Chapter 46

Additives in Fish Feeds: Non-Conventional Way for Improving Fish Health

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ABSTRACT

More than half of the world's population gets their protein from fish, which is an affordable and effective source of lean meat. Nevertheless, aquaculture has financial loss, fish health issues, and viral illnesses. Proper nutrition accounts for 50–80% of the costs associated with aquaculture output. If growth performance and feed efficiency are improved in commercial aquaculture, production costs should go down. Fish would have significantly lower total production costs if their ability to survive increased. Aquaculture feeds are composed of various substances to give fish the nutrition they require for normal physiological functions such as growth, reproduction, and the upkeep of a strong natural immune system. To ensure that the dietary elements are taken in, broken down, absorbed, and given to the cells, an increasing number of feed additives are being employed in aquatic diets. Chemicals added to fish diets in trace amounts are known as feed additives. Additives can be Essential (Vitamins, minerals), non-essential (antibiotics, prebiotics, enzymes) and Auxiliary (binders, Color enhancers) additives, each having specific functions. To guarantee sustained growth in aquaculture, the right amount of chemicals must be employed.

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INTRODUCTION

Feed additives have been used since the past, with salt added to animal feed to make it more palatable. The application expanded in the early 1900s, with vitamins discovered in the 1920s to boost growth rates and prevent deficits. Additional feed additives, including minerals, amino acids, and enzymes, were created. Governmental organizations control the use of feed additives to ensure their effectiveness and safety (Bai et al., 2022).

Since fish are a cheap and efficient source of lean meat, more than half of the world's population depends on them for their dietary protein needs (Oramary et al., 2016). However, aquaculture suffers difficulties like financial loss, health problems with fish, and infectious infections (Awad and Awaad, 2017). In aquaculture, 50–80% of output costs are related to proper nutrition (Ogunkalu, 2019). The term "feed additives" describes substances added to a diet or feed in trace amounts to aid in nutritional quality preservation (Abdelhamid et al., 2010; He et al., 2012), feed pelleting or ingredient dispersion, and ease of feed ingestion and consumer acceptance and nutrients availability or remove an anti-nutrient presence (Ebru and Cengiz, 2016).

Selection of Feed Additives

Each feed additive in feed should be present for a specific reason as described Kruger and Mann, (2003)

- Designed to identify, treat, reduce, cure, or avoid illnesses
- Pharmacological and physiological actions
- Other than dietary effects, no intentional effects on the body
- Impact on feed functionality
- Biologically active
- Exposure throughout life

Additionally, Wani et al., (2023) also defined selection of feed additives as follows.

- The material needs to be reasonably priced
- Readily available in sufficient quantities
- It shouldn't have an unfavorable effect on the meat of the animal

Classification of Feed Additives

The primary goal of feed additives is to promote faster, healthier growth that will increase yield. European legislation on animal feed provides a framework for ensuring feedstuffs do not pose environmental or human health risks, including laws on genetically modified food, feed material usage, hygiene standards, and addressing unwanted substances in feed. Feed additives tend to fall into certain categories which describe their action in the feed or in the animal (Yadav et al., 2021).

1. Essential additives.
2. Growth-promoting but non-essential additives.
3. Auxiliary additives

Essential Additives

According to Revesz and Biro (2019), these additions are also referred to as nutritious supplements. The formula contains small amounts of vital substances to improve nutritional balance and promote healthy growth. Deficient sickness may arise from prolonged abstinence from feeding (Luo et al., 2005).

