Comprehensive Research and Reviews in
Biology and Pharmacy
Journal homepage: https://crrjournals.com/crrbp/
ISSN: 2961-3590 (Online)

(REVIEW ARTICLE)

A review of the application of probiotics and prebiotics for sustainable development of aquaculture

Alemu Kebede Abdi [1] * and Demessa Negessu Gemachu [2]

[1] *Animal Health Institute, Fish Disease laboratory, Sebeta, Ethiopia.*
[2] *Animal Health Institute, Viral isolation laboratory, Sebeta, Ethiopia.*

Comprehensive Research and Reviews in Biology and Pharmacy, 2022, 01(01), 005–012

Publication history: Received on 20 July 2022; revised on 26 August 2022; accepted on 29 August 2022

Article DOI: https://doi.org/10.57219/crrbp.2022.1.1.0032

Abstract

Aquaculture is one of the wildest developing food-producing subdivisions of the world. World aquaculture has vastly developed during the previous few years, and also attracts an economically significant sector. Like any other production sector aquaculture is also exposed to pressure conditions that induce the aquaculture,s immune system. Also, some factors increase their vulnerability to diseases. Accordingly, it disturbs both the financial development and socio-economic status of the local people in several developed and developing nations specifically developing nations. The disease regulator strategy in aquaculture production has succeeded by following different approaches expanding traditional methods: artificial chemicals, and antibiotics. The practice of antimicrobial drugs and pesticides has directed the evolution of resistant straining of bacteria. Consequently, other techniques are much more vital to maintaining a healthy bacteriological environment in aquaculture production organizations. The recent review précises and deliberates the effects of probiotics and prebiotics direction on growth performance, stress forbearance, intestinal microbiota, immune response, and well-being of aquatic organisms.

Keywords: Aquaculture; Probiotic; Prebiotic; Aquaculture

1. Introduction

Aquaculture is one of the favorable and fastest growing food-producing sectors worlds with the biggest potential to accomplish the growing demand for aquatic food (Hodar et al., 2020). Over the past few years, global aquaculture has expanded significantly and developed into an important economic sector. Diseases and the deterioration of the environment are significant issues in fish farming that cause enormous economic losses due to the rising commercialization and intensification of aquaculture operations (Stentiford et al., 2012). Antibiotics have been utilized traditionally during the past few decades for disease prevention and control, as well as for fish development and competence of feed conversion.

Though, the appearance of microorganisms that are resistant to antibiotics was acknowledged and poses a serious risk to people (Harris et al., 2012). According to, using antibiotics is damaging to aquatic species because it kills favorable microbiota in the Digestive system of fish, and it also amasses in their products which are unsafe for human consumption. Given these elements, advancements in non-antibiotic drugs are preferable for aquaculture health control (Denev, 2008). Probiotics and prebiotics are dietary supplements that both prevent generalized disease and act as growth-promoting agents. There is a need to conduct additional research on probiotics and prebiotics in aquaculture production since studies examining the use of these nutrients in fish have gotten very slight attention and the data currently available are still inadequate. Studies assessing the efficiency of probiotics and prebiotics in aquaculture have received very little attention, and available data are still insufficient there is a need to undertake more studies relating

* Corresponding author: Alemu Kebede

to probiotics and prebiotics in aquaculture production systems. The objective of this review is to assemble the current figures proceeding with the use of probiotics and prebiotics in culture fish.

2. Probiotics

The word probiotic means "for life" (Parker, 1974). Probiotics are "Organisms and substances, which contribute to intestinal and microbial equilibrium" (Zorriehzahra, Mohammad I alil, et al., 2016). Probiotics are described by Fuller (1989) as "live microbial feed supplements that advantageously affect the host animal by enhancing its gut microbial balance". Probiotics have been used in aquaculture to increase productivity (El-Saadony et al.,2021), and nutrition (Alemayehu and Tewodros et al., 2018) to reduce diseases (Irianto and Austin, 2002 and strengthen the immune system (Alishahi et al., 2014).

