29

# Use of Natural by Products in Fish Nutrition

**AUTHORS DETAIL**

Nasreen MohiAlddin Abdulrahman and Emad Tayar Sadeeq

College of Veterinary Medicine/University of Sulaimani
College of Agricultural Engineering Science, University of Duhok
*Corresponding author:
nasreen.abdulrahman@univsul.edu.iq

**Received: Oct 01, 2022 Accepted: Dec 30, 2022**

## INTRODUCTION

Fish are raised in captivity under strictly controlled conditions in order to meet the need of white meat for human consumption. In industrial fish farming, productivity is increased by making individual fish heavier (Schuchardt et al. 2008). Fish development with maximal weight in a short period of time is improved by using artificial feed in aquaculture (Bhosale et al. 2010). To increase the effectiveness of the feed conversion process, resulting in fish development, new compounds are being added to the fish feed. According to a study, herbs have positive benefits on fish health and growth. (Fernández-Navarro et al. 2006).

The formation of drug resistance bacteria and the generation of hazardous compounds unsafe to both human health and the environment are caused by the overuse of antimicrobials, hormones and other synthetic drugs in aquaculture to prevent infections, promote fish growth (Esiobu et al. 2002) and weakening the host's immunity (Panigrahi and Azad 2007). As a result, their use has drawn criticism across the world (Baruah et al. 2008). Herbs are used in place of antibiotics in the management of fish health because these are less expensive, environment friendly, and have less adverse effects. The World Health Organization promotes diets that include medicinal herbs or plants as a supplement to reduce the requirement for chemicals in fish meals (Dada 2015). In this situation, including herbs and herbal items in fish diets can help the cultured fish to consume more feed (Levic et al. 2008).

Animal nutrition uses bioactive substances found in a variety of plants to increase feed intake, enhance digestive enzyme output, and trigger immunological responses Additionally, there are many plants reported to have antiviral, antibacterial, and antioxidant properties (Citarasu 2010). Aquaculture practices include a diversity of herbs and herbal products to produce healthy fish by treating illnesses, promoting growth, lowering stress levels, enhancing immunity, stimulating appetite and preventing infections (Citarasu et al. 2001; Shalaby 2004).

## Functions of Natural Products

Miguel et al. (1997) performed research on the dietary quality of cowpea seed protein concentrate as an ingredient in functional tilapia fry diets. Cowpea seed protein concentrate has been determined to be a potential element for use in tilapia feeding as there has been no documentation of mortality linked to dietary plant protein. Fish have benefited more from duckweed supplementation than from water spinach or other polyculture fish supplements (Thy et al. 2008). The results showed that effects of different amounts of *Ipomea batatas* peels on development, feed consumption, and specific cichlid biochemical responses of *Oncorhynchus (O.) niloticus* could survive up to 15% of inclusion of sweet potato peel. The research's findings are significant because it showed that sweet potato peel can be used in fish food to reduce the expenses of processing farmed fish. Similar effects of Tilapia fingerlings were exhibited by Adewolu (2008) and Faramarzi et al. (2012).

Mohddin et al. (2012) evaluated the impact of adding mushrooms as a prebiotic to a diet high in super worms on the growth of red tilapia fingerlings. Specific growth rate, Feed conversion ratio, and Protein efficacy ratio levels rose, and survival reached up to 93.33%. The 10% supplementation of mushroom stalk meal (MSM) as a tilapia prebiotic may be utilized in the insect-based diet of *Zophobas morio*. The Nile tilapia (*O. niloticus*) grows faster when the melon shell is included in its diet as a source of energy (Orire and Ricketts 2013). *O. niloticus* can be utilize up to 75% of mixing melon shell meal in tilapia diets successfully. The mean feed intake, survival rate, protein intake, protein efficiency ratio, gross feed conversion efficiency, feed efficiency and percentage weight gain all rose as the amount of dietary cowpea (*Vigna unguiculata*) husk meal increased. When cowpea hull meal is used in place of maize meal, growth efficiency improves by 50 to 100 times (Thy et al. 2008).

Dorojan et al. (2014) investigated the effects of specific phytobiotics (thyme, sea buckthorn) on the growth output of stellate sturgeons (*Acipenser stellatus*) in a system of economic recirculating aquaculture. Thyme (*Thymus vulgaris*) and sea buckthorn (Phytobiotics) were inserted in feed using gelatin at a concentration of 2% per kilogram of feed. The crude protein utilized was 48%. It was concluded that two types of essential plants (thyme and sea camel), when given at a concentration of 2% / kg of fodder, had an impact on astrocytes' ability to proliferate. The growth performance of tilapia (*O. niloticus*) fingerlings was studied by Gaber et al. (2014), in which diet were supplemented by Digestarom and it was concluded that the diet with 30% wet date and 0.03 percent Digestarom showed the highest net gain and looked to be preferably level.