Vitamins

Animal development, reproduction, survival, and health all depend on vitamins. Because they cannot synthesize most vitamins, animals must get them from their diet. Both fat-soluble and water-soluble vitamins have distinct functions (NRC, 2011). Table 1 shows vital water and fat soluble vitamins and their significance

Table 1: Vital water and fat soluble vitamins and their significance

Vitamins	Functions
Water Soluble Vitamins	
Thiamine (B1)	Cofactor for the enzymatic processes that produce energy.
Riboflavin (B2)	Protein, fat, and carbohydrate metabolism.
Nicotinic acid (B3)	NAD and NADP are components of a coenzyme that synthesizes cholesterol and fatty acids.
Pantothenic acid	Part of the acetyl coenzyme A
Pyridoxine (B6)	Protein and carbohydrate metabolism, mRNA and acetyl coenzyme A production.
Biotin (B7)	Carbohydrate and fat metabolism has a role in the urea cycle and protein synthesis.
Inositol (B8)	Cell growth in the liver and bone marrow, RNA synthesis
Folic acid (B9)	Amino acid metabolism and the creation of nucleotides, purines, and pyrimidines.
Cyanocobalamin (B12)	Maturation, erythrocyte development, and nerve tissue preservation (NRC, 2011).
Choline	Lipid transport and nerve impulse transmission.
Ascorbic acid (Vitamin C)	Participate in bone and cartilage production (Kraus et al., 2004) and immunological response (Barros et al., 2014).
Fat Soluble Vitamins	
Retinol (A)	The development of embryos, epithelial cells, and cell differentiation are all impacted by vision.
Cholecalciferol (D)	creation of calcium-binding proteins is involved in the creation of melanin, the stress response, and muscular function.
Tocopherol (E)	Antioxidant activity, including intracellular and extracellular, gene expression, and cell selection.
Phylloquinone (K)	Transport of calcium and blood coagulation (NRC, 2011)

According to Revesz and Biro (2019), vitamin premixes are concentrated blends of key vitamins in a steady state with base feed that is frequently added at amounts above dietary needs to comprehensive practical fish diets. Because choline has been shown in tests to decrease the stability of other vitamins, it is not included in these premixes. The addition of these premixes ranges from 0.5 to 4% (Demott et al., 1995).

Minerals

Minerals, often known as inorganic elements, are essential nutrients for fish life. Maintaining health and stress tolerance necessitates a diet with roughly twenty components. These elements are separated into macro- and micro-elements based on their concentration, ensuring that fish can tolerate stress and resist disease (NRC, 2011; Webster and Lim, 2015). Table 2 lists significant macro and micro minerals along with their purposes.

Fatty Acids

PUFA-rich fish oils like cod liver, sardine, squid, and clam oil have antibacterial and antioxidant properties, improve intestinal health, increase feed palatability, and stimulate growth (Sutili et al., 2018). All cellular and subcellular membranes rely on lipids for proper function (FAO, 2014). Fish oil is added to meals at a rate of two to three percent to increase growth and food conversion ratio (Deng et al., 2013). Fish muscle uses triglycerides, including free fatty acids, as its primary aerobic fuel source for energy metabolism. It also serves as a carrier for fat-soluble vitamins during absorption. Lipids maintain neutral buoyancy and support essential body organs (FAO, 2014).

Table 2: Important macro and micro minerals and their functions

Macro minerals	Functions
Magnesium (Mg)	The development of muscle and nerve tissue, as well as bone and cartilage (Webster and Lim, 2015)
Calcium (Ca)	Nerve impulse transmission, control over the permeability of cell membranes, vital components of bone and cartilage, and blood clotting.
Potassium (K), Sodium (Na)	Osmoregulation and the body acid-base equilibrium
Chloride (Cl)	The principal component of hard tissues like scales and bone
Phosphorus (P)	Blood oxygen and carbon dioxide transport, osmoregulation, and the body's acid-base balance (Lall, 2002)
Micro minerals	
Cobalt (Co)	Component of vitamin Bl2 (Lall, 2002).
Copper (Cu)	Iron metabolism, cellular energy production, protection of cells from free radical damage, collagen synthesis and melanin production (Linder, 2002).
Iodine (I)	An essential constituent of the thyroid hormones T3 and T4 (Lall, 2002).
Iron (Fe)	Electron transfer reaction, gene regulation, binding and transport of oxygen and regulation of cell growth and differentiation (Bury et al., 2003).
Selenium(Se)	Involved in hydrogen peroxide signaling, detoxification of hydro-peroxides and maintaining cellular redox homeostasis (Roman et al., 2014).
Zinc (Zn)	The catalytic role, stabilizes the tertiary structure of enzymes and regulates gene expression (McCall and Huang, 2000).