2.1 Probiotic Micro-organisms

Probiotics are frequently employed as "functional food" for human health in addition to curative, preventative, and development supplements of aquaculture (Pandiyan et al., 2013). The Gram-positive and Gram-negative bacteria, as well as numerous other species including yeast, bacteriophages, and unicellular algae, are all examples of probiotics (Mukherje, et al 2016). Furthermore, Lactic Acid Bacteria, are Lactobacilli, and Bifidobacteria, which are often found in the intestine of healthy fish, have been widely employed as probiotic strains, according to Pandiyan et al. (2013) microorganisms reduced into gram-positive and gram-negative categories. The primary gut microbiota is composed of gram-positive bacteria such as Enterococcus, and Streptococcus, which serve as shared probiotic straining (Prasad et al.,(2003). And Aquaculture and other animals' digestive tracts are predominately colonized by Gram-negative facultative anaerobes.

2.2 Probiotics and Nutrition

Probiotic microorganisms aid aquatic animals' GIT in both the energy-producing process and the digestion of dietary components (Ring et al., 2018). According to Michael *et al*. (2014), several microorganisms have a beneficial effect on the digestive processes of aquatic organisms. Yang et al. (2019) the enhanced probiotics applications encourage in an Aquaculture area in the digestive microbiota of the fish host, increasing nutrient absorption of the feed and also enhancing the nutritional cost, and strengthening resistant responses to pathogens. Probiotics have a valuable result on the digestive system1` of aquatic animals because probiotic strains synthesize extracellular enzymes such as proteases, and lipases as well as provide growth factors of vitamins and fatty acids (Balcazar, J. L. et al.,2006). Nutrients are absorbed more professionally when the feed is added with probiotics (E. Haroun, et al.,2006). In fish, the reports show that *Bacteroides* and *Clostridium* sp. have contributed to the host's nutrition, especially by supplying fatty acids and vitamins (Peng et al., 2020). Agrobacterium sp., Pseudomonas sp., Brevi-bacterium sp., Microbacterium sp., and Staphylococcus sp. can donate to nutritional processes in Salvelinus alpinus L (Ringø, et al., 2018).

2.3 Probiotics and water quality

The compounds of Nitrogenous pollution such as ammonia, nitrite, and nitrate in aquaculture systems/ponds have a serious concern. The vulnerability of cultured aquatic species to excessively high concentrations of these compounds is generally species-specific, but in excessive concentrations, these compounds may be extremely destructive and cause mass mortality in all cases (Ma et al., 2009). Due to this Probiotics reduce the accumulation of the organic load (ammonia, nitrite, and nitrate) and uphold water quality in a well-organized technique. Probiotics recover water quality by changing organic matter into smaller units. The Breakdown of organic matters evolves humbler substances like glucose and amino acids that are used as food for beneficial bacteria which reduce the accumulation of organic pressure and provide a friendly environment to cultivated stock.

Bacillus sp. had been developed as an agent to decompose organic material and control bacterial pathogens. *Bacillus* spp., *Saccharomyces* spp., and lactic acid bacteria are probiotic strains that originate in the very few positive benefits of probiotics to water or bottom soil quality. Commercial probiotics are available in liquid and powder form, with the latter being more commonly used in water (Mamun et al., 2019). Organic waste can be converted to $CO2$ by probiotic bacteria like Bacillus sp., reducing the amount of organic effluent in the aquatic system. The amount of nitrate, nitrite, and ammonia is greatly decreased by the use of nitrifying. These principles of purifying the water in the hatchery enhance larval existence and growth (Moriarty, 1998 Sayesn et al., 2017). Additionally, Bacillus sp., another famous probiotic bacteria, is employed to reduce metabolic waste in the aquatic system.

The affluence of different nitrogenous substances including ammonia, nitrite, and nitrate has a significant issue in the aquaculture system, claim Michael et al. (2014). Certain substances are fatally hazardous when present in large quantities. According to Ma et al. (2009), Lactobacillus sp. alongside removes pathogens and nitrogen from contaminated Fish farms. In general, gram-positive microbial are more effective converting organic matter back to CO2 than gram-negative microbial, which would instead turn organic carbon into bacterial biomass or slime, according to Stanier et al. (1963. Bacillus sp. and other aerobic gram-positive bacteria are linked to the improvement of water quality, the decrease in pathogenic populations in the cultural environment, the enhancement of the survival and growth rate, and the better health condition of juvenile *Penaeus monodon* (Ngan and Phu, 2011).

2.4 Growth Promoters

Probiotics are used in culture fish to improve the growth of cultivable fish and the ability of organisms to out-grow the pathogens in favor of the host or to improve the growth of the host and yet no side effect on the host completes it a probiotic bacteria. Yassir et al. (2002) used probiotics Micrococcus luteus microorganisms for development and reported the highest development performance on Oreochromis niloticus. