to Luo *et al*. (2010), phospholipids in the diet of Japanese Sea bass (*Lateolabrax japonicus* L.) raised in freshwater promote cholesterol and triglyceride mobilization from the gut to the hepatopancreas, haemolymph, and muscle. Phospholipids in fish meal can therefore influence lipid deposition, resulting in increased lipid accumulation in the fish when used as an additive. Based on these findings, phospholipids stand out as the most crucial ingredient for formulating Tilapia fish diets in order to achieve exceptional growth throughout the culture period.

Cholesterol

Cholesterol is an essential steroid for the nutrition of fish. Adding 0.1% to 0.5% cholesterol to fish meal improves growth and survival (Deng *et al*., 2014). The prawn head refuse meal contains cholesterol that should be included in the formulation of fish feed. And because bony fish can synthesize cholesterol, it is not necessary to supplement their diets with cholesterol for their health (Deng *et al*., 2013). However, recent studies suggest that adding cholesterol and soybean meal-based additives to Rainbow Trout (*Oncorhynchus mykiss*) formulated feeds as a protein source will enhance their growth performance. Similarly, Deng *et al*. (2014) observed that Rainbow Trout's (*Oncorhynchus mykiss*) nonspecific immunity can be enhanced by ingesting 0.6-1.2% cholesterol. Despite the discovery by Wu (2022) that cholesterol is tightly linked to Tilapia fish stress via the hypothalamic-pituitary-interregnal (HPI) axis when reared in brackish waters with high salinity, our understanding of alternative physiological functions that cholesterol can play to improve fish health under stressful conditions is limited. In relation to this finding, Tilapia fish feed should include cholesterol as a feed additive to enhance the immunity and stress tolerance of fish in culture systems, despite the fact that freshwater fish do not inherently require cholesterol.

Vitamin Premix

The vitamin premixes are concentrations where the necessary vitamins are mixed with base feed in continuous forms (Rohani *et al*., 2023). Nile Tilapia grow more quickly thanks to vitamin E therapy because their muscles are better developed. Similar improvements were made in Nile Tilapia reproductive performance and egg and larva quality when different vitamin C doses were used (Sarmento *et al*., 2018). Since choline chloride has been shown to decrease the stability of various vitamins, including water-soluble vitamins, it is not present in vitamin premixes. added portions of the diet that range from 0.5 to 4%. Vitamins are essential nutritional elements that take part in cell metabolism as well as physiological and biochemical alterations in the fish's body. There are two types of vitamins: fat-soluble and water-soluble. Thiamine, riboflavin, pyridoxine, pantothenic acid, niacin, biotin, folic acid, and vitamin B12 are examples of water-soluble vitamins. Waagbø *et al*. (2010) studied along with other water-soluble nutrients, such as choline and ascorbic acid, which have little nutritional value for fish, vitamins play a similar role in fish growth. However, fishes like Tilapia need thiamine for a healthy digestive system, development, and fertilization. It is also necessary for the proper development of neural tissue. Thiamine and other mineral element deficiencies were found to result in impaired glucose breakdown, decreased fish appetite, poor development, and increased susceptibility to stress (Prabhu *et al*., 2019). Similar to this, Carps fed thiamine-deficient diets experienced subcutaneous haemorrhages and skin bulging (Kumar *et al*., 2022).

Examples of fat-soluble vitamins, also known as phylloquinones, that serve as supplements in fish feed are vitamins A, D, E, and K. Due to its crucial function as an antioxidant in fish, vitamin E is the most prevalent fat-soluble vitamin. Fish with normal blood capillary permeability and heart muscle integrity benefit from vitamin E (Baker & Davies, 1997). Rohani *et al*. (2023) claims that vitamin E administration increased Nile Tilapia growth by promoting muscular development. Although significant research has been done in this area using highly purified meals and controlled experiments with young developing fish, no vitamin D requirements for fish have yet been documented (Brown & Robinson, 1992; Fraser, 2018; Lock *et al*., 2010). As a result, vitamin premix in fish feed as an addition is necessary for culture fish to grow sustainably and function biochemically.