Phospholipid

In fish, phospholipids can function as an energy source under specific conditions, such as embryonic and early larval development, although triacylglycerols are the main type involved in lipid storage and energy provision (Salze et al., 2005). In young fish, dietary phospholipids improved digestibility (Kasper and Brown, 2003). Soybean lecithin, when added to the diet at a rate of 1-2 percent, accelerates growth and increases feed conversion ratio. According to Heo et al. (2013), phospholipids are physiologically significant for the body's lipid transportation system.

Growth-promoting but Non-essential Additives

Also called a zootechnical additive (Revesz and Biro, 2019). Feed additives include plant and animal-based materials, single-cell proteins, and some synthetic materials that help feeds develop and produce more quickly. They won't result in any deficiency diseases if they are left out of the diet (Apenuvor, 2014). However, when added to feed, they have advantages. These are attractants and growth boosters. Additionally, zootechnical additives can lessen the negative effects of animal production on the environment (Revesz and Biro, 2019). Ex. Probiotics, Animal materials, enzymes, Antibiotics, Drugs etc.

Antibiotics

Antibiotics do not reduce parasites, fungi, or viruses, however medicated feed is frequently advised to manage bacterial illness outbreaks in farmed fish (Kelly, 2013). Antibiotics act by decreasing or eliminating the activity of pathogens, getting rid of bacteria that create toxins that stunt growth, encouraging the growth of helpful microorganisms that synthesize nutrients, and lowering microorganisms that compete with the host for nutrients—all of which promote growth in young animals as opposed to adults (Hardy and Barrows, 2003). Table 3 includes a list of antibiotics that are authorized for use in medicated fish feed. The U.S. Food and Drug Administration (FDA) has approved only four antibiotics for use in food fish, including Terramycin, Romet, and Florfenico. Fish can be treated with antagonists via bath, flush, oral route, dip, bio-encapsulation, and injection (Haya et al., 2005).

Antibiotics function by one of two methods:

(a) Bactericidal, which kills bacteria by interfering with cell wall formation or cell contents.

(b) Bacteriostatic, which stops bacteria from multiplying by interfering with protein production, DNA replication, or other aspects of bacterial cellular metabolism (Romero et al., 2012).

Antimicrobial

Aquaculture uses both synthetic and natural antimicrobial medicines are rarely used as growth promoters; instead, they are mostly employed as preventative and therapeutic agents (Shao, 2001). These substances exhibit precise cellular targeting and can function as selective ligands for targets associated with disease, which can influence disease-related pathways and maintain a healthy biological network (Chin et al., 2006; Lagunin et al., 2010). Natural ingredients make up over half of FDA-approved medications (Chin et al., 2006; Kingston, 2011), with plants providing 25% of these. Herbal remedies are more accurate and less expensive than chemotherapy drugs, making them suitable for aquaculture-related issues such as immunological stimulants, growth promoters, appetite stimulants, tonics, and anti-stress agents (Rates, 2001). Fish medications are rarely derived from animals (Berger et al., 2005), and synthetic medications mimic naturally occurring drugs (Romero et al., 2012). The two most popular ways to administer antimicrobials in aquaculture are medicated feed and water medication (Singh and Singh, 2018). Table 4 shows FDA-approved pharmaceuticals are safe and efficient and have few unanticipated side effects (US FDA, 2017).

Table 3: Antibiotics Approved for use in Medicated Feed for Food Fish (kelly, 2013)

Antibiotics	Treatment
Terramycin	Furunculosis and Enteric septicemia
Romet	Furunculosis, Bacterial hemorrhagic septicemia, Pseudomonas illness, and Ulcer sickness.
Florfenico	Furunculosis, Enteric Septicemia, Columnaris and Streptococcal septicemia.

