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The Role of Functional Feed Additives in Tilapia Nutrition

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Abstract

Aquaculture feeds are formulated with a vast pool of ingredient to meet nutritional requirements of fish for normal physiological functions, including maintaining a highly effective natural immune system, growth, and reproduction. To ensure the dietary nutrients are ingested, digested, absorbed, and transported to the cells, an increasing diversity of non-nutritive feed additives are being used in aquatic feeds. Feed additives are supplemented in small amounts to tilapia for a specific purpose in aquaculture. Feed containing functional feed additives promote the growth and health of tilapia, improve their immune systems, and induce physiological benefits beyond traditional feeds. Probiotics, prebiotics, phytogenic substances, immune-stimulants, enzymes, hormones, mycotoxin binders, organic acids etc., are best functional feed additives to manage and regulate tilapia performance and improve aquaculture profit.

Keywords: Functional feed additives; Immune-Stimulants; Mycotoxin binders; Organic acids; Phytogenic substances; Prebiotics; Probiotics

Introduction

Products that improve feed efficiency are particularly important since feed costs are a major expense in aquaculture production. Non-nutritive feed additives are being used in aquatic feeds to ensure ingestion, digestion, and absorption of dietary nutrients. Feed additives may be both nutritive and non-nutritive ingredients and work by either direct or indirect methods on the animal's system [1-3]. According to Bai et al. [2], feed additives are supplemented in small amounts (alone or in combination) for a specific purpose, such as to improve the quality of fish as a final product, to preserve the physical and chemical quality of the diet or to maintain the quality of the aquatic environment.

The range of feed additives used in aquatic feeds is very diverse. Additives are used in fish feed to preserve the nutritional characteristics of a diet or feed ingredients prior to feeding (e.g. antioxidant and mold inhibitors) [2], enhance ingredient dispersion or feed pelleting (e.g. emulsifiers, stabilizers and binders) [1,2,4], facilitate feed ingestion and consumer acceptance of the product (e.g. feed stimulants or attractants) [5-8] and promote growth (e.g. growth promoters, including antibiotics, probiotics and hormones) [2,9-14]. Enzymes also used to improve the availability of certain nutrients (e.g. proteases, amylases) or to eliminate the presence of certain anti-nutrients (e.g. phytase) [15,16].

Methods

Types of feed additives in tilapia nutrition

Nowadays, there are more sustainable ways to modulate the health and performance of tilapia by supplementing feeds with nutraceuticals or functional foods. Functional feed (feed containing functional feed additives) promote the growth and health of cultivated organisms, improve their immune systems, and induce physiological benefits beyond traditional feeds. According to Barrows et al. [1], feed additives can be categorized into: (1) additives that affect fish performance and health (functional feed additives) and (2) additives that affect feed quality and feed up take. There are several options available to manage and regulate fish performance and health such as the fish gut environment which includes probiotics, prebiotics, immune-stimulants, phytogenic substances, enzymes, hormones, mycotoxin binders and organic acids. There are also different feed additives such as pellet binders, attractants, antioxidants, color/pigmentation agents and antimicrobial compounds used to maximize feed up take and maintain feed quality in tilapia culture.

Roles of functional feed additives in tilapia nutrition

Phytogenic substances: Phytogenics are plant-derived products which are added to the feed in order to improve palatability of feeds or animal performance [17,18]. These plant active ingredients can exert multiple effects on the organisms, including improvement of feed efficiency and digestion, reduction of nitrogen excretion and improvement of gut flora and health status. Phytogenic feed additives are an extremely heterogeneous group of feed additives originating from leaves (e.g. extract of *Moringa oleifera* [19]), roots, tubers (e.g. Garlic, *Allium sativum* [20]; Ginger, *Zingiber officinale* [14]) or fruits of herbs, spices or other plants. They are either available in a solid, dried or ground form or as extracts or essential oils [17,21].

Gbadamosi et al. [19] tested hepatoprotective and stress-reducing effects of dietary *M. oleifera* extract against *Aeromonas hydrophila* infections and transportation-induced stress in *O. niloticus* fingerlings. They reported that a dose of 0.10 g per 100 g dietary moringa leaf supplementation was sufficient as a hepatoprotective and stress-reducing agent in Nile tilapia. Pachanawan et al. [22] also evaluated effect of dry leaf powder of *Psidium guajava* and ethanol extract of *P. guajava* leaf as feed additive to control *A. hydrophila* infection in tilapia culture. Fish diets containing either dry leaf powder of *P.*

guajava or dried ethanol extract of *P. guajava* leaf reduced mortality of *A. hydrophila* infected tilapia compared with commercial tilapia diet supplemented with oxytetracycline. According to Zilberg et al. [23], Nile tilapia fed with dried rosemary (*Rosmarinus officinalis*) leaves significantly reduced mortality following infection with *Streptococcus iniae*. They reported that, 44% mortality in the group fed 8% rosemary, similar to oxytetracycline treatment (43% mortality), and significantly lower than the control (65%). Goda [24] reported that Nile tilapia fingerlings fed diets containing at least 200 mg/kg ginseng herb for 17 weeks enhanced growth performance, diet utilization efficiency, and hematological indices. The fingerlings also had significantly higher protein efficiency ratio (PER) compared to fish fed the control diet. This is also the case in Dada [25] report in which Nile tilapia supplied with 5.0 g kg^{-1} of commercial herbal growth promoter feed additive powder (superliv). Chinese herb, Astragalus radix can modulate the innate immune system of tilapia (*Oriochromis niloticus*). They reported that feeding tilapia with 0.1 and 0.5% Astragalus radix for one week enhanced lysozyme activity and for three weeks stimulated phagocytosis by phagocytic blood cells [26].

Probiotics: Probiotics are live microorganisms when supplied in adequate amount to cultured organisms confer a health benefit of the host. Probiotics are live non-pathogenic and nontoxic microorganisms without undesirable side-effects when administered to aquatic organisms. Probiotics are live microbial feed supplement which beneficially affects the host animal by improving its intestinal balance [27-30]. The range of probiotics examined for use in aquaculture has included both Gram-negative and Gram-positive bacteria, yeasts [31-33], bacteriophages, and unicellular algae [31,33].

Probiotics have several uses in the host animals in aquaculture. They have antiviral activities against infections; they produce inhibitory chemicals [30,34] they improve water quality by participating in turnover of organic nutrients and toxic NH_3 and NH_2 in aquaculture system [27,29,30,35-38] they enhance immune response by increasing the phagocytic activity of leucocytes [30,35] they compete for nutrients otherwise consumed by pathogenic microbes; they also compete for adhesion site and food with the pathogens in the gut epithelial surface and prevent colonization [32] and probiotics are sources of nutrients and secrete a variety of enzymes to increase feed degradation-assimilation enhancing its nutritional values [29,30,32,39,40].

Zhou et al. [41] reported that adding *Bacillus coagulans* and *Rhodopseudomonas palustris* at concentration of 1× 9107 CFU ml^{-1} every two days had significantly higher final weight, daily weight gain, and specific growth rate compared with without probiotics (control) in Nile tilapia. Wang et al. [42] analyzed the effect of a probiotic bacterium, *E. faecium* on growth performances and immune responses of tilapia (*O. niloticus*). Tilapia was treated with *E. faecium* at concentration of 1×107 CFU ml^{-1} in aquaria water every four days. Tilapia supplemented with the probiotic showed significantly better final weight and daily weight gain (DWG) than those fed the basal diet (Control). In addition, myeloperoxidase activity and the respiratory burst activity of blood phagocytes were higher ($P<0.05$) in *E. faecium* treated tilapias than the controls. This was also the case where Nile tilapia fingerlings supplemented with a diet containing probiotics *Bacillus amyloliquefaciens* at level of 1 × 9106 CFU ml^{-1} [43]. Pigott et al. [4] evaluated the effects of three types of probiotics, two bacteria (bacterial mixture containing *Streptococcus faecium* and *Lactobacillus acidophilus*) and yeast (*Saccharomyces cerevisae*) on growth performance in Nile tilapia. Fry fed diets with a probiotics supplement exhibited greater growth than those fed with the control diet without supplements. Of the probiotic treatments, the 40% protein diet supplemented with yeast produced the best growth performance and feed efficiency. Aly et al. [44] also studied on *Bacillus subtilis* and *L. acidophilus*, as potential probiotics, on the immune response and resistance of *O. niloticus* to pathogenic bacterial infections. Both *B. subtilis* and *L. acidophilus* inhibited the growth of *A. hydrophila*. In addition, *B. subtilis* inhibited development of *P. fluorescens* while *L. acidophilus* inhibited the growth of *S. iniae*.

Prebiotics: A prebiotic was defined by Gibson et al. [45] as: 'a non-digestive food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, and thus improves host health'. Prebiotics are food for bacterial species, which are considered beneficial for health and well-being and important dietary additions for modulating the growth and activity of specific bacterial species in the colon [46]. In order for a food ingredient to be classified as a prebiotic, it should (1) be neither hydrolysed nor absorbed in the upper part of gastrointestinal tract; (2) be fermentable by intestinal microbiota; (3) be a selective substrate for one or a limited number of beneficial bacteria to the colon, which are stimulated to grow and/or are metabolically activated; and (4) consequently, be able to alter the colonic flora in favour of a healthier composition [28,45,47,48].

Prebiotics bring about a specific modulation of the gut microbiota, particularly increased numbers of bifidobacteria and/or lactobacilli cell counts or a decrease in potential harmful bacteria is a sufficient criterion for health promotion [46]. The most common prebiotics used in fish are carbohydrates like inulin, fructooligosaccharides, short-chain fructooligosaccharides, oligofructose, mannanoligosaccharides, trans-galactooligosaccharides, which are nondigestible but can be fermented by the intestinal flora [49,50].