Fatty Acids

The percentage of lipids (fats), a high-energy component, in fish diets should be around 15%. They primarily carry fat-soluble vitamins and serve as a source of essential fatty acids (EFA) in the diet. Omega 3 and omega 6 fatty acids, sometimes called n-3 and n-6, are the most crucial lipids needed for fish feeding (Hoseinifar *et al*., 2017). According to Hearn *et al*. (1987), 1% of highly unsaturated fatty acids (HUFA) such eicosatetraenoic acid (20:5 W3) and docosahexaenoic acid (22:6 W3) can be added to fish feed to boost growth. Tilapia and other freshwater fish don't need long-chain, highly unsaturated fatty acids, but they do need linolenic acid (18:3-n-3) in feed formulations in quantities ranging from 0.5 to 1.5% (Hoseinifar *et al*., 2017). This is due to the fact that freshwater fish cannot synthesize this fatty acid; as a result, it must be added as a supplement to fish feed during eating. However, a few of freshwater fish may consume this fatty acid and then convert it using enzyme systems to a long-chain polyunsaturated fatty acid.

Non-Essential but Growth-Promoting Substances Fish Feed Additives

Feed ingredients derived from plants and animals, single-cell proteins, and certain synthetic compounds are non-essential growth promoters that can be added to feed to hasten fish growth and increase productivity. Inclusion of non-essential growth boosters in fish diet meals does not result in deficient sickness (Opiyo, 2019; Xu *et al*., 2021). However, they play a more recommended important function in fish growth when added as fish feed supplements. Single-cell proteins, antibiotics, medications, and other substances like these are examples of attractants and growth promoters that can be derived from plant or animal components.

Enzymes

In the aquaculture industry, enzymes like protease, amylase, lipase, esterase, cellulase, xylanase, and urease are frequently utilized to encourage the growth of cultured fish species (Khorshidi *et al*., 2022). Since they can increase nutrient intake, enhance nutrient uptake in

the gastrointestinal system, and hasten fish maturity, these enzymes are given to fish as additives. Wangkahart *et al.*, (2022), complex carbohydrates, collagen in the skin and bones, and other feed components are all broken down by an enzyme in the fish body. The ideal temperature range for handling enzymes is between 40°C and 50°C (Wiszniewski *et al.*, 2021). Therefore, feed that is heated above 65 °C has its enzymes denatured and is no longer useful to fish. As a result, meals are commonly supplemented with enzymes after pelleting.

Probiotics and Prebiotics

Probiotics are dietary additives consisting of live microorganisms that promote fish growth by influencing the intestinal microbiota flora density. Probiotics may consist of a single species or a mixture of microorganisms from different species. These supplements contain bacteria that colonize the intestines and eliminate pathogenic microorganisms. Permitting the fish to avoid expending metabolic energy combating hazardous pathogens. The diets must be supplemented with probiotics after pelleting (Cano-Lozano at al., 2022; Guimarães *et al.*, 2019). Similarly, Prebiotics are nondigestible fibers that benefit the health of the host by encouraging the growth and activity of specific microorganism genera in the colon, primarily lactobacilli and bacteria in the post-larval diet of Nile Tilapia (de Araújo *et al.*, 2018).

Hormones

In aquaculture, hormones are used for sex reversal and artificial reproduction in hatcheries. Hatcheries and other production facilities produce fingerlings continuously thanks to artificial reproduction (Yamazaki, 1976). When the male and female growth rates differ noticeably and they potentially achieve differing weights and sizes at maturity, hormones are used in sex reversal. Aquaculture has also made use of a number of natural and synthetic hormones for spawning induction, sex reversal, producing mono-sex populations, and growth enhancement (Higgs *et al.*, 1982; Shore & Shemesh, 1859). The hormones that cause fish to grow include thyroid hormone, gonadotropin, prolactin, insulin, and several steroids (Hoseinifar *et al.*, 2017). Growth promoters include non-steroidal hormones like thyroxin, as well as growth hormones like androgen, estrogen, and progestogens (Behrends *et al.*, 1982).

Antibiotics

Antibiotics are used in aquaculture to treat diseases brought on by bacteria in either prawn or fish farms. Antibiotics can be used to treat infections and diseases caused by bacteria, but they are typically used to prevent infections by treating the fish or the water before the condition manifests (Romero *et al.*, 2012). According to Zhou (2020), antibiotics are frequently seen to boost growth in juvenile fish rather than adult fish, especially when added to fish diet. Antibiotics therefore work effectively in fish diets made with vegetable proteins. Antibiotics reduce or stop pathogen activity in the fish culture system and get rid of the microbes that make the toxins that stop growth (Romero *et al.*, 2012). Antibiotic use can sometimes promote the growth of beneficial bacteria, such as probiotics, which produce nutrients for fish, reduce the number of bacteria that compete with the host for nutrients, and increase the intestine's capacity for absorption. Given that the widespread use of antibiotics in aquaculture production has been forbidden by the majority of EU nations, we highly advise using antibiotics as an additive in fish meals but at lower dosages.