Table 4: FDA-approved aquaculture drugs (permitted for application in fisheries and aquaculture) (US FDA, 2017)

Drugs	Treatment
Formalin	For limiting the propagation of monogenetic trematodes, protozoa, and fungi.
Florfenicol	For the decrease in intestinal septicemia-related catfish mortality.
Papain	To improve hatchability and reduce disease incidence, fish egg masses should have their gelatinous matrix removed.
Onion	Used to treat external crustacean parasites and stop sea lice from reaching the outside surface
Calcium chloride	Utilized to increase the water's calcium concentration to guarantee proper egg hardening
Fuller's Earth	To reduce the stickiness of fish eggs to improve hatchability
CaCO3	To maintain the osmotic balance of fish throughout storage and transportation, the water should be made harder.
Garlic	Used to get rid of helminth infections and sea lice

Hormones

Hormones are chemical messengers that facilitate communication between various cell types that identify and act through protein structures called receptors that are trained in molecular identification (Chrousos, 2007). In aquaculture, hormones are utilized for sex reversal (Taranger et al., 2010) and growth promotion. The goal of using hormones in fish farming to reverse sex is to create a monosex population to accelerate growth or cause weight gain. Raising individuals of the most profitable gender is beneficial from a commercial standpoint as it leads to more uniform lots and reduces unwanted breeding (Singh, 2013). Hormones like 17β-estradiol, estradiol valerate, 17α-methyl testosterone, or 17α-methyl dihydrotestosterone (via food and immersion techniques) to feminize a population. Conversely, testosterone is utilized by masculine females (Piferrer, 2001). In species where males grow faster than females and attain larger sizes, tamoxifen, 17α-methyl testosterone, 17α-ethynyl testosterone, and 17α-ethynyl estradiol have all been used to produce an all-male population (Liao et al., 2014).

Hormones are utilized in aquaculture for artificial reproduction, controlling ovulation and maturation in the gonad. They can induce, accelerate, or stop fish development, and extend reproductive periods for more flexibility in marketability. Fish breeding hormone procedures involve intramuscular or intraperitoneal injections (Mylonas et al., 2010). The pituitary gland extract from mature fish is the oldest and most commonly used hormone, while gonadotropin-releasing hormone (GnRH) is produced by salmon and mammals. Various species use analogs, dopamine antagonists, and synthetic hormones (Almeida, 2013)

Enzyme

Biological catalysts, or biocatalysts, are substances that accelerate biochemical reactions in living things. They can be isolated from cells and utilized as catalysts for a variety of significant commercial activities (Robinson, 2015). The detrimental effects of anti-nutritional variables have an impact on fish development performance and how well they absorb dietary components. Exogenous enzymes can help solve these issues (Mazurkiewicz, 2008). Enzymes are utilized in the digestion of other feed ingredients, collagen in the skin and bones, and complex carbohydrates. Table 5 shows Different enzymes and their effects on various fish species. Generally speaking, temperatures exceeding 65º C denature enzymes. According to Strobel et al. (2012), enzyme supplements are therefore usually applied to meals following pelleting.

Prebiotics

Prebiotics are any substance, fiber, long-chain sugar, vitamin, or substrate that provides sustenance for the good bacteria in the digestive tract of the host (Mountzouris, 2022). To improve the host's health, prebiotics were employed to encourage the growth of microbes already present in the gut of the organism (Rohani et al., 2021). By functioning as a receptor, a modulator of the host immune system, and an inflammatory controller, a prebiotic can inhibit the attachment of pathogenic microorganisms to epithelial cells and eradicate them from gut epithelial cells (Mohammadi et al., 2021). Table 6 lists the effects of various probiotics on fish.

Table 5: Different enzymes and their effects on various fish species

Enzymes	Effects
Microbial phytase	Enhanced phosphorus and energy availability (Cheng et al., 2002)
Pepsin, papain, amylase	Increased feed utilization and growth efficiency (Alemayehu et al., 2018)
Non starch polysaccharides (cellulose, Xylans)	Increased the aquatic animals' digestibility (Sinha et al., 2011).
Glucanase, cellulase, xylanase	Increased nitrogen retention, feed conversion ratio and feeding efficiency ratio, decreased ammonia excretion (Ai et al., 2007)
Alpha - amylase	According to Kumar et al. (2006), starch digestibility improved growth and had a protein-sparing impact.

The following criteria should be a must for prebiotics, which is used in feed:

i) vulnerability to the fish upper digestive tract.
ii) The gut bacteria should be able to ferment it with ease.
iii) The host's health ought to benefit (Lee and Salminen, 2009).

Table 6: Effects of different probiotics on fish

Prebiotics	Effects
Fructo-oligosaccharides	improved the digestibility and uptake of feed (Grisdale-Helland et al., 2008)
Inulin	Enhanced the concentration of RBC, magnesium, calcium, and iron; also, it lengthened the intestinal villi and boosted lysozyme activity (Tiengtam et al., 2015)
Mannan	thickens the intestinal muscle layer and raises the height of the intestinal fold (Yuji-Sado et al., 2015)
Fermacto prebiotic	increased feed conversion ratio and growth (Mazurkiewicz et al., 2008)

Auxiliary Additives

Also known as technological additive (Revesz, and Biro, 2019).). Certain ingredients added to feed formula function as components to the physical qualities of feed, according to Shahidi et al. (2019). This ultimately contributes to improved feed utilization and increased feed efficiency. These substances could be categorized as supplementary substances. These include fats, molasses, binders, and feed color. For example, color, glue, molasses, etc.

Feed Colorants

To improve fish color, which is a crucial characteristic for aquaculture and the trade in ornamental fish, color enhancers are added to fish feed (Naeem et al., 2021). They have also been shown to enhance fish survival and growth (Yadav et al., 2021). Animals and plants of many kinds contain more than 300 pigments. Carotenoids and xanthophyll are the two most significant types of pigments. Fish and crustaceans contain carotenoid pigments, while plants contain the majority of xanthophyll (Wagde et al., 2018). Additional examples of color enhancers are blue-green algae called spirulina, which has natural pigments like phycocyanin and chlorophyll. The naturally occurring pigment beta-carotene is present in a variety of fruits and vegetables, including sweet potatoes and carrots. It is used to bring out the orange and yellow hues of fish, such as goldfish. To guarantee that synthetic colorants are safe for fish and consumers, strict regulations are in place. It is used to certain fish species to accentuate their blue and green hues. It's crucial to remember that there are certain disadvantages to using color enhancers in fish feed. The ecology and fish health may suffer if these enhancers are used excessively (Naeem et al., 2021).

Binders

Aquafeed production requires the use of binders because they keep the feed cohesive and stop it from dissolving. Materials that can be used to make binders include synthetic materials, plant- and animal-based products, and more (Karim et al., 2022). Used at a level of 2 to 8% to increase pellet stability (Hardy and Barrows, 2003).

Binders may be:

1. In the manufacturing of fish feed, plant-based binders including starches and gums are frequently utilized. Manufacturers choose these binders because they are affordable and easily accessible. They might not, however, offer as strong of a binding as synthetic or animal-based binders.
2. The manufacturing of fish feed also makes use of binders derived from animals, such as collagen and gelatin. These binders have a high binding strength and are made from animal byproducts. They might not work well with all kinds of fish feed, though, since certain fish species might respond negatively to these binders.
3. In the process of making fish feed, synthetic binders including carboxymethyl cellulose and polyvinyl alcohol are

gaining popularity. When compared to binders derived from plants and animals, these binders are much more efficient and can offer higher binding strengths. But compared to other types of binders, they could be more expensive and harder to get. (Arthithan et al., 2012).