**Citation:** Abdulrahman NM and Sadeeq ET, 2023. Use of natural by products in fish nutrition. In: Abbas RZ, Saeed NM, Younus M, Aguilar-Marcelino L and Khan A (eds), One Health Triad, Unique Scientific Publishers, Faisalabad, Pakistan, Vol. 2, pp: 209-215. https://doi.org/10.47278/book.oht/2023.62

The effects of hunger stimulation on the functioning of digestive enzymes may be another potential mechanism of the action of phytogenic bioactive chemicals on the growth output of farm animals. According to Abdulrahman and Ahmed (2015), feeding animals fructooligosaccharides boosted their daily body weight gain by boosting their amylase and protease activity. Additionally, the pancreas and intestinal mucosa of these animals were used in a study that revealed feeding them a diet rich in lactic acid and a commercial blend of essential oils significantly increased the activity of digestive enzymes, which in turn significantly increased the production of pancreatic and intestinal mucosa enzymes. (Metwally 2009). It has been proven that using hot spices like cinnamon and pepper will cause salivation. The availability of nutrients from feedstuffs and digestibility may both benefit from the increase in enzyme synthesis (Yuan et al. 2008).

Higher vertebrates and fish have two critical components in their immune systems. The endogenous, regular, or non-specific defensive mechanism is the initial component. It is made up of a series of cellular and humoral elements. The second element is the acquired, specific, or adaptive immune system, which is distinguished by cellular immune response mediated by T-lymphocytes and humoral immunological response via antibody formation. Immunostimulant prophylaxis is the most successful techniques to improve the immune system for disease prevention in aquaculture. Some elements (such as the fundamental cells and molecules of adaptive immunity: B lymphocytes (B cells), T lymphocytes (T cells), immunoglobulins (Igs), and major histocompatibility complex (MHC) of fish's innate immunity have been found to be improved by immunostimulants (Esiobu et al. 2002).

Like other antimicrobial medicines, certain plant bioactive compounds work by altering the cell membrane of microorganisms. Minimum inhibitory concentrations (MIC50) and minimum bactericidal concentrations (MBC50) are correlated with the concentration of the active ingredient and the quality of the plant extract (Kamel 2001). Additionally, a significant increase in the hydrophobicity of microbial species can change the surface properties of microbial cells and therefore alter the virulence qualities of microorganisms in the presence of specific plant extracts (Miguel et al. 1997). This could be a key antibacterial mechanism in certain plant extracts. This description perhaps has impacts on the intestines, as certain pathogenic microflora depends on the adherence of bacteria to intestinal mucosal cells, which is strongly impacted by the hydrophobic surface features of microbial cells (Denev 2008).

Numerous essential oil blends that primarily consist of naturally occurring polyphenolic chemicals or flavonoids have shown promising results as antibacterial and antioxidant agents. A healthy gut flora can be established by supplementing broiler diets with essential oil blends, which will encourage optimal digestion and increase bird productivity (Denev 2008). Findings of Citarasu et al. (2006) showed that Black tiger shrimp's diet contains a variety of methanolic plant extracts. Shrimp fed a 25-ppm extract of turmeric fared which was substantially better against *V. harveyi*. According to another study, the ethanol extract of *Psidium guajava* was shown to have the highest antibacterial activity when it was tested against *Aeromonas hydrophila* infection in tilapia (*O. niloticus*) (Levic et al. 2008).

According to another experimental study, effective combination of plant extracts with antibacterial and antiparasitic characteristics is used to treat pangasius catfish and led to better disease resistance to two significant bacterial pathogens (*Edwardsiella ictaluri* and *Aeromonas hydrophila*), higher growth, and improved feed conversion.

From the experimental findings of Abdulrahman et al. (2019) it can be concluded that using 25-50% of the protein from commercial dry yeast *S. cerevisiae* in the diets of common carp led to a significant improvement in the chemical composition of common carp (*C. carpio* L.) meat, as well as an improvement in the sensory evaluation of fish meat.