Binders

Fish feed must be durable enough to withstand normal handling and transport without degrading. In addition, fish food must be stable in water. Binders are therefore added to fish feeds during formulation in order to increase their stability in water and prevent their dissolution before the fish ingest them. The majority of plant starches are used as fundamental feed components during preparation and formulation, acting as binders in feed. Binder components consist of agar- agar, carboxymethylcellulose (CMC), bentonite, guar gum, lignin sulphate, plaster of Paris, polyvinyl alcohol, sodium alginate, and wheat gluten (Désiré *et al.*, 2022).

Binders are required to provide the desired water stability to the feeds, preventing the dissolution of the fish feeds into the culture water before the fish ingest them. Selection of binders and inclusion levels are influenced by the binding strength and cost (Hossain *et al.*, 2019). Gelatinized starch from tapioca, wheat flour, and rice flour are the most commonly used binders in aquaculture because they are readily available, cost-effective, and sustainable for the average fish farmer. The recommended levels of binder's guar gum and gum-acacia are 1% to 2%; gelatin, collagen, carrageenan, and agar are 2% to 5%; and wheat gluten (10 to 12%), wheat flour, and tapioca starch may be used in relatively high concentrations (Flefil *et al.*, 2022). It may be more effective and cost-efficient to use a combination of these binders. Similarly, chitin and chitosan can be incorporated into larval feed portions to some extent.

Molasses

The molasses is frequently added to fish feed as an additive to facilitate the pelleting process. The presence of molasses also improves the palatability of nutrients. Similarly, it is an excellent energy source for fish in feed (Khanjani *et al.*, 2021). Molasses (with a C/N ratio of 1:2) was found to increase the pH of pond water, thereby encouraging the growth of beneficial bio floc in the pond (Alfiansah *et al.*, 2022). Molasses enhanced carbohydrates and proteins in bio-flocs and maintained an abundance of beneficial microbes, resulting in a low availability of inorganic nutrients to the fish. Molasses is therefore suitable for Tilapia and shrimp aquaculture to increase growth rate and production.

Chemo-Attractants

These are the compounds that encourage animals to eat more and increase feed intake. Nucleotides and

free amino acids are the most important. L-amino acid, glycine-betaine, inosine, or mixes of inosine-5-phosphate are thought of as "universal feeding stimulants" for fish (Straus *et al*., 2013). Several finfish species are known to require particular feeding stimulants in general.

Drugs

When used together with fish food, arsenicals and sulfa treatments help Tilapia species grow. 3-nitro-4-hydroxy phenyl arsenic acid, para-amino-phenyl arsenic acid, and sodium salt are all types of arsenicals that can be used as fillers when making feed (Bijoy *et al*., 1879; Opiyo *et al*., 2018). Sulphonamides are one type of medicine made with sulfa. Medicines boost the immune system and help young fish grow, which is good for their general health and biochemical processes. Most research on drug use in aquaculture, however, says that the exact way these medicines work in fish is unknown, but their effects seem to be like those of antibiotics (Zhou *et al*., 2021). Because of the benefits to the fish, it makes sense to add veterinary meds and drugs to fish feed.

Synbiotics and Phytobiotics

Gibson introduced synbiotics by combining prebiotics and probiotics to create Symbiotic substances (Mohammadi *et al*., 2022). By selecting fostering an extension of symbiotic benefits to the fish, the survivability and adoption of live microbiological food supplements within the gastrointestinal system were boosted. The photobiotic vial is defined as a plant-derived nutrient infusion used to feed in arrangements to improve the performance of aquatic animals. Herbs, spices, and the leaves, roots, tubers, and fruits of other plants are all used as probiotics. Pytobiotics are extensively used in fish and prawn cultures to boost growth and productivity (Saeed *et al*., 2014). All of these feed additives should be included in the Tilapia fish diet, although in limited amounts due to environmental concerns about the photobiotic phototherapeutic nature.

