Minireview Article

Current Status and Trend on the Adoption of fish feed additives for SustainableTilapia aquaculture production: A Review.

Abstract

Duringfish feed production, feed additives are regarded as an essential component of the fish diet. The use of feed additives in fish feeds is essential for boosting the growth and immunity of cultured fish. An exploratory research design was used in the study to review and comprehend various peer-reviewed papers published in national and international publications journals on issues surrounding fish feed additives currently used in Tilapia aquaculture production, and the current and future status of essential fish feed additives in use. Feed additives are ingredients that are added in small quantities in fish diets to enhance nutrients and preserve the feeds.Preservatives, binders, feeding stimulants, and food colorants constitute common feed additives. With increased growth in aquaculture, the use of additives must be promoted in order to optimize the production of farmed fish. The aim of feed additives in fish feed is to promote healthier and faster fish growth of cultured fish. As a result, fish diets should incorporate the right quantities of feed additives. The conclusions made succinctly suggest that fish feed with no feed additives is comparable to "a vehicle without fuel" and should be regarded as Poor feed when fed to fish in a culture system.

Keywords:*Fish feeds, Feed additives, ingredient, oil, colorant, digestibility, attractants, stimulants*

1.0.Introduction

Tilapia fishthe world's most diverse intensively farmed fish species have recently hit unprecedented levels of production.In 2030, tilapia output is expected to be approximately 10.8 million metric tonnes based on FAO projection(FAO, 2022). The tilapia sector is now increasing at a 4% annual pace (Oglend, 2020). Disease outbreaks, particularly Streptococcus infection in red Tilapia and slow growth rate pose a significant concern to tilapia production(Hernández et al., 2009). To overcome these increasing challenges, the industry has developed special commercial fish feeds with different feed additives that are both essential and nonessential to the growth rate and disease resistance level of tilapia Similarly a variety of novel strains of Red tilapia(Behrends et al., 1982) and Genetically modified farmed Tilapia(GIFT)(Oliveira et al., 2021) has been introduced. the new strains of red tilapia have appealing colours, quicker development rates, and high market demand(Fitzgerald, 1979). The availability of high-quality feeds with all-inclusive feed additives will be critical in realizing the predicted expansion of this Tilapia farming industry.Feed additives are compounds that are added to a fish diet or feed ingredients in trace proportions to enhance or preserve it. Preservatives, binders, feeding stimulants, and food colorants are all common feed additives. To meet specific requirements of fish feeds according to (Désiré Adéyèmi et al., 2022) an ingredient or combinations are added to the basic fish feed mix in small levels. In formulated fish feeds attractants, flavors, and digestive aids are added to make the fish meal more appealing, appetizing, and digestible to by the cultured fish. Binding materials are used to keepfish feed from disintegrating in the surroundingculture system (Yossa et al., 2021) Feed free of nutritional components are additives added to diets for purposes besides

supplying nutrients (Hossain et al., 2019). These substances, in substantial part, have little or no nutritive value, but they are essential components of fish feeds, boosting pellet durability, diet safety, diet flavor, and fishhealth status, and their effect on the end quality of the feed. According to (Tacon & Metian, 2015)Feed binders, carotenoid supplementation, medicines and antibiotics, hormones, antifungals, antioxidants, fiber, flavorings, and water are examples of non-nutritive feed components added to fish feeds. In relation to (Adéyèmi et al., 2020) the primary objective of feed additivesin fish feeds is to ensure healthier and quicker fish growth, which leads to increased productivity. Therefore, fish feeds should be incorporated with feed additives in the required proportions.There are several types of additives used in the formulation of fish feeds which can be categorized as Essential additives, Non-essential rather than growth-promoting substances additives, and Supplementary additives.

2.0. Material and Methods

The exploratory researchdesign wasused in this article review to evaluate and understand different peer-reviewed papers published in national and international publications journals on matters related to fish feed additives used in global aquaculture production and the current and future status of the crucial fish feed additives on a commercial scale. A comparative critical exploratory approach was used to assess the authors' contributions based on the journals and articles compilations made herein.

3. Results of the findings.

3.0. Types of fish feed additives used in Tilapia feed production

There are three different additives used for the purposes of tilapia fish feed production. These can be categorized as:

1. Essential fish feed additives,
2. Non-essential rather than growth-promoting substances fish feed additives, and
3. Supplementary additives (Auxiliary additives).

3.1.Essential fish feed additives

Essential fish feed additives are added in smaller doses to improve the nutritional value of the fish diet and promote healthy growth. Their extended absence in the fish diet may result in nutritional deficiency diseases, especially in red tilapia (Hernández et al., 2009; Wang et al., 2019). Vitamins, minerals, and so forth are equally vital in fish feed.The fish health management practices for instance adopted among Kenyan fish farmers that involve the usage of formulated fish feeds with the right concentration of fish additives such as calcium and vitamin premix as well as probiotics in Oreochromis *niloticus* production (Opiyo et al., 2018; Syanya F.J & Mathia W. Munala, 2022)is worth emulation. Notably commonly used essential fish feed additives in aquaculture are not limited to the one discussed below.

3.1.1 Vitamin premix

According to,Rohani et al., (2023) vitamin premixes are concentrations in which continuous forms of required vitamins are blended with basal feed.Vitamin E therapy improves Nile tilapia growth through improved muscle development.Similarly,the reproductive efficiency and egg and larvae quality of Nile tilapia given varying amounts of vitamin C improved significantly.(Sarmento et al., 2018). Choline chloride is not included in the vitamin premixes since it has been demonstrated to reduce the stability of somevitamins such as water-solublevitamins. Added amounts ranging from 0.5 to 4% of the diet. Vitamins are vital dietary components that participate in cell metabolism and physiological and biochemical changes in the body of the fish. Vitamins are categorized as water-soluble and fat-soluble. Water-

soluble vitamins includevitamin B complex members such as thiamine, riboflavin, pyridoxine, pantothenic acid, niacin, biotin, folic acid, and vitamin B12(Waagbø, 2010) Similarly water-solublenational factors alongside the vitamins with a key role in fish growth includes: choline, ascorbic acid; and anthervitamins with minimal value to fish nutrition. However,Thiamine is required fora good digestion system, growth, and fertility in fishes includingTilapia. It is equallyrequired for appropriate neural tissue development According to Prabhu et al., (2019) deficiency of Thiamine and other mineral elements I Salmon was observed to cause decreased glucosebreakdown low appetite in fish poor growth, and increased vulnerability to fishstress. Similarly, Kumar et al., (2022) observed that Carps fed thiamine-deficient diets developed skin bulging and subcutaneous hemorrhage.

Vitamins A, D,E, and K are examples of fat-soluble vitamins also referred to as phylloquinone that act as fish feed additives. Vitamin E is the most common of fat-solublevitamin due to its key role as an antioxidant in fish.Vitamin E helps to maintain normal blood capillary permeability and heart muscle integrity of the fish (Baker & Davies, 1997).

. According to (Rohani et al., 2023)Vitamin E treatment was reported to improve Nile tilapia growth through enhanced muscle development. However sofar, no vitamin D requirements for fish have been reported, though some study has been done in this field utilizing highly purified diets and controlled studies with young developing fish(Brown & Robinson, 1992; Fraser, 2018; Lock et al., 2010). Therefore, vitamin premix in fish feed as the additive is not an exception for sustainable growth and biochemical functioning of culture fish.

3.1.2. Inorganic Minerals.

Major minerals that are considered with a wide range of use in the aquaculture sector include Calcium, phosphorus, sodium, molybdenum, chlorine, magnesium, iron, selenium, iodine, manganese, copper, cobalt, and zinc are all considered required for fish physiological functioning(Antony Jesu Prabhu et al., 2016). These mineral elements can be supplemented with fluorine and chromium, for the case of tilapia fish species both of which have been found to be essential elements when incorporated with feed as additives for their enhanced growth. According to Kord et al., (2022)In the diet of Tilapia Fry and fingerlings Calcium, phosphorus, sodium, potassium, iron, manganese, magnesium, copper, chloride, iodine, cobalt, and zinc are considered necessary minerals to be in cooperated in the feeds. Therefore,their inefficiency may result innutritional deficiency disease outbreaks in the culture system. When trace minerals like copper, zinc, cobalt, iodine, and manganese are supplied in the fish diet as additives, the growth of the fish is generally enhanced (Sørensen, 2012). Similarly, Calcium and phosphorus are required for bone and exoskeleton development in most fishes and crustaceans, while sodium, potassium, magnesium, and chloride are involved in osmoregulation(Antony Jesu Prabhu et al., 2016). Biochemical enzymes contain magnesium, manganese, and zinc as cofactors (Yu et al., 2021).There is a need to incorporate most of the essential mineral elements as feed additives when formulating fish feed for aquaculture production as reported by the finding of most of these authors.

3.1.3 Fish oils

Fish oil (FO) has traditionally been the primary lipid source that has been used as fish feedadditives due to its high concentrationof 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 oilwhen incorporated in the fish feeds provides dietary energyand the requiredessential fatty acids for the cultured fish, especially Tilapia species. According to Lin & Shiau, (2007),There is a significant effect on growth and non-specific immunological responseson the use of a fish

oil-corn oil dietary combination on grouper, (*Epinephelus malabaricus)*. Fish oil is therefore added at 2- 3% as additives in Tilapia fish feeds during feed formulation in order to improve growthand food conversion ratio as well as the palatability of the feeds by the fish. Similarly, according to Karapanagiotidis et al., (2022) fish oils high in polyunsaturated fatty Acids (PUFA) such as cod liver oil, sardine oil, squid oil, and clam oil are commonly used as feed additives in the aquaculture sector. The feeds containing fish oil as additives are considered highly palatable by fish and promote FCR and digestibility of the feeds by the cultures fish.