Preservatives

Fish feed frequently contains preservatives to lengthen its shelf life and stop it from spoiling (Prokopov and Tanchev, 2007). Also known as antioxidants. The food to be preserved and the microbe it targets dictated which antibiotic to use as a preservative (Davidson and Branen, 2005). These preservatives, which are added to the feed during the manufacturing process, might be synthetic or natural. To guarantee that fish feed stays fresh and nutrient-rich for fish to eat, preservatives are used in it (Yadav et al., 2019).

Ethoxyquin and butylated hydroxyanisole are common preservatives in fish feed. Both are synthetic antioxidants that prevents oxidation, spoilage, and degradation of fats and oils. Butylated hydroxyanisole also maintains the nutritional value of fish feed (Lundebye et al., 2010). Feeds commonly use fat-soluble Vitamin E (Frank, 2004), ascorbic acid (Bou et al., 2001) and carotenoids (Escalante et al., 2001), as antioxidants. Dihydroquercetin is a potent antioxidant that blocks the lipid peroxidation processes in cell membranes, can enter the cytoplasm of a cell to shield it from the damaging effects of free radicals (Ponomarev et al., 2022).

Benefits of Feed Additives

Fish feed additives has following advantages (Dawood et al., 2018; Bharathi et al., 2019):

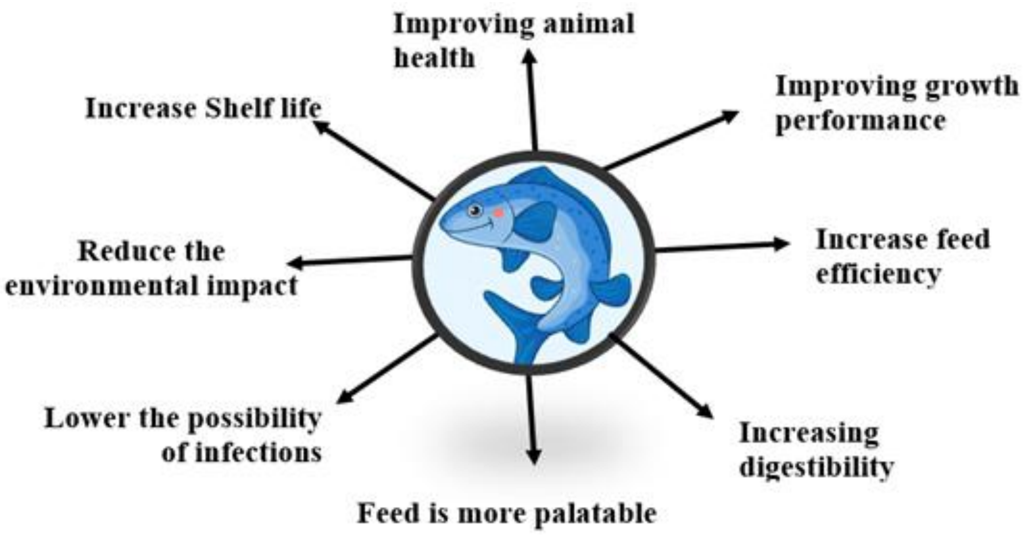

Fig. 1: Benefits of feed additives

Conclusion

In order to maximize nutrient uptake and boost productivity, feed additives are crucial to the production of poultry and animals. Since the turn of the 20th century, these additives—such as vitamins and salt—have been utilized to raise the quality and growth rates of animal feed. They fall into three categories: growth-promoting non-essential additions, auxiliary additives, and essential additives. Vitamins, minerals, and fatty acids are examples of essential additives that are necessary to sustain disease resistance, healthy growth, stress tolerance, and food conversion ratio. Aquaculture uses non-essential additives, including as hormones and antibiotics, to improve feed digestibility, cure illnesses, and create monosex populations. To increase feed utilization and efficiency, auxiliary additives such as carotenoids, binders, and feed colorants are crucial parts of fish feed formulae. In conclusion, feed additives enhance growth and production, make diets more attractive, palatable, and digestible, and increase digestibility.

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