By using a plant extract derived from the leaves of the olive tree (*Olea europaea*) and its primary component (oleuropein), salmonid rhabdovirus has successfully be controlled and viral haemorrhagic septicaemia rhabdovirus (VHSV) can be used as an antiviral agent (Dorojan et al. 2014). White Spot Syndrome Virus infection had an effect on the survival and viral load of black tiger shrimp fed on a combination of methanolic plant extracts (*Penaeus monodon*). The herbal medicinal products applied in *P. monodon* larviculture contain nutrients that enhance growth promotion, the appetizer to increase consumption and anti-stress characteristics and, therefore immensely used in the culture of shrimps. This practice reduces the side effects caused by applying synthetic chemical compounds. Hence the alternative herbal compounds prove to be very effective in the shrimp larviculture (Citarasu et al. 2002).

The outcomes of adding *Chlorella* algae to fish feed in the study of Abdulrahman et al. (2019) had an impact on feed consumption. The T3 and T4 food conversion ratios were noticeably lower than other therapies. No discernible variations across the treatments were seen in the food efficiency ratio. T3 and T4 had significantly higher protein efficiency ratios than other therapies. In both T2 and T3, fish weight without viscera was significantly higher. In the chemical studies (proximate analyses) of the common carp meat, T4 had a much greater protein to ash ratio, although T4 and T3 had a significantly larger lipid to moisture ratio. In comparison to the control, adding *Chlorella* to fish diets at all levels had a substantial impact on the color, juiciness, and overall acceptability of the meat.

When added to the diet of tilapia, the reddish hue seen in red sandalwood (*Pterocarpus santalinus*) is seen to boost the acceptance of the meal. Both the body and the flesh of the fish were painted pink. Fish fed colored feed displayed higher feed intake and growth rate (Gaber et al. 2014). Joseph et al. (2011) examined the effects of four herbal supplements (*H. rosasinensis*, *Rosa indica*, *Ixora coccinea* and *Crossandra* *infundibuliformiss*) on the development and body coloring of an ornamental fish with a red sword tail, *Xiphophorus hellerei* (Heckel), They came to the conclusion that *I. coccinea* had the highest amount of color pigments found in adult fish, at a level of 1%.

Jha et al. (2012) investigated that, natural pigments influenced cichlid color, and the groups showed no differences in feed conversion or growth rates. It was concluded as a result that these pigment sources affect the color of cichlid fish. With the addition of dietary supplements and an increase in marigold flower meal and beetroot meal, body carotenoid levels grow at linear rate.

Improving meat quality and aquaculture productivity depends on several variables, including density, the quality of the water and feed, as well as additional environmental variables such as the water's salinity and level of dissolved oxygen (Bhosale et al. 2010).

Environmental variables including rain, high temperatures, floods, landslides, predatory fish entering earthen ponds or reservoirs, blooming of algal, etc. are also the cause of a decreased aquaculture product. These elements lead to stress and insufficient usage of regular feed, which lowers the feed's conversion ratio. Drugs like antibiotics and synthetic medications that are used to treat illnesses can injure the liver and have an impact on the development of cultured fish, which lowers output. By addressing these issues, it will be possible to enhance commercially viable production. However, to maintain fish health overall and address environmental issues without compromising growth survival, enough herbal feed supplementation is necessary (Dada 2015).

Due to rising demand and a parallel decrease in wild fisheries, aquaculture is growing faster than all other animal food-producing sectors. With advanced cultivation/rearing techniques, numerous species of plants and animals continue to increase every year. Despite the various policy initiatives supported by numerous research studies aimed at boosting fisheries production in most countries, the deficiency in the production target is a key feature of the sector as the consumption of fisheries and products continues to increase. Production of aquaculture can be based on a short production cycle to fill the production gap. The feed conversion rate will be improved in this process, which in turn would encourage weight gain and boost the production potential of animal meat and have a bactericidal impact on wastewater aquaculture. Natural substances are promising to adjust the demand curve to fulfill existing demand in fisheries. Natural products may stimulate the growth of antimicrobial agents, increase the assimilation of proteins and the conversion rate of feed, so that animals gain weight more rapidly without substantial cumulative toxicity. Several herbs are used to lower stress, boost defenses, and control bacterial development, such as *Thymus vulgarism*, *Coriandrum sativum*, *Apium graveolens*, *Hygrophila spinosa*, *Withania somnifera*, *Zingiber officinalis*, *Solanum trilobatum*, *Andrographis paniculata*, *Psoralea corylifolia*, *Eclipta erecta*, *Ocimum sacnctum*, *Picrorhiza kurooa*, *Phyllanthus niruri* and *Tinospora cordifolia* (Citarasu et al. 2002). Similarly, it is known that in aquatic animals, fenugreek, black seed, licorice, anise, marjoram, caraway, basil, anise, fennel, and garlic boost development, food conversion, improve protein digestion, and sustain energy (Platel et al. 2002).

Significant improvements in fish growth, coloring, reproduction, and flesh quality can be achieved by adding *Spirulina platensis* to fish diets as a feed supplement or as a partial replacement for fishmeal (Abdulrahman et al. 2019). According to the latest research, common carp diets can substitute 20% of their fish meal with lentil seed for improved growth (Abdulrahman et al. 2021).

Allicin is an active garlic compound that causes increases in diet intake (Zeng et al. 1996). Research recorded that after 45 days of culture, the addition of 50 mg/kg synthesized allicin to the fish diet improve 2-3% of its weight gain (Lee and Gao 2012). As growth-promoting agents in *O. niloticus*, other culinary herbs including basil (*Ocimum basilium*), caraway (*Carum carvi*), and red clover (*Trifolium pratense*) showed promising outcomes (Ahmad and Abdel-Tawwab 2011). Another showed that green tea methanol extract (*Camellia sinensis*) improved the survival rate, growth, use of feed and protein content of black rockfish (*Sebastess chlegeli*). In *O. niloticus*, the supplemented diet of garlic increased weight gain and basic growth rate. High growth rates of 2.5 percent garlic in the feeding diet were observed in the same species. The diet supplemented with garlic increased weight and specific growth rate in tilapia. The 3.2% garlic powder diet showed the strongest performance in *O. niloticus* (Metwally 2009). Table 1 summarizes different prebiotics' effects on various carp species.

Similarly, diets that included garlic supplements showed significant advancements in weight gain, food conversion, and protein production. Due to increased protein synthesis, *Labeo rohita* fed with herbal diet supplements improved feed consumption, leading to better growth (Baruah et al. 2008). To improve fish health and wellbeing, earth apples were employed as a source of prebiotics which showed an improvement in weight gain and various growth parameters (Abdulrahman 2022).

*Sesbania grandiflora*, *Moringa oleifera*, *Coleus aromaticus*, *Ocimum basilium*, and *Solanum verbascifolium* leaves used to enhance growth in *O. mossambicus*. In a study, *O. Mossambicus* fed with diets containing *Moringa oliefera* demonstrated a maximum increase in weight gain. An increase in fish length was observed in fish fed with a diet supplemented with *Ocimum basilicum*. Additionally, in *O. aureus*, red clover (*Trifolium pretense*) mixed with diet promoted the growth rate (Levic et al. 2008). Juvenile pike perch (*Sander lucioperca*) supplied with control diets grew slower than those fed with diets supplemented with therapeutic herbs. Red sea bream, *Poecilia reticulata*, *Cryptoheros nigrofasciatus*, and common carp *C. carpio* growth was enhanced when medicinal plants were added to Pagru's main diet. Ginseng herb consumption accelerated the growth of *O. niloticus* fingerlings (Harada 1990).

**Table 1:** Effect of different prebiotics on carp species

| Fish species | Prebiotic | Results | References |
|---|---|---|---|
| Common carp | Chitosan chitin | Increase in weight gain, lysozymes, Amylase and Lipase enhancement and increased defense against diseases | (Gopalakannan and Arul 2006) |
| Crucian carp | XOS | Increase in weight gain, and enhancement of Protease and Amylase activity | (Xu et al. 2009) |
| Common carp | MOS | Increase in condition factor, weight gain, and Protein efficiency ratio | (Atar and Ates 2009) |
| Crucian carp | MOS | Increased of immunoglobulin, lysozyme activity and acidophosphatase enzyme | Akrami et al. (2012) |
| Common carp | MOS+BG Immunogen | Increase in feed and Protein efficiency ratio, feed conversion ratio, Hemoglobin and plasma protein | (Ebrahimi et al. 2012) |
| Mirror carp | β- glucan | Increased heterotrophic bacteria, Increased growth performance, hemoglobin, hematocrit, and proximate analysis | (Kühlwein et al. 2014) |
| Common carp | FOS | Increased survival rate, growth parameters, white blood cells and diseases resistance | (Hoseinifar et al. 2014) |
| Crucian carp | Chitosan | Increased phagocytosis, Decreased cholesterol and triglyceride | (Chen et al. 2014) |
| Common carp | FOS | Increased survival rate, lactobacilli count, amylase and lipase activity, no effect on growth performance | (Hoseinifar et al. 2016) |
| Common carp | β- glucan | Increased microbial load | (Jung-Schroers et al. 2016) |
| Common carp | FOS | Increased white blood cells and platelets counts | (Abdulrahman and Ahmed 2015) |

**Table 2:** Natural resources of natural prebiotics

| Type of Prebiotic | Source | Reference |
|---|---|---|
| Maltooligosaccharides | Starch | (Kaneko et al. 1994) |
| Isomaltooligosaccharides | Starch | (Kaneko et al. 1995) |
| Raffinose oligosaccharides | Legumes, Lentil, Peas and Beans | (Johansen et al. 1996) |
| Xylooligosaccharides | Bamboo Shoots, Fruits, Vegetables, Milk, Honey and Wheat Bran | (Vazquez et al. 2000) |
| Galactooligosaccharides | Human Milk, Cow's Milk, and Glucan Dissolved in Water | (Alander et al. 2001) |
| Lactosucrose | Lactose | (Kawase et al. 2001) |
| Lactulose | Milk Lactose | (Villamiel et al. 2002) |
| Cyclodextrins | Glucan Dissolved in Water | (Singh et al. 2002) |
| Isomaltulose | Honey and Sugar Cane Juice | (Lina et al. 2002) |
| Palatinose | Sucrose | (Lina et al. 2002) |
| Fructooligosaccharides | Sugar Beet, Garlic, Dandelion, Barley, Onion, Honey, Banana, Sugar Cane Juice | (Sangeetha et al. 2005) |
| Soybean oligosaccharide | Soybean | (Mussatto and Mancilha (2007) |
| Arabinoxylooligosaccharides | Wheat Bran | (Grootaert et al. 2007) |
| Enzyme-resistant dextrin | Potato Starch | (Barczynska et al. 2012) |

To improve growth effectiveness and meat quality, antibiotics may be given with an adjusted dose of garlic. Garlic was advised to be added to fish feed by Metwally (2009) to encourage growth and improve survival rates. Four distinct plants, including *Eichinacea purpurea*, *Allium sativum*, *Nigella sativa*, and *Origanum marjorana*, were utilized by John et al. (2007) as feed supplements to promote the growth and survival of *O. niloticus*.

Phytobiotics are defined as plant-based supplements given to animal feed to improve performance (Faramarzi et al. 2012). Phytobiotics have a broad range of properties, such as: growth promoters, antioxidant, anticarcinogenic, antimicrobial, analgesic, antiparasitic, insecticidal, anticoccidial, bile secretion stimulants and digestive enzyme function enhancement. In aquaculture, prophylactic administration of immunostimulants is among the most efficient methods of improving the defense system and control of diseases (Denev 2008).

According to a study, the treatment had a variety of impacts on the blood parameters that were examined, with 2.5 g/kg of fructooligosaccharide and dry yeast having a substantial impact on hemoglobin, white blood cells, and red blood cells (Abdulrahman and Ahmed 2015).

According to recent developments in immuno-nutrition studies, the immune condition of fish is related to particular nutrients. This brought the immune system protection and fish growth to the attention of fish nutritionists. Yuan et al. (2008) investigated the effects of common carp meals including a combination of *Astragalus Membranaceus* (root and stem), *Polygonum multiflorum*, *Isatis tinctoria*, and *Glycyrrhiza glabra* (0.5 and 1%). The levels of total protein, albumin, globulin, and nitric oxide activity increased significantly with both amounts, but there were no statistically significant differences in the activities of superoxide dismutase, lysozyme, or triglyceride levels. Fish immunological function has been reported to be improved by the root extracts of the Chinese herb Astragalus, which contain organic acids, alkaloids, polysaccharides, glucosides, and volatile oils as its main active ingredients. The oriental medicinal herb *G. glabra* (liquorice) comprises flavonoids and pentacyclic triterpene saponin, including liquiritin, liquiritigenin, isoliquiritigenin, liquiritin apioside, glycyrrhizin and glycyrrhizic acid as major constituents and is reported to have antioxidant effects (Yin et al. 2011).

The usefulness of adding herbs to fish feed to control abnormalities and promote healthy fish is the subject of numerous research. Fish feed can benefit from the use of natural plant products for improved development, health, and productivity. Aquacultural activities that use herbal products can promote development, operate as immune system boosters, stimulate hunger, raise feed consumption, induce maturation, and have antibacterial and anti-stress properties. The application of plants may pave the way for better coordination of fisheries with horticulture, providing a better connection between aquaculture and agriculture and achieving the objective of increased aquaculture production in a sustainable, cost-efficient, and eco-friendly method (Abdulrahman 2022), as shown in Table 2.

Green herbs and herbal items have been added to the feed to help fish raised in a farming system to resist infections, promote growth, reduce stress, and boost their immune systems. Diet supplementation of fish with herbal products is more affordable and environmentally safe, and neither the fish nor the consumers will experience any side effects. As a result, using herbs as medications to treat ailments in aquaculture is becoming more and more common. Compared to the numerous medications and vaccinations used in disease prevention, these have a greater impact on safety (Abdel-Tawwab et al. 2022).

## Conclusion

It is evident that plant by products can affect physiological functions and modulate the intestinal microbiota of different animal species, showing potential to be used as growth- and health-promoting agents in fish production. Natural products can be used as growth promoter, immune-stimulants, appetite stimulators, antibacterial, antiviral, antifungal, and anti-stress agents. Further studies are needed to gain more insights to understand the mechanisms of action of various by products on both pathogenic micro-organisms and the more abundant normal microbiota of the gut and evaluate their impact on the environment and the host.

## REFERENCES

Abdulrahman NM, 2022. Effect of germinated barely and earth apple (*Helianthus tuberosus*) powders in some physio-biological indices of common carp (*Cyprinus carpio* L.). Iranian Journal of Veterinary Medicine 16(2): 119-125.

Abdulrahman NM and Ahmed VM, 2015. Comparative effect of probiotic (*Saccharomyces cerevisiae*), prebiotic (fructooligosaccharides FOS) and their combination on some differential white blood cells in young common carp (*Cyprinus caprio* L.). Asian Journal of Science and Technology 6: 1136–1140.

Abdulrahman NM et al., 2019. Effect of the diet with commercial dry yeast (*Saccharomyces cerevisiae*) on organolepticqualities, chemical and biological parameters of common carp (*Cyprinus carpio* L.). Agricultural Science and Technology 11(1): 84 – 89. DOI: 10.15547/ast.2019.01.014E.

Abdulrahman NM et al., (2021). Effect of fish meal replacement with lentil seed (Lens culinaris) in common carp (Cyprinus carpio) L. diet. Omni-Akuatika 17 (1): 37 – 45.

Abdel-Tawwab M et al., 2022. Effects of dietary oak (*Quercus aegilops* L.) acorn on growth performance, somatic indices, and hemato-biochemical responses of common carp, *Cyprinus carpio* L., at different stocking densities. Journal of Applied Aquaculture 34: 4.

Adewolu MA, 2008. Potentials of sweet potato (*Ipomoea batatas*) leaf meal as dietary ingredient for *Tilapia zilli* fingerlings. Pakistan Journal of Nutrition 7(3): 444- 449.

Ahmad MH and Abdel-Tawwab M, 2011. The use of caraway seed meal as a feed additive in fish diets: Growth performance, feed utilization, and whole-body composition of Nile tilapia, (*Oreochromis niloticus*) (L.) fingerlings. Aquaculture 314: 110-114.

Akrami R et al., 2012. Effect of dietary mannan oligosaccharide (MOS) on growth performance and immune response of Gibel carp juveniles (*Carassius auratus gibelio*). Journal of Veterinary Advances 2(10): 507-513.

Alander M et al., 2001. Effect of galacto-oligosaccharide supplementation on human faecal microflora and on survival and persistence of Bifidobacterium lactis Bb-12 in the gastrointestinal tract. International Dairy Journal 11(10): 817-825.

Atar HH and Ates M, 2009. The effects of commercial diet supplemented with Mannanoligosaccharide (MOS) and vitamin B12 on the growth and body composition of the carp (*Cyprinus carpio* L. 1758). Journal of Animal and Veterinary Advances 8(11): 2251-2255.

Barczynska R et al., 2012. The tartaric acid-modified enzyme-resistant dextrin from potato starch as potential prebiotic. Journal of Functional Foods 4(4): 954-962.

Baruah K et al., 2008. Organic acids as non-antibiotic nutraceuticals in fish and prawn feed. Aquaculture Health International 12: 4–6.

Bhosale SV et al., 2010. Formulation of Fish feed using Ingredients from Plant Sources. Research Journal of Agricultural Sciences 1: 284–287.

Chen Y et al., 2014. Effect of dietary chitosan on growth performance, haematology, immune response, intestine morphology, intestine microbiota and disease resistance in gibel carp (Carassius auratus gibelio). Aquaculture Nutrition 20(5): 532-546.

Citarasu T et al., 2001. Control of pathogenic bacteria using herbal biomedical products in the larva culture system of *Penaeus monodon*. Proceedings of International Conference on Advanced Technologies in Fisheries and Marine Sciences, M. S. University, Tirunelveli, India; pp: 104.

Citarasu T et al., 2002. Developing Artemia enriched herbal diet for producing quality larvae in *Penaeus monodon* (Fabricius). Asian Fisheries Sciences 15: 21–32.