3.1.4. Phospholipids as fish feed additives.

For fish growth, phospholipids provide choline, phosphorus, and necessary fatty acids that need to be provided through dietary feeds. Dietary phospholipids improve growth performance indirectly by increasing CCK levels, which stimulate pancreatic secretion by increasing chylomicron levels(Luo et al., 2010).Similarly,Phospholipids, such as phosphatidylcholine, are necessary for fish growth and long-term survival.Khorshidi et al., (2022) reported thatcommon carp (*Cyprinus carpio*) diet containing 1-2% soybean lecithin boosts accelerated growth and enhances the feed conversion ratio. This too is practically possible for tilapia fish species. Furtherphospholipids are physiologically significant in the transfer of lipids in the body(Wu et al., 2022).Many plant and animal sources have phospholipids, although not all of them have large quantities of certain phospholipids. Vegetable phospholipids, do not have sufficientlong-chain polyunsaturated fatty acids (LC-PUFAs) such as EPA and DHA that are vital especially in Tilapia fish farming. Therefore, due to this deficiency, Soya phospholipids are the most commonly used phospholipid source inred Tilapia fish feed additives during fish feed formulation. This is due to their low (phosphatidylcholine; a kind of phospholipid) concentration and omega-3 fatty acid levels.Therefore, for optimal growthand survival as well as prevention of fish skeletal deformities phospholipids are a requirement in the fish diet.Lack of sufficient dietary phospholipids limits lipoprotein synthesis in enterocytes, leading to impaired transport of lipids to the tissues in carps (Khorshidi et al., 2022).Similarly, according to (Luo et al., 2010)Japanese sea bass (*Lateolabrax japonicus L.*) reared in freshwaterdietary phospholipids increase cholesterol and triglyceride mobilization from the gut to the hepatopancreas, hemolymph, and muscle. Phospholipids therefore in thefish mealwhen used as an additive are able to influence lipid deposition, resulting in enhanced lipid accumulation in the fish. Based on these findings Phospholipids stand out as the most essential additive when formulating Tilapia fish feeds in order to record outstanding growth during the culture period.

3.1.5. Fatty Acids:

Lipids (fats) are high-energy nutrients that should make up about 15% of fish diets. Their primary role in the diet is to provide essential fatty acids (EFA) and to transport fat-soluble vitamins. The most important required lipids for fish feeding are omega 3 and omega 6 fatty acids, often known as n-3 and n-6.(Hoseinifar et al., 2017) Similarly (HEARN et al., 1987) reported that to improve growth, 1% of highly unsaturated fatty acids (HUFA) such as eicosatetraenoic acid (20:5 W3) and docosahexaenoic acid (22:6 W3) can be added to fish feed.Freshwater fish such as Tilapia do not require long-chain highly unsaturated fatty acids, but they do require linolenic acid (18:3-n-3) in amounts ranging from 0.5 to 1.5% of the feed formulated (Hoseinifar et al., 2017)This is because Freshwater fishes are unable to synthesize this fatty acid, thus it must be provided as additives within the fish feed during the feeding process. Several freshwater fish however may ingest this fatty acid and use enzyme systems to extend to a long-chain polyunsaturated fatty acid.

3.1.6. Cholesterol:

Cholesterol is a nutritionally important steroid in the diet of fish. The addition of 0.1- 0.5% cholesterol to a fishmeal boosts growth and survival(Deng et al., 2014). The prawn head waste meal contains cholesterolthat should be incorporated to fish feeds during formulation. And because bony fish can synthesize cholesterol, it is not necessary to supplement dietary cholesterol for their health(Deng et al., 2013), however recent studies that have suggested that adding cholesterol and soybean meal-based additives to rainbow trout (*Oncorhynchus mykiss*) formulated feeds as protein source will increase their growth performance. Similarly, (Deng et al., 2014) observed that the Nonspecific immunity of rainbow trout (*Oncorhynchus mykiss)* can be improved by consuming 0.6-1.2% cholesterol. Nevertheless, our understanding of alternative physiological functions that cholesterol can play to enhance fish health under stress circumstances is limited, despite the finding made by (C. Xu et al., 2018) that cholesterol is tightly connected to tilapia fish stress via the hypothalamic-pituitary-interregnal (HPI) axis when reared under brackish waters with high salinity.In relation to this finding Tilapia fish feed should incorporate cholesterol as a feed additive to boost the immunity and stress endurance of the fish in the culture systems even though freshwater fishes do not necessarily require cholesterol.

3.2. Non-essential but growth-promoting substances fish feed additives

Non-essential growth promoter substances are feed Ingredients that are sourced from plants and animals, single-cell proteins, and certain synthetic chemicals which can be utilized as feed supplements to promote faster fish growth and higher yield. Non-essential growth promoters do not cause deficiency illness if they are not included in the fish diet meal (Opiyo et al., 2019; W. Xu et al., 2021). However, when supplemented with fish feed as additives they have a more recommended significant rolein fish growth. They are attractants and growth boosters either from Plant or animal materials, as well as single-cell proteins, antibiotics, drugs, and so on are examples worth mentioning.

3.2.1 Antibiotics:

In aquaculture, Antibiotics are administered to combat infections caused by bacteriain either shrimp or fish farms. Antibiotics may be utilized to curebacterial-related infections and diseases, but they are usually used to prevent infections by treating the water or fish before the disease emerges (Romero et al., 2012).Antibiotics, according to Zhou et al., (2021), are often observed to increase growth in juvenile fish rather than adult fishes, especially when incorporated in fish feeds as an additive. Therefore, Antibiotics perform well in fishdiets prepared with vegetable proteins. Anti-biotics result in the Decrease or eliminationof pathogen activity from the fish culture systemand Remove microorganisms that create poisons that inhibit growth.(Romero et al., 2012). The use of antibiotics sometimes encourages the development of helpful bacteria such as probiotics that synthesize nutrients for the fish, decrease bacteria that compete for nutrition with the host, and Improve the intestine's absorption capacity.Based on these findings we strongly recommend the use of antibiotics as an additive in fish feeds however in smaller concentrations since the Massive use of antibiotics in aquaculture production has been outlawed by most EU countries.

3.2.2. Hormones:

Hormones are utilized in aquaculture for artificial reproductionin hatcheries and sex reversal. Artificial reproduction keeps the production units such as hatcheries constantly producing fingerlings (Yamazaki, 1976). Hormones are employedin sex reversal when the male and female growth rates differ significantlyand are able to gain differentweights and sizes atmaturity.Several natural and synthetic hormones havealso beenutilized in aquaculture

forinstance spawning induction, sex reversal, mono-sex population production, and growth promotion.(Higgs et al., 1982; Shore & Shemesh, 2003) Growth hormones, such as thyroid hormone, gonadotropin, prolactin, insulin, and different steroids are the hormones responsible for fish growth(Higgs et al., 1982). Growth hormones such as androgen, estrogens, and progestogens, as well as non-steroidal hormones such as thyroxin, are utilized as growth promoters (Yamazaki, 1976).

3.2.3. Drugs:

Arsenicals and sulpha medicines whencooperatedwith fish feeds promote growth in Tilapia species specifically. The arsenicals that can be used asadditives during feed formulation include 3-nitro-4-hydroxy phenyl arsenic acid, para-amino-phenyl arsenic acid, and sodium salt (Bijoy et al., 2018; Opiyo et al., 2018). Sulphonamides are among the sulpha medicines used. Medicines work as an immune promoterand for growth in juvenilefish, improving their overall health and biochemical activities.However, according to most literature on drug usage in aquaculture, the precise method of action of these medicines in fish is unknown, their actions appear to be comparable to those of antibiotics(Zhou et al., 2021). Therefore,it's prudent enough to incorporate Veterinary medicines and drugs as additives during fish feed formulation due to the associated benefits to the fish cultured.

3.2.4. Enzymes in fish diet

Protease, amylase, lipase, esterase, cellulase, xylanase, and urease are commonly used enzymes in the aquaculture sector to promotethe growth of the culture fish species (Khorshidi et al., 2022). These enzymes are administered to fish as an additivesince they can boost nutritional intake, improve the uptake of nutrients in the gastrointestinal tract, and accelerate fish maturation. According to Wangkahart et al., (2022) enzymes used as additives in fish feeds improve feed digestibility infish hence being digested effectively. An enzyme in the fish body is also utilized to digest complex carbohydrates, collagen in the skin and bones, and other feed ingredients by the fish. Enzymes should be handled within optimum temperatures of between 40 ^{oc} to 50^{oc}. (Wiszniewski et al., 2022) Therefore Temperatures exceeding 65^{oc} denature enzymes in the feed and hence become of no value to the fish. As a result, enzyme supplements are frequently applied to meals after pelleting.