Tiengtam et al. [51] evaluated inulin as prebiotic ingredients in the diet of juvenile Nile tilapia (*O. niloticus*). Fish fed the inulin diets exhibited better growth performance compared with control groups. Dietary inulin (5 g kg^{-1}) increased red blood cell number, goblet cell number, magnesium, calcium, iron content, increased the height of intestinal villi and lysozyme activity. Supplementation of 0.4% prebiotic (mannan oligosaccharides) increased intestinal fold height and intestine muscular layer thickness in Nile tilapia [52]. Abu-Elala et al. [53] tested *S. cerevisiae* as a whole yeast cell (probiotic), its extract (mannan-oligosaccharide-Prebiotic) and Pre-Probiotic mixture (synbiotic) as growth promoters and immunostimulants in cultured *O. niloticus*. Synbiotic feed additive has showed significant enhancement of fish innate resistance against selected fish pathogens (*A. hydrophila*, *P. fluorescens* and *F. columnare*) as well as positively increased the growth performance of challenged fish. Hassaan et al. [54] also showed that increasing dietary *B. licheniformis* and yeast extract levels significantly improved growth performance and nutrient utilization in *O. niloticus*. Contrarily to this, Shelby et al. [55] reported that incorporation of yeast and yeast subcomponents consisting mainly of β-glucan or oligosaccharide feed additives to juvenile Nile tilapia have no effect on growth, antibody responses or survival following *S. iniae* or *Edwardsiella tarda* infection.

Organic acids: Organic acids are organic carboxylic compounds of general structural formula R-COOH whose acidity is associated with their carboxyl group (-COOH). They are weak acids because they partially dissociate in water to form a hydrogen ion (H^+) and a carboxylate ion (-COO-) (e.g. acetic CH_2COOH) [56]. Dietary acidification by the addition of organic acids has been widely used in animal nutrition and organic acids have become a promising feed additive to improve gut health and performance [57]. There are two different mode of action of organic acids in the intestinal tract of fish: the pH-decreasing action of organic acids in stomach and small intestine contributes to an improved activity of digestive enzymes and some organic acids can penetrate the cell wall of certain types of bacteria, disrupt the normal physiology and inhibits the growth of pathogens bacteria [3,56]. Organic acids also used in fish feeds to reduce the potential threat of microbial contamination including pathogenic bacteria and molds or fungi (due to *Aspergillus*, *Penicillium*, and *Fusarium*) that may grow during feed storage [56]. The most commonly used organic acids as feed additive includes: (1) individual or combinations of organic acids such as propionic, sorbic, benzoic, butyric acids, malic acid, lactic acids, and acetic acids, and (2) salts of organic acids such as calcium propionate, potassium sorbate, and sodium benzoate [2,3,56].

According to Lim et al. [56], during periods of high feed intake, such as when the animals are young or when the feeds are high in protein, hydrochloric acid concentrations in the stomach are reduced. This reduction negatively impacts pepsin activation and pancreatic enzyme secretion and impairs digestion. Abu-Elala et al. [58] reported that *O. niloticus* fed on 0.2% and 0.3% organic acid, potassium diformate (KDF) exhibited significant improvements in their feed intake, live weight gain, specific growth rate, feed conversion ratio (FCR) and protein efficiency ratio compared with control. The reduction of the stomach and the upper gut pH in KDF-supplemented fishes may be the primary reason for improving the growth performance and protein digestibility. The lower gastric pH associated with a higher pepsin activity contributes to improve the protein digestibility and nitrogen retention. According to them, the second reason for improving the growth performance may be KDF-supplemented diet also markedly decreased the total bacterial counts in faeces. Because the low molecular weight organic acids can diffuse across the cell membrane of gram-negative bacteria, acidification of their metabolism can lead to bacterial cell death.

Koh et al. [59] evaluated the effects of oxytetracycline or organic acids (consists of five organic acids, formic acid, lactic acid, malic acid, tartaric acid and citric acid) supplementation on growth, nutrient utilization and faecal/gut bacterial counts of red hybrid tilapia. Tilapia fed 0.5% oxytetracycline or 0.5% organic acids blend diet had significantly higher resistance to *S. agalactiae* than those fed the control diet (no additives). They reported that dietary organic acids can potentially replace oxytetracycline as a growth promoter and antimicrobial in tilapia feeds. This also the case in which Nile tilapia supplemented with organic acids, formic and propionic acid/salt mixture in 1 g/kg and 2 g/kg respectively [60]. The best protection against challenged *A. sobria* was also observed in fish supplemented with formic acid and propionic acid compared with oxytetracycline. Khaled [61] evaluated the effect of sodium diformate as commercial feed additives on growth performance and feed utilization of hybrid tilapia *(O. niloticus* × *O. aureus*) fingerlings. Supplementation of 3 g/ kg^{-1} sodium diformate showed significant improvement in FCR and PER compared with other groups of fish at various supplementation levels of organic acids salts and better than control. Protein and lipid digestibility among fish groups fed the experimental diets supplemented by sodium diformate also improved significantly compared to the control group.