Citarasu T et al., 2006. Influence of selected Indian immuno-stimulant herbs against white spot syndrome virus (WSSV) infection in black tiger shrimp, *Penaeus monodon* with reference to haematological, biochemical and immunological changes. Fish and Shellfish Immunology 21: 372- 384.

Citarasu T, 2010. Herbal biomedicines: a new opportunity for aquaculture industry. Aquaculture International 18: 403–414.

Dada AA, 2015. Improvement of Tilapia (*Oreochromis niloticus*, Linnaeus, 1758) Growth Performance Fed Three Commercial Feed Additives in Diets. Journal of Aquatic Research Development 6: 325.

Denev SA, 2008. Ecological alternatives of antibiotic growth promoters in the animal husbandry and Aquaculture. PhD

Dissertation, Department of Biochemistry Microbiology, Trakia University, Stara Zagora, Bulgaria.

Dorojan OG et al., 2014. The Influence of some phytobiotics (Thyme, Sea buckthorn) on growth performance of stellate sturgeon (*A. stellatus*, Pallas, 1771) in an industrial recirculating aquaculture system. Animal Science and Biotechnologies 47(1): 205-210.

Ebrahimi GH et al., 2012. Effects of a prebiotic, Immunogen®, on feed utilization, body composition, immunity and resistance to *Aeromonas hydrophila* infection in the common carp *Cyprinus carpio* (Linnaeus) fingerlings. Journal of Animal Physiology and Animal Nutrition 96(4): 591-599.

Esiobu N et al., 2002. Antibiotic resistance in soil and water environments. International Journal of Environmental Health Research 12: 133-144.

Faramarzi M et al., 2012. Influences of different levels of sweet potato peels on growth and feeding parameters and biochemical responses of *Cyprinus carpio* (Cyprinidae). American- Eurasian Journal of Agriculture and Environmental Sciences 12(4): 449-455.

Fernández-Navarro M et al., 2006. Maslinic acid as a feed additive to stimulate growth and hepatic protein turnover rates in rainbow trout (*Onchorhynchus mykiss*). Comparative Biochemistry and Physiology C Toxicology and Pharmacology 144: 130–140.

Gaber MM et al., 2014. Effect of partially replacing corn meal by wet date on growth performance in Nile tilapia (*Oreochromis niloticus*) fingerlings, diets supplemented with digestarom. Journal of Geoscience and Environment Protection 2: 60-67.

Gopalakannan A and Arul V, 2006. Immunomodulatory effects of dietary intake of chitin, chitosan and levamisole on the immune system of *Cyprinus carpio* and control of *Aeromonas hydrophila* infection in ponds. Aquaculture 255(1): 179-187.

Grootaert C et al., 2007. Microbial metabolism and prebiotic potency of arabinoxylan oligosaccharides in the human intestine. Trends in Food Science and Technology 18(2): 64-71.

Harada K, 1990. Attraction activities of spices for oriental weather fish and yellowtail. Bulletin of the Japanese Society for the Science of Fish 56: 2029-2033.

Hoseinifar SH et al., 2014. Effects of dietary fructo-oligosaccharide supplementation on the growth performance, haemato-immunological parameters, gut microbiota and stress resistance of common carp (*Cyprinus carpio*) fry. British Journal of Nutrition 112(8): 1296-1302.

Hoseinifar SH et al., 2016. Modulation of growth performances, survival, digestive enzyme activities and intestinal microbiota in common carp (*Cyprinus carpio*) larvae using short chain fructooligosaccharide. Aquaculture Research 47(10): 3246-3253.

Jha GN et al., 2012. Effect of marigold flower and beetroot meals on growth performance, carcass composition, and total carotenoids of snow trout (*Schizothorax richardsonii*). The Israeli Journal of Aquaculture.

Johansen HN et al., 1996. Influence of extraction solvent and temperature on the quantitative determination of oligosaccharides from plant materials by high-performance liquid chromatography. Journal of Agricultural and Food Chemistry 44(6): 1470-1474.

John G et al., 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. Egyptian Journal of Aquatic Biology and Fisheries 11(3): 1299 -1308.

Joseph B et al., 2011. Influence of Four ornamental flowers on the growth and colouration of orange sword tail Chicilidae fish (*Xiphophorus hellerei* Heckel, 1840). International Journal of Phytomedicines and Related Industries 3(3): 249- 253.

Jung-Schroers V et al., 2016. Feeding of β-1, 3/1, 6-glucan increases the diversity of the intestinal microflora of carp (*Cyprinus carpio*). Aquaculture Nutrition 22(5): 1026-1039.