3.2.5. Probiotics and Prebiotics

Probiotics are live microorganisms' dietary additives that promote fish development by influencing the intestinal microbiota flora density. Probiotics can be a single species or a combination of microorganisms of various species. The supplements contain bacteria that colonize the intestines and kill harmful microbes. Enabling the fish to avoid wasting metabolic energy fighting against harmful pathogens. After pelleting, probiotics must be introduced to the diets(Cano-Lozano et al., 2022; Guimarães et al., 2019). Similarly, Prebiotics are nondigestible fibers that benefit the host's health by specifically encouraging the development and activity of certain genera of microorganisms in the colon, primarily lactobacilli and bacteria in Nile Tilapia post-larvae diet (de Araújo et al., 2018)

3.2.6. Synbiotics and phytobiotics

Synbiotics were first proposed by Gibson where he incorporated, prebiotics with probiotics to form Symbiotic compounds (Mohammadi et al., 2022). The survivability and adoption of live microbiological dietary supplements within the gastrointestinal system were promoted by selectively encouraging expansion of symbiotic benefits to the fish. The photobiotic vial is defined as plant-derived nutrients infusion to feed in arrangements to promote aquatic species performance. Herbs, spices, and other plants' leaves, roots, tubers, and fruits are all utilised as pytobiotics. Pytobiotics are commonly utilised to improve growth and yield in fish and prawn

culture (Saeed et al., 2014). All these feed additives ought to be included in the Tilapia fish diet however in small proportions due to environmental concerns of Phyto therapeutic nature of photobiotic.

3.3. Supplementary additives (Auxiliary additives).

Auxiliary fish feed additives are small ingredients applied to feeds during formulation (Owatari et al., 2022). They serve as ingredients to enhance the physical appearances of fish feed. This, in turn, aids in increased digestibility of the feeds by the fish and hence culminating to increased feed efficiency. These additives can also be considered as supplementary additives. They include and not limited to Feed colouration, binders, molasses, fats, attractants, and so on.

A range of substances are added to fish diets to protect water - soluble nutrients from dissolving into the culture systems before the feeds are consumed by the fish and can also promote nutrient effective utilisation by cultured fish. Binders, antioxidants, mould inhibitors, antibacterial agents, attractants, growth promoters, mendicants, colours, and other ingredients are frequently used as supplementary additives in GIFT tilapia fish farming (W. Xu et al., 2021). The active ingredient selected and used should not be hazardous to the cultured fish species or the farmer and end fish consumers. Similarly, Van Doan et al., (2021) in his finding while supplementing pineapple peel powder and Lactobacillus plantarum as disease resistance substances in Nile Tilapia (*Oreochromis niloticus*) Feedsreported that the supplementary additives used should not react with the feed ingredients and negatively affect the nutritional value of the feed, and should not reduce the desirable qualities of the fish feeds produced by affecting its taste, appearance, flavor, and texture. This shows that the best Auxiliary additives should have minimal impact on the quality and nutritional values of the fish feeds as well as the source of material used should be readily available to an ordinary farmer in adequate quantities and at an affordable price.

3.3.1 Fish Feed Colourants and Pigments.

Fish feeds colorants are commonly considered to be of Plant and animal origin. Currently, there are roughly 300 pigments found in plants and animals used in both finfish and shellfish aquaculture as pigment supplementary additives. According to Tuan Harith et al., (2022)

Reported that Carotenoids and astaxanthins can be found in both natural and synthetic sources and that the most significant pigment classes are xanthophyll and carotenoids. Mostlyxanthophyll is found in plants, while carotenoid pigments are present in crustaceans and fish (Tuan Harith et al., 2022b).Additionally,these pigments have been equally observed to increase fish growth and survival. The main role of these colorations is to ensure the correct pigmentation of cultivated organisms.The colour of red tilapia fish (Basavaraja & Raghavendra, 2017; Wohlfarth et al., 1990)has a significant impact on market pricing and demand since the consumers havea perception of Red tilapia being similar to most colored marine species in the market due to its red coloration. Carotenoids are the most significant of the substances that give color to the Red tilapia Fish as well as crustaceans that cannot produce colors, but they may change the compounds by oxidation.The effect of dietary astaxanthin enrichment on the colour and development of red tilapia, Oreochromis spp is well documented as having a significant effect on growth as well (Tuan Harith et al., 2022a). The addition of carotenoids to broodstockdiets was observed to cause a decrease in maturation time, an increase in egg quantity, and improved egg hatchability, and larval survival(Wan-Mohtar et al., 2021). The right dosage of Fish Feed colorants is of wide economic benefit to the aquaculture sector and therefore its usage needs to be encouraged during the fish feed formulation stage since fish farmers in the rural setting have no idea of the proper usage and supplement required dosage for these fish feed additives even though they could be aware of the economic and nutritional benefits values of the additives to the cultured fish**.**

3.3.2. **Binders:**

Fish feed must be robust enough just to sustain typical handling and transportation without degradation. Moreover, fish feed must be water-stable. For this reason, Binders are added to fish feeds during formulation to increase their stability in water without being disintegrated before the feed is consumed by the fish. Most plantStarches are used as basic feed components during preparation and formulation which act as a binder in feed. Binder ingredients include agar-agar, carboxymethylcellulose (CMC), bentonite, guar gum, lignin sulphate, plaster of Paris, polyvinyl alcohol, sodium alginate, and wheat gluten(Désiré Adéyèmi et al., 2022).