Enzymes: Nowadays, a number of exogenous enzymes (e.g. phytase, carbohydrase, protease and lipase) are used in aquaculture feeds to overcome the negative effects of anti-nutritional factors, and to improve the digestion of dietary components and enhance growth of fish [15,16]. For instance, phytase, an enzyme specific to hydrolyze indigestible phytate, has been increasingly used in fish feed during the past two decades [62]. According to Bai et al. [2], up to 80% of phosphorus (P) in plant seeds are in the form of phytate. The digestibility and availability of phytate phosphorus for fish is very low and consequently lost to the environment as waste. Thus, use of phytase enhances bioavailability phytate phosphorous [62-64]. However, effect of temperature on the stability of enzymes applied in the feed processing, leaching loss of the enzyme in water and the effectiveness of some enzymes (e.g. microbial enzymes) that have 37°C optimum temperature, when applied in cold water aquatic animals that have low body temperatures are constrains regarding the effectiveness of enzyme applications in aqua feeds.

Liebert et al. [65] conducted a study on nutrient utilization of *O. niloticus* fed plant based low phosphorus diets supplemented with microbial (yeast) phytase. Significant improvements due to phytase addition were found for growth, feed conversion ratio, protein efficiency ratio, and specific growth rate compared with control. Phytase supplementation also increased protein and phosphorus utilization significantly. In addition, the mineral composition of scale and vertebra was significantly affected. Similar result was reported by Nwanna et al. [16,66] in which Nile tilapia supplemented with phytase compared with control. Goda et al. [24] also conducted a research to evaluate the effect of baker yeast, *S. cerevisiae* and exogenous digestive enzymes (pepsin, papain and amylase) dietary supplementation on growth performance, feed utilization and hematological indices of *O. niloticus* fingerlings. They reported that, growth performance and feed utilization efficiency were significantly higher in all treatments receiving *S. cerevisiae* and enzymes supplemented diets than the control diet (without additives).

Hormones: Various hormones have been used for different reason in aquaculture (e.g. growth hormone, steroid hormones etc.). For instance, growth hormone [11] and thyroid hormone (thyroxin) [13] plays an essential role in the stimulation of somatic growth and survival of tilapia. Monosex fish production is common practice in aquaculture and possible in 47 species using steroid hormone (e.g. methyl testosterone) [9,10]. According to Beardmore et al. [10], the potential advantages sought from monosex production in different fish species may include one or more of the following features: achievement of higher average growth rate, elimination of reproduction, reduction of sexual/territorial behaviour, reduction of variation in harvest size, and reduction of risk of environmental impact resulting from escapes of exotic species. Early sexual maturity in tilapia culture is well recognized problem which results in inbreeding in overstocked fish ponds, reduced production, and farmed stocks of generally low quality. To overcome these problems, mono-sex (all male) production is a solution and they (male of tilapia) grow faster than females. Sex reversal by oral administration of feed incorporated with methyl testosterone is the most effective and practical method for production of all male tilapia [10,12,14,67]. However, currently there is an argument on use of methyl testosterone hormone due to some research reports that concluding its effect on consumer, fish feed producer and the environment [67,68].

Mycotoxin binders: Mycotoxins are toxic metabolites produced by a diverse group of fungi (e.g. *Aspergillus*) that contaminate agricultural crops prior to harvest or during storage post-harvest [69]. Mycotoxins represent a serious problem in fish production worldwide. Its effects includes reduction of weight gain and feed efficiency, causing liver and kidney damage, worsening the overall health of the fish and which can result in serious economic implications to farmers [70,71]. According to Selim et al. [72], 0.5% of hydrated sodium calcium aluminosilicates (HSCAS) effectively reduced aflatoxin B1 (AFB1) toxicity in *O. niloticus*. HSCAS binds aflatoxin in the gastrointestinal tract, thereby reducing overall bioavailability to the bloodstream. Muanglai et al. [73,74] reported that 1% bentonite clay reduced growth inhibitory effect, bioaccumulation of AFB1 in muscle of Nile tilapia as well as tissue lesions due to AFB1.

Immunostimulating agents: An immunostimulant is a naturally occurring compound that modulates the immune system by increasing the host's resistance against diseases that in most circumstances are caused by pathogens [75]. *O. niloticus* supplied with diet containing plant additives 0.25% *E. purpurea*, 3% garlic (*A. sativum*) or 3% *Nigella sativa* showed higher survival in response to challenge infection than fed on control (without additives) [76]. According to Aly et al. [77] survival rate was significantly high (>85%) after challenge infection using pathogenic *A. hydrophila* in *O. niloticus* supplemented with feed containing *E. purpurea* and garlic (3%). Shalaby et al. [78,79] also reported that adding 3% garlic to fish diet can promote growth, reduce total bacteria and improve fish health. According to Acar et al. [80] 0.1%, 0.3% or 0.5% oil extracted from sweet orange peel (*Citrus sinensis*) enhanced growth rate of tilapia (*O. mossambicus*) and disease resistance against *S. iniae*. Hassanin et al. [33,81] also reported that ginger (*Z. officinale*) supplementation of *O. niloticus* protected against pathogenic strain of *A. hydrophila* in aquaculture.

Results

Nutrition is one of the most important factors influencing the ability of cultured tilapia to exhibit its genetic potential for growth and it is greatly influenced by factors such as behavior of fish, stocking density, quality of feed, daily ration size, feed frequency and others. In addition to the above factors, use of functional feed additives in tilapia nutrition improve feed conversion ratio, improve the digestion of dietary components, boosts immune system, binds toxic substances in the gastrointestinal tract, thereby reducing overall bioavailability to the bloodstream and functional feed additive like prebiotics modulate the gut microbiota.