Kamel C, 2001. Racing modes of action and the roles of plant extracts in non–ruminants. Recent Advances in Animal Nutrition 2001: 135-150.

Kaneko T et al., 1994. Effects of Isomaltooligosaccharides with different degrees of polymerization on human fecal bifidobactcria. Bioscience, Biotechnology and Biochemistry 58(12): 2288-2290.

Kaneko T et al., 1995. Digestibility characteristics of isomaltooligosaccharides in comparison with several saccharides using the rat jejunum loop method. Bioscience, Biotechnology and Biochemistry 59(7): 1190-1194.

Kawase M et al., 2001. Lactosucrose production using a simulated moving bed reactor. Chemical Engineering Science 56(2): 453-458.

Kühlwein H et al., 2014. Effects of dietary β-(1, 3)(1, 6)-D-glucan supplementation on growth performance, intestinal morphology and haemato-immunological profile of mirror carp (Cyprinus carpio L.). Journal of Animal Physiology and Animal Nutrition 98(2): 279-289.

Lee JY and Gao Y, 2012. Review of the application of garlic, *Allium sativum*, in aquaculture. Journal of the World Aquaculture Society 43: 447-458.

Levic J et al., 2008. Herbs and organic acids as an alternative for antibiotic growth promoters. Achieve Zootechnica 11: 5-11.

Lina BAR et al., 2002. Isomaltulose (Palatinose®): a review of biological and toxicological studies. Food and Chemical Toxicology 40(10): 1375-1381.

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(1): 56-64.

Miguel A et al., 1997. Cowpea (*Vigna unguiculata*) protein concentrate as replacement for fish meal in diets for Tilapia (Oreochromis niloticus) fry. Aquaculture 158: 107-116.

Mohddin ARJ et al., 2012. Effect of mushroom supplementation as a prebiotic compound in super worm based diet on growth performance of red tilapia fingerlings. Sains Malaysiana 41(10): 197- 1203.

Mussatto SI and Mancilha IM, 2007. Non-digestible oligosaccharides: a review. Carbohydrate Polymers 68(3): 587-597.

Orire AM and Ricketts OA, 2013. Utilisation of mellon shell as dietary energy source in the diet of Nile Tilapia (*Oreochromis niloticus*). International Journal of Engineering and Science 2(4): 5-11.

Panigrahi A and Azad IS, 2007. Microbial intervention for better fish health in aquaculture: the Indian scenario. Fish Physiology and Biochemistry 33: 429-40.

Platel K et al., 2002. Digestive stimulant action of three indian spice mixes in experimental rats. Die Nahrung 46: 394-398.

Sangeetha PT et al., 2005. Recent trends in the microbial production, analysis and application of fructooligosaccharides. Trends in Food Science and Technology 16(10): 442-457.

Schuchardt D et al., 2008. Effects of different dietary protein and lipid levels on growth, feed utilization and body composition of red porgy (*Pagrus pagrus*) fingerlings. Aquaculture Nutrition 14(1): 1-9.
Shalaby SMM, 2004. Response of Nile tilapia, *Oreochromis niloticus*, fingerlings to diets supplemented with different levels of fenugreek seeds (Hulba). Journal of Agricultural Science, Mansoura University 29: 2231–2242.
Singh M et al., 2002. Biotechnological applications of cyclodextrins. Biotechnology Advances 20(5): 341-359.
Thy S et al., 2008. Effect of water spinach and duckweed on fish growth performance in polyculture ponds. Livestock Research for Rural Development 20(1).
Vazquez MJ et al., 2000. Xylooligosaccharides: manufacture and applications. Trends in Food Science and Technology 11(11): 387-393.
Villamiel M et al., 2002. Lactulose formation catalyzed by alkaline-substituted sepiolites in milk permeate. Food Chemistry 76(1): 7-11.
Xu B et al., 2009. Effects of prebiotic xylooligosaccharides on growth performance and digestive activities of allogynogenetic crucian carp (*Carassius auratus gibelio*). Fish Physiology and Biochemistry 35: 351–357.
Yin G et al., 2011. Administration of a herbal immunoregulation mixture enhances some immune parameters in carp (*Cyprinus carpio*). Fish Physiology and Biochemistry 37: 209-216.
Yuan C et al., 2008. Effects of Astragalus polysaccharides (APS) on the expression of immune response genes in head kidney, gill and spleen of the common carp, *Cyprinus carpio* L. International Immunopharmacology 8: 51-58.
Zeng H et al., 1996. Application of allicin in tilapia feed. China Feed 21: 29-30.