Binders are required to provide the desired water stability to the feeds, preventing the disintegration of the fish feeds into the culture water before the fish consumes the feeds. The binding strength and cost influence binder selection and inclusion levels (Hossain et al., 2019). The commonly used binders in aquaculture are Gelatinised starch from tapioca, wheat flour, and rice flour which are considered readily available and cost-effective to the common fish farmer and hence being sustainable. Recommended levels of binder's guar gum, gum-acacia, are 1-2%; gelatin, collagen, carrageenan, and agar 2-5%; and wheat gluten (10-12%) and wheat flour and tapioca starch could be used in relatively high levels(Flefil et al., 2022). A mixture of some of these binders may be consideredmore effective and economical to use.Similarly, to some extent, chitin and chitosan can be used in larvalfeed meals during larval rearing.

3.3.3. Molasses

The addition of molasses tofish feed as an additiveoften aids in the smooth pelleting process offish feed. Thepalatabilityof feeds is also improved due to the presence of molasses. Similarly, it'sa good source of energyfor fish in feed (Khanjani et al., 2021).However,Molasses (with a C/N ratio of 1:2) was observed to raise the pH of pond water, promoting the production of beneficial biofloc in the pond(Alfiansah et al., 2022). Molasses also enhanced carbohydrates and proteins in bio-flocs and kept beneficial bacteria in abundance, resulting in low inorganic nutrient availability to the fish. As a result, molasses is appropriate for Tilapia and shrimp farming to boost growth rate and production.

3.3.4. Chemo-attractants and feeding stimulants

These are chemicals that stimulate eating patterns in animals and enhance feed consumption. The most crucial are free amino acids and nucleotides. Several finfish species are known to require special feeding stimulants in general, L-amino acid, glycine-betaine, inosine, or inosine-5-phosphate mixtures are regarded as 'universal feeding stimulants' for fish(Straus et al., 2013).

4.0.Current Emerging trend on the use of additives in fish feed in aquaculture.

Fish feed additives have increasingly been used in different aquaculture fish production systems depending on whether finfish/shellfish species are under culture. Different authors have reviewed theseissues as well as conducted research on the current usage scale of additives in fish feed production, and their effect on the quality of aquaculture products in the market. Based on the study done by H. Lin et al., (2022)the novel elements such as benzyl paraben incorporated in fish feeds as additives promoted growth and acted as antioxidant and lipid metabolism of Nile tilapia (*Oreochromis niloticus*). This is an indication that some vital compounds can be incorporated in fish feeds during formulations as feed additives on alleviating toxicity in farmed fish. Similarly, fin fishes are considered valuable and less expensive sources of omega-3 fatty acids and vital mineral elements in 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 expenses, increase nutrient utilization, and prevent the remaining effects of hormones and antibiotics on fish tissues, which in turn have impacts on people who consume them. According toYu et al., (2021b) Neuropeptide Y used as a feed additivehas a significant effect of stimulating andpromoting the growth of Tilapia (*Oreochromis niloticus*), especially when fed on a low fish meal diet. This is an indication that the presence of feed additives in fish meals promotes tilapia growth, improves their resistance to disease, and provides therapeutic benefits as compared to standard diets.

Probiotics, prebiotics, phytogenic ingredients, immunological stimulants, enzymes, hormones, mycotoxin binders, organic acids, and other functional feed additives are the optimum feed additives currently used in aquaculture.(Cano-Lozano et al., 2022; de Araújo et al., 2018).The authors observed that these additives have an influence on the growth of Tilapia fish species and recommended these feed additives be used in aquaculture for fish-formulated diets.In developing countries such asnot limited to Kenya Tanzania Thailand India, the aquaculture industry is rapidly expanding.(Basavaraja, 2015; Hishamunda & Ridler, 2006)at an equal rate, fish feed demand is on the high rise, and to improve the quality of fish feed produced locally for aquaculture use feed additives are mandatory to be in cooperation. The purpose of using feed additives in aquaculture is to improve fish feed palatability, efficiency,and profitability. However, due to the biodiversity loss of most organisms that can be used as vital additives in fish feeds during formulation, environmental degradation, and the release of feed additive residues into the environment, a moral judgment option on feed additives has become compulsory by law.Further studies focused on boosting fish production through additives will allow the right fish feed. According to Gabriel, (2019); Poolsawat et al., (2021) certain studies on enzymes, herbal feed additives, and probiotics utilized as additives in fish feed have been reviewed. These feed additives enhance feed flavor and texture, feed color, and feed nutritional quality, as well as feed digestibility and, eventually, production efficiency.

Researchers such as Dang et al., (2021); Mamdouh et al., (2021) investigated whether feed additives in Tilapia fish diets can act as chemoprevention, mitigating the toxicity risk of various contaminants and detoxifying some active toxic substances in the fish feed. And therefore, having a clearoverview of the internal action pathways of various protective feed additives may provide novel alternative treatments for the feeds during storage. Similarly studying fish nutritionalrequirementsought to be donewith a lot of caution and hence there isa need to look for revolutionary feed additives and supplements that ensure cheap feed costs, and maximum digestibility, but few detrimental consequences on fish and the environment (Désiré Adéyèmi et al., 2022; Syed et al., 2022)Similarly,Genschick et al., (2021)in their work assessed how high-quality feed is prepared from acceptable and readily available feed additives. Beneficial feed additives improve not only the growth and yield of the fish but also the health function of the fish. Prebiotics, probiotics, seaweeds, microalgae, enzymes, organic acids, mycotoxin binders, phytobiotic substances, and yeasts are among the beneficial feed additives.Similarly,Zhou et al., (2021)evaluated the use of antibiotics in Tilapia fish farming feeds to control viral illnesses and increase growth performance, which is a common practice. Recently, the precautionary use of antibiotics and chemotherapy treatments was condemned, leading to their general ban in the global fish markets. The use of beneficial feed additives as an alternative to antibiotics in aquaculture diets is being encouraged among most fish farmers(Romero et al., 2012).The current study provides a comprehensive and practical consolidation of previous studies on various feed additives used in aquaculture, especially for

Tilapia fish production with examples including probiotics, prebiotics, synbiotics, immunostimulants, organic acids, nucleotides, and medicinal plants.
In addition, according to,El-Kady et al., (2022) the use of probiotics, prebiotics, and synbiotics for the sustainable growth of tilapia fish specieshas beenevaluated. The authors highlight and discuss the effects of probiotic, prebiotic, or synbiotic administration on growth performance, stress tolerance, intestinal microbiota, immune response, and healthof Nile Tilapia *(Oreochromis niloticus).*Harikrishnan et al., (2020) also analyzedhow a Dried lemon peel-enriched diet improves the antioxidant activity, growth, and metabolism of *Labeo rohita*. Dried lemon peels can therefore be used to modulatethe immune antioxidantof Tilapia as well. A similarfinding was reported by (Syed et al., 2022) that Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fed ondifferent levels of Aloe vera extract as feed additives in a closed aquaculture system enhanced growth. Gabriel et al., (2017) observed that a fish diet containing Aloe vera (*Liliaceae*) as feed additives geneticallyenhances sex reversal in Farmed Nile Tilapia Fingerlings.
The use of Aloe vera in fish feeds has no adverse effect on the health ofthe fish, farmer and it's considered environmentally sustainable. This study, therefore, recommends the use of Aloe vera in sex reversal and growth promoters in the production ofall male Tilapia fish species in order to regulate the prolific breading nature of the fish for sustainable aquaculture production. Plant compounds prove to be environmentally and user-friendly when used in aquaculture feed production as a basic feed additive. Furthermore, plant extract additives are readily available and cheap to a common fish farmer this as a result will lower the cost of feed production and hence lowers the cost of feeds as well. Based on the study's findings,Syed et al., (2022) established that Aloe Vera fortification at 400g/kg diet is essential to enhancing the growth performance and metabolism of Nile Tilapia (*Oreochromis niloticus*). Another studyby Ojha et al., (2014)examined howthe fish feed in cooperated with *Pedalium murex* as an additiveplay a role in improving the survival, metabolism, and immunity of *Labeo rohita* (Hamilton, 1822) fingerlings. Their finding shows that *Pedalium murex*extracts feedadditives havea significant effect on promoting the growth performance of *Labeorohita*, fingerlingsin addition to improving the fish's metabolism anddisease resistance. The authors, therefore,recommended adoseof (0.08 gm/100 gm diet) in the diet *Labeo rohita* feed during formulation. This Review study, therefore, makes a strong recommendation for theuse of *Pedalium murex*as growth promoter feed additives for Tilapia fish farmingand may indeed be recommended forcommercial aquaculture production globally.