References

1. Barrows FT, Hardy RW (2000) Feed Additives. In: Encyclopedia of Aquaculture. pp: 336-340.
2. Bai SC, Katya K, Yun H (2015) Additives in aquafeed: an overview. In: Feed and Feeding Practices in Aquaculture pp: 171-202.
3. Nates SF (2016) Feed additives. In: Aquafeed Formulation. (Nates SFM, Editor). Academic Press, USA.
4. Pigott GM, Tucker BW (2003) Special Feeds. In: Fish Nutrition, Academic Press. USA pp: 651-669.
5. Kasper CS, White MR, Brown PB (2002) Betaine can replace choline in diets for juvenile Nile Tilapia, Oreochromis niloticus. Aquaculture 205: 119-126.
6. El-Husseiny OM, Din GE, Abdul-Aziz M, Mabroke RS (2008) Effect of mixed protein schedules combined with choline and betaine on the growth performance of Nile tilapia (Oreochromis niloticus). Aquaculture Research 39: 291-300.
7. Abdelhamid AM, Mehrim AI, El-Barbary MI, El-Sharawy MA (2010) An attempt to improve the reproductive efficiency of Nile tilapia brood stock fish. Fish Physiol Biochem 36: 1097-1104.
8. He S, Zhou Z, Liu Y, Cao Y, Meng K, et al. (2012) Do dietary betaine and the antibiotic florfenicol influence the intestinal autochthonous bacterial community in hybrid tilapia (Oreochromis niloticus x O. aureus). World J Microbiol Biotechnol 28: 785-791.
9. Pandian TJ, Sheela SG (1995) Hormonal induction of sex reversal in fish. Aquaculture 138: 1-22.
10. Beardmore JA, Mair GC, Lewis RI (2001) Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects. Aquaculture 197: 283-301.
11. Leedom TA, Uchida K, Yada T, Richman III NH, Byatt JC, et al. (2002) Recombinant bovine growth hormone treatment of tilapia: growth response, metabolic clearance, receptor binding and immunoglobulin production. Aquaculture 207: 359-380.
12. Marjani M, Jamili S, Mostafavi PG, Ramin M, Mashinchian A (2009) Influence of 17-Alpha methyl testosterone on masculinization and growth in tilapia (Oreochromis mossambicus). Journal of Fisheries and Aquatic Science 4: 71-74.
13. Khalil NA, Khalaf-Allah HMM, Mousa MA (2011) The effect of maternal thyroxine injection on growth, survival and development of the digestive system of Nile tilapia, Oreochromis niloticus, larvae. Advances in Bioscience and Biotechnology 2: 320-329.
14. El-Sayed AM, Abdel-Aziz EH, Abdel-Ghani HM (2012) Effects of phytoestrogens on sex reversal of Nile tilapia (Oreochromis niloticus) larvae fed diets treated with 17α-Methyltestosterone. Aquaculture 360-361: 58-63.
15. Lin S, Mai K, Tan B (2007) Effects of exogenous enzyme supplementation in diets on growth and feed utilization in tilapia, Oreochromis niloticus x O. aureus. Aquaculture Research 38: 1645-1653.
16. Ebru Y, Cengiz K (2016) Feed Additives In Aquafeeds. Scientific Papers-Animal Science 66: 155-160.
17. Encarnacao P (2009) The Potential of Phytogenic Compounds in Aquaculture. In: Phytogenics in Animal Nutrition, Nottingham University Press. UK pp: 147-156.
18. Karaskova K, Suchy P, Strakova E (2015) Current use of phytogenic feed additives in animal nutrition: a review. Czech J Anim Sci 60: 521-530.
19. Gbadamosi OK, Fasakin AE, Adebayo OT (2016) Hepatoprotective and stress - reducing effects of dietary Moringa oleifera extract against Aeromonas hydrophila infections and transportation-induced stress in Nile tilapia, Oreochromis niloticus (Linnaeus 1757) fingerlings. International Journal of Environmental & Agriculture Research 121-127.
20. Metwally MAA (2009) Effects of Garlic (Allium sativum) on Some Antioxidant Activities in Tilapia Nilotica (Oreochromis niloticus). World Journal of Fish and Marine Sciences 1: 56-64.
21. Jeney G, De Wet L, Jeney Z, Yin G (2015) Plant Extracts. In: Dietary Nutrients, Additives, and Fish Health, Wiley-Blackwell. Canada pp: 321-333.
22. Pachanawan A, Phumkhachorn P, Rattanachaikunsopon P (2008) Potential of Psidium guajava Supplemented Fish Diets in Controlling Aeromonas hydrophila Infection in Tilapia (Oreochromis niloticus). Journal of Bioscience and Bioengineering 106: 419-424.
23. Zilberg D, Tal A, Froyman N, Abutbul S, Dudai N, et al. (2010) Dried leaves of Rosmarinus officinalis as a treatment for streptococcosis in tilapia. Journal of Fish Diseases 33: 361-369.
24. Goda ASA (2008) Effect of Dietary Ginseng Herb (Ginsana_G115) Supplementation on Growth, Feed Utilization, and Hematological Indices of Nile Tilapia, Oreochromis niloticus (L.), Fingerlings. Journal of the World Aquaculture Society 39: 205-214.
25. Dada AA (2012) Effects of herbal growth promoter feed additive in fish meal on the performance of Nile Tilapia (Oreochromis niloticus (L.)). Egypt Acad J Biolog Sci 4: 111-117.
26. Yin G, Jeney G, Racz T, Xu P, Jun X, et al. (2006) Effect of two Chinese herbs (Astragalus radix and Scutellaria radix) on non-specific immune response of tilapia, Oreochromis niloticus. Aquaculture 253: 39-47.
27. Mohamed HA, Trafalgar RF, Serrano AE (2013) Assessment of Probiotic Application on Natural Food, Water Quality and Growth Performance of