Supplementary Additives

The small substances are added to feeds during formulation as auxiliary fish feed additives (Owatari *et al*., 2022). They act as additives to improve the aesthetics of fish feed. This helps to boost the fish's ability to digest the foods, which ultimately results in higher feed efficiency. These ingredients may also be referred to as supplemental ingredients. They consist of, but are not limited to, attractants, binders, molasses, and colorants for feed.

Diverse additives are added to fish diets to prevent water-soluble nutrients from dissolving into the culture systems before the feeds are eaten by the fish and to help cultured fish use nutrients effectively. In GIFT Tilapia fish production, binders, antioxidants, mold inhibitors, antibacterial agents, attractants, growth stimulants, mendicants, pigments, and other chemicals are frequently utilized as supplemental supplements (Xu *et al*., 2021). The active substance chosen and employed should not pose a risk to the species of cultured fish, the farmer, or the final fish consumers. According to Van *et al*. (2021), Nile Tilapia (*Oreochromis niloticus*) diets can be supplemented with pineapple peel powder and *Lactobacillus plantarum* to increase disease resistance. The author claimed that the additional additives shouldn't interact with the feed components in a way that lowers the feed's nutritional value. They further decided that these additives shouldn't alter the taste, appearance, flavor, or texture of the fish feeds created, as this would lessen their favorable attributes. This demonstrates that the finest auxiliary additions have to have a negligible effect on the nutritional content and quality of fish feeds, and the materials employed ought to be accessible to the average farmer in sufficient amounts and at a reasonable cost.

Colorants and Pigments

Colorants used in fish feed are frequently thought to have both plant and animal origins. There are currently about 300 supplemental pigment additives utilized in both finfish and shellfish aquaculture that are derived from plants and animals (Tuan *et al*., 2022a). It was stated that xanthophyll and carotenoids are the most prominent pigment groups, and that carotenoids and astaxanthins can be found in both natural and synthetic sources. Plants primarily contain xanthophyll, but Crabs and fish contain carotenoid pigments (Tuan *et al*., 2022b). Additionally, it has been proven that these pigments promote fish development and survival. The primary purpose of these colorations is to guarantee that cultured organisms have the proper coloring. Given that consumers believe Red Tilapia to be similar to most other marine species that are dyed red (Basavaraja & Raghavendra 2017, Wohlfarth *et al*., 1990), the coloring of Red Tilapia fish has a substantial impact on market pricing and demand. The Red Tilapia Fish and crustaceans that are unable to manufacture color but can change the components through oxidation rely most heavily on carotenoids for their color. It is well known that dietary astaxanthin enrichment has a considerable impact on growth as well as the color and development of Red Tilapia, *Oreochromis* spp. (Tuan *et al*., 2022a). It was found that adding carotenoids to broodstock diets reduced maturation times, increased egg production, enhanced egg hatchability, and increased larval survival (Waaqi *et al*., 2021). Fish farmers in rural areas lack knowledge of proper usage and supplement requirements for these fish feed additives, despite the fact that they may be aware of the economic of the additives and nutritional benefits to cultured fish. As a result, their use must be encouraged during the fish feed formulation stage. Fish feed colorants have a wide range of economic benefits for the aquaculture sector.

CONCLUSION

The most common fish feed additives used in aquaculture production are essential fish feed additives, non-essential fish feed additives that help fish grow, and secondary

fish feed additives. The reviewed literature makes it clear how important they are to fish health, from helping them grow to changing their sexes and making their immune systems stronger in most cultured fish species, including Tilapia. People say that feed additives like preservatives, binders, feeding stimulants, and food colorants help fish grow faster and healthier, which leads to more output and yield. So, it's important that all locally made fish feeds stick to the amounts of essential, non-essential, and auxiliary fish feed additives in the fish diet. Lastly, feed additives are added to fish food to help fish grow faster and be less likely to get sick. They also make fish food more appealing, tasty, and easy to swallow. This means, in short, that fish feed with no feed additives is like "a car without petrol" and is usually thought of as "No feed" when given to fish in a culture system. If there are no chemicals, fish should be fed natural foods like copepods, artemia, phytoplankton, zooplankton, and algae. That shows how important fish feed additives are for raising fish in a healthy way.

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