The impact of an ethanolic extract of *Mucuna pruriens* on the growth, biochemistry, and sex reversal of Nile Tilapia (*Oreochromis niloticus*), and the spermatogenic influence of ethanolextract*mucuna pruriens*was evaluated by the authors(Etta et al., 2009; Mukherjee et al., 2015). Their findings showed a significant effecton the growth, metabolism, and hematological parameters of Nile Tilapia (*Oreochromis niloticus)* fingerlings. The male population was also enhanced by Mucuna additives in the diet. This is a clear indication that *Mucuna pruriens* is the best-fit feed additive to be used in the commercial production of aquaculture. Furthermore, it has the potential to boost the fish's digestion and resistance. In addition, according to Nuhu Ozovehe, (2013) in his study onthe impacts of varied quantities of *Moringa oleifera* leaf meal diet on African catfish *Clarias gariepinus* growth performance, hematological indices, and biochemical enzymes (Burchell 1822) the author reported that the growth performance of Juveniles *Clarias gariepinus* significantly improvedwhen fed on feeds containing additives of moringa oleifera leaves. Based on thesefindings the effect of *Moringa oleifera* on growth performance, Haematological effects, and biochemical activities in the

body of different species of Tilapia such as Red Tilapia, Nile Tilapia, Tilapia Zilli, Oreochromis Mozambique among other Tilapia strainsshould be done and documented.A similar finding was made by Saha et al., (2011) in their study on the Evaluation of the Nutritive Value of Water Hyacinth (*Eichhornia crassipes*) Leaf Meal in Compound Diets for Rohu, Labeo fingerling diets following fermentation with two microbial isolates derived from the gut microbiome. Theirfindings geared towards the recommendation that 40% of fish mealscan be substituted with water hyacinth leaf meal fermented with fish gut bacteria, asa feed additive with no adverse effect ondifferent fishspecies. This finding when successfully implemented will make cost-effective formulated fish feed with high nutritional additives. The health and nutrition properties of Mucunaseed meal and its intake in the diet of *Clarias gariepinus*as feed additives are quite promising. Ayorinde et al., (1985); Okomoda et al., (2017) bothconcluded that toasting Mucuna seed mealsignificantly improved the nutritional quality of the fish feeds and palatability hence, allowing better consumption ofthe feed by the African catfish *C. gariepinus* at an inclusion level of 200g/Kg. In relation to these studies, this review paper recommends the adoption of Mucuna seed meal toasted to Tilapia fish farming to enhancethe nutritional value of the fish feeds.

Dietarycooperation of carrots (*Daucus carota*) used as colorant pigmentation in swordtail (*Xiphophorus helleri*) significantly enhanced the orange coloring of the body, especially when supplemented with dietary spinach at 1.3g/100g of the fish diet(S. Mukhopadhyay, 2021)

Based on the findings of this authorthis study recommends thatsinceartificial carotenoid is costly, natural carotenoid sources like as carrots and spinach can be incorporated into the fish dietas pigmentation coloration additives to improvethebody color of Red Tilapia and O. Mozambique as well. The impact of the substitution of sunflower oil for fish oil in the diet of juvenile *Catla catla* (Ham) on growth performance and feed utilization has also been studied (P. K. Mukhopadhyay & Rout, 1996; SP et al., 2015). The results of the authorsclearly show that sunflower oil may be largely 50% substituted with no harmful effect on the growth performance of Indian Carp*(catla catla*). This study further recommendsa similar study to be done on different species of Tilapiato optimize the right formulation dosage for sunflower oil as additives in Tilapia fish feed production.Similarly,Liu et al., (2019) evaluated the significance of oils on the nutritional value of fillets in Nile tilapia and ascertained that oils are inexpensive providers of essential fatty acids. The utilization of food oils in precise amounts as required by different fish species and not limited to fin fishes only but even crustaceans for optimal growth and muscle and body mass index development. These oils in fish diets are advantageous to fish due to their antibacterial, anti-oxidative, and growth-promoting properties, as well as their potential to improve feed palatability, digestibility, and binding capacity. This study strongly recommends the use of oils and fats as essential additives during fish feed formulation for sustainable aquaculture production.

5.0.Conclusion.

In conclusion, Essentialfish feed additives, growth-boostingbut non-essentialfish feed additives, and auxiliary additives currently are the most common fish feed additives under usein aquaculture production. The reviewed literature spells out clearly their importance in fish health ranching from promoting growth to sex reversal immune boostersin most culture fish species inclusive of Tilapia. Preservatives, binders, feeding stimulants, and food

colorants are major feed additives that have been reported to promote healthy and quicker fish growth, resulting in increased production and yield. Therefore, it's essential that all locally formulated fish feeds should adhere to the inclusion levels of both essential, non-essential, and auxiliary fish feed additives in the fish diet. Lastly, feed additives are added to fish feed to improve growth and disease resistance levels and make fish feeds more appealing, palatable, and digestible- attractants, tastes, and increased digestibility. This summarily indicates that fish feed with No feed additives is like "a vehicle without fuel" and in the ordinary scenario is considered as NO feed when given to fish in a culture system. If additives are not included then the fish should better be fed on natural feeds such as copepods, artemia, phytoplankton, zooplankton, and algae. That explains how vital fish feed additives are to cultured fish for sustainable aquaculture production.

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