Saline Tilapia Oreochromis mossambicus L. Cultured in Concrete Tanks. Fisheries and Aquaculture Journal 5: 1-7.

28. Lauzon HL, Dimitroglou A, Merrifield DL, Ringo E, Davies SJ (2014) Probiotics and Prebiotics: Concepts, Definitions and History. In: Aquaculture Nutrition, John Wiley & Sons Ltd. UK pp: 169-184.
29. Michael ET, Amos SO, Hussaini LT (2014) A Review on Probiotics Application in Aquaculture. Fisheries and Aquaculture Journal 5: 1-4.
30. Olmos J, Paniagua-Michel J (2014) Bacillus subtilis A Potential Probiotic Bacterium to Formulate Functional Feeds for Aquaculture. J Microb Biochem Technol 6: 361-365.
31. Irianto A, Austin B (2002) Probiotics in aquaculture. Journal of Fish Diseases 25: 633-642.
32. Ghouse M (2015) Use of Probiotics as Biological Control Agents in Aquaculture for Sustainable Development. International Journal of Food, Agriculture and Veterinary Sciences 5: 112-119.
33. Hai NV (2015) The use of probiotics in aquaculture. Journal of Applied Microbiology 119: 917-935.
34. Lantegan MJ, Booth W, Shimmon R, Gibson LF (2006) An inhibitory substance produced by Aeromonas media A199, an aquatic probiotics. Aquaculture 254: 115-124.
35. Al-Dohail MA, Hashim R, Aliyu-Paiko M (2009) Effects of the probiotic, Lactobacillus acidophilus, on the growth performance, hematology parameters and immunoglobulin concentration in African Catfish (Clarias gariepinus, Burchell 1822) fingerling. Aquaculture Research 40: 1642-1652.
36. Zhou X, Wang Y, Li W (2009) Effect of probiotics on larvae shrimp (Penaeus vannmei) based on water quality, survival rate, digestive enzyme activities. Aquaculture 287: 349-353.
37. Gaddipati GR, Gunturu C, Rajkumar R, Raghavaiah GV (2015) Ecotech: A Probiotic for maintaining water quality and Control of vibrio sp in vitro. Journal of Research in Agriculture and Animal Science 3: 01-04.
38. Aly HA, Abdel-Rahim MM, Lotfy AM, Abdelaty BS, Sallam GM (2016) The Applicability of Activated Carbon, Natural Zeolites, and Probiotics (EM®) and Its Effects on Ammonia Removal Efficiency and Fry Performance of European Seabass Dicentrarchus labrax. Journal of Aquaculture Research Development 7: 1-8.
39. Wang Y (2007) Effect of probiotics on growth performance and digestive enzyme activity of the shrimp penaeus vannamei. Aquaculture 269: 259-264.
40. Talpur AD, Ikhwanuddin M, Abdullah MDD, Bolong AA (2013) Indigenous Lactobacillus plantarum as probiotics for larviculture of blue swimming crab, portunus pelgicus (Linnaeus, 1758): effect on survival, digestive enzyme activities and water quality. Aquaculture 416-417: 173-178.
41. Zhou X, Tian Z, Wang Y, Li W (2010) Effect of treatment with probiotics as water additives on tilapia (Oreochromis niloticus) growth performance and immune response. Fish Physiol Biochem 36: 501-509.
42. Wang Y, Tian Z, Yao J, Li W (2008) Effect of probiotics, Enteroccus faecium, on tilapia (Oreochromis niloticus) growth performance and immune response. Aquaculture 277: 203-207.
43. Reda RM, Selim KM (2015) Evaluation of Bacillus amyloliquefaciens on the growth performance, intestinal morphology, hematology and body composition of Nile tilapia, Oreochromis niloticus. Aquacult Int 23: 203-217.
44. Aly SM, Ahmed YA, Ghareeb AA, Mohamed M F (2008) Studies on Bacillus subtilis and Lactobacillus acidophilus, as potential probiotics, on the immune response and resistance of Tilapia nilotica (Oreochromis niloticus) to challenge infections. Fish & Shellfish Immunology 25: 128-136.
45. Gibson GR, Roberfroid M (1995) Dietary modulation of the human colonic microbiota: Introducing the concept of prebiotics. J Nutr 125: 1401-1412.
46. Ringo E, Olsen RE, Gifstad TO, Dalmo RA, Amlund H, et al. (2010) Prebiotics in aquaculture: a review. Aquaculture Nutrition 16: 117-136.
47. Crittenden R, Playne MJ (2009) Prebiotics. In: Handbook of Probiotics and Prebiotics. John Wiley & Sons, Inc. New Jersey pp. 533-562
48. Song SK, Beck BR, Kim D, Park J, Kim J, et al. (2014) Prebiotics as immunostimulants in aquaculture: A review. Fish & Shellfish Immunology 40: 40-48.
49. Anadon A, Martinez-Larranaga MR, Caballero V, Castellano V (2010) Assessment of Prebiotics and Probiotics: An Overview. In: Bioactive Foods in Promoting Health: Probiotics and Prebiotics pp: 19-41.
50. Ringo E, Dimitroglou A, Hoseinifar SH, Davies SJ (2014) Prebiotics in Finfish: An Update. In: Aquaculture Nutrition: Gut Health, Probiotics and Prebiotics, John Wiley and Sons Ltd. UK pp: 360-394.
51. Tiengtam N, Khempaka S, Paengkoum P, Boonanuntanasarn S (2015) Effects of inulin and Jerusalem artichoke (Helianthus tuberosus) as prebiotic ingredients in the diet of juvenile Nile tilapia (Oreochromis niloticus). Animal Feed Science and Technology 207: 120-129.
52. Yuji-Sado R, Raulino-Domanski F, de Freitas PF, Baioco-Sales F (2015) Growth, immune status and intestinal morphology of Nile tilapia fed dietary prebiotics (mannan oligosaccharides-MOS). Lat Am J Aquat Res 43: 944-952.
53. Abu-Elala N, Marzouk M, Moustafa M (2013) Use of different Saccharomyces cerevisiae biotic forms as immune-modulator and growth promoter for Oreochromis niloticus challenged with some fish pathogens. International Journal of Veterinary Science and Medicine 1: 21-29.
54. Hassaan MS, Soltan MA, Ghonemy MMR (2014) Effect of synbiotics between Bacillus licheniformis and yeast extract on growth, hematological and biochemical indices of the Nile tilapia (Oreochromis niloticus). Egyptian Journal of Aquatic Research 40: 199-208.
55. Shelby AR, Lim C, Yildirim-Aksoy M, Welker TL, Klesius PH (2009) Effects of Yeast Oligosaccharide Diet Supplements on Growth and Disease Resistance in Juvenile Nile Tilapia, Oreochromis niloticus. Journal of Applied Aquaculture 21: 61-71.
56. Lim C, Luckstadt C, Webster CD, Kesius P (2015) Organic Acids and Their Salts. In: Dietary Nutrients, Additives and Fish Health, Wiley-Blackwell. Canada pp: 305-320.
57. Hassaan MS, Wafa MA, Soltan MA, Goda AS, Mogheth NMA (2014) Effect of Dietary Organic Salts on Growth, Nutrient Digestibility, Mineral Absorption and Some Biochemical Indices of Nile Tilapia; Oreochromis niloticus L. Fingerlings. World Applied Sciences Journal 29: 47-55.
58. Abu-Elala NM, Ragaa NM (2015) Eubiotic effect of a dietary acidifier (potassium diformate) on the health status of cultured Oreochromis niloticus. Journal of Advanced Research 6: 621-629.
59. Koh C, Romano N, Zahrah AS, Ng W (2016) Effects of a dietary organic acids blend and oxytetracycline on the growth, nutrient utilization and total cultivable gut microbiota of the red hybrid tilapia, Oreochromis sp., and resistance to Streptococcus agalactiae. Aquaculture Research 47: 357-369.
60. Reda RM, Mahmoud R, Selim KM, El-Araby IE (2016) Effects of dietary acidifiers on growth, hematology, immune response and disease resistance of Nile tilapia, Oreochromis niloticus. Fish & Shellfish Immunology 50: 255-262.
61. Khaled M (2015) Effect of Organic Acid Salt Supplementation on Growth Performance and Feed Utilization in Practical Diets of Hybrid Tilapia (O. Niloticus X O. Aureus) Fingerlings. Egyptian J Anim Prod 52: 81-88.
62. Cao L, Wang W, Yang C, Yang Y, Diana J, et al. (2007) Application of microbial phytase in fish feed. Enzyme and Microbial Technology 40: 497-507.
63. Yoo Y, Wang X, Choi S, Han K, Kang C, et al. (2005) Dietary microbial phytase increased the phosphorus digestibility in juvenile Korean rockfish Sebastes schlegeli fed diets containing soybean meal. Aquaculture 243: 315-322.
64. Cao L, Yang Y, Wang WM, Yakupitiyage A, Yuan DR, et al. (2008) Effects of pretreatment with microbial phytase on phosphorous utilization and growth performance of Nile tilapia (Oreochromis niloticus). Aquaculture Nutrition 14: 99-109.

65. Liebert F, Portz L (2005) Nutrient utilization of Nile tilapia Oreochromis niloticus fed plant based low phosphorus diets supplemented with graded levels of different sources of microbial phytase. Aquaculture 248: 111-119.

66. Nwanna LC (2007) Effect of Dietary Phytase on Growth, Enzyme Activities and Phosphorous Load of Nile tilapia (Oreochromis niloticus). Journal of Engineering and Applied Sciences 2: 972-976.

67. Mlalila N, Mahika C, Kalombo L, Swai H, Hilonga A (2015) Human food safety and environmental hazards associated with the use of methyltestosterone and other steroids in production of all-male tilapia. Environ Sci Pollut Res 22: 4922-4931.

68. Megbowon I, Mojekwu TM (2014) Tilapia Sex Reversal Using Methyl Testosterone (MT) and its Effect on Fish, Man and Environment. Biotechnology 13: 213-216.

69. Manning BB (2015) Mycotoxin Contamination of Fish Feeds. In: Dietary Nutrients, Additives and Fish Health, John Wiley and Sons Inc. Canada pp: 237-248.

70. Deng S, Tian L, Liu F, Jin S, Liang G, et al. (2010) Toxic effects and residue of aflatoxin B1 in tilapia (Oreochromis niloticus×O. aureus) during long-term dietary exposure. Aquaculture 307: 233-240.

71. Anater A, Manyes L, Meca G, Ferrer E, Luciano FB, et al. (2016) Mycotoxins and their consequences in aquaculture: A review. Aquaculture 451: 1-10.

72. Selim KM, El-hofy H, Khalil RH (2014) The efficacy of three mycotoxin adsorbents to alleviate aflatoxin B1-induced toxicity in Oreochromis niloticus. Aquacult Int 22: 523-540.

73. Muanglai P, Tengjaroenkul B, Sukon P, Pimpukdee K, Tengjaroenkul U (2010) Efficacy of Bentonite on Reducing Toxicity of Aflatoxin B1 in Diet of Nile Tilapia Fish. KKU Vet J 20: 21-33.

74. Hussaina D, Mateena A, Gatlin III DM (2017) Alleviation of aflatoxin B1 (AFB1) toxicity by calcium bentonite clay: Effects on growth performance, condition indices and bioaccumulation of AFB1 residues in Nile tilapia (Oreochromis niloticus). Aquaculture 475: 8-15.

75. Bricknell I, Dalmo RA (2005) The use of immunostimulants in fish larval aquaculture. Fish Shellfish Immunol 19: 457-472.

76. John G, Mesalhy S, Rezk M, El-Naggar G, Fathi M (2007) Effect of some immunostimulants as feed additives on the survival and growth performance of Nile tilapia, Oreochromis niloticus and their response to artificial infection. Egypt J Aquat Biol Fish 11: 1299-1308.

77. Aly SM, Mohamed MF (2010) Echinacea purpurea and Allium sativum as immunostimulants in fish culture using Nile tilapia (Oreochromis niloticus). Journal of Animal Physiology and Animal Nutrition 94: 31-39.

78. Shalaby AM, Khattab YA, Abdel-Rahman AM (2006) Effects of garlic (Allium sativum) and chloramphenicol on growth performance, physiological parameters and survival of nile tilapia (Oreochromis niloticus). J Venom Anim Toxins Incl Trop Dis 12: 172-201.

79. Diab AS, Aly SM, John G, Abde-Hadi Y, Mohammed MF (2008) Effect of garlic, black seed and Biogen as immunostimulants on the growth and survival of Nile tilapia, Oreochromis niloticus (Teleostei: Cichlidae), and their response to artificial infection with Pseudomonas fluorescens. African Journal of Aquatic Science 33: 63-68.

80. Acar U, Kesbic OS, Yilmaz S, Gultepe N, Turker A (2015) Evaluation of the effects of essential oil extracted fromsweet orange peel (Citrus sinensis) on growth rate of tilapia (Oreochro mismossambicus) and possible disease resistance against Streptococcus iniae. Aquaculture 437: 282-286.

81. Sahan A, Ozutok S, Kurutas EB (2016) Determination of Some Hematological Parameters and Antioxidant Capacity in Nile Tilapia (Oreochromis Niloticus Linnaeus, 1758) Fed Ginger (Zingiber Officinale Roscoe) to Aeromonas hydrophila. Turkish Journal of Fisheries and Aquatic Sciences 16: 197-204.

82. El-Sayed HM, Hakim Y, El-Sayed BM (2014) Dietary effect of ginger (zingiber officinale roscoe) on growth performance, immune response of Nile tilapia (Oreochromis niloticus) and disease resistance against Aeromonas hydrophila. Abbassa Int J Aqua 7: 35-52.

83. Goda AMA, Mabrouk HAH, Wafa MAH, El-Afifi TM (2012) Effect of Using Baker's Yeast and Exogenous Digestive Enzymes as Growth Promoters on Growth, Feed Utilization and Hematological Indices of Nile tilapia, Oreochromis niloticus Fingerlings. Journal of Agricultural Science and Technology 15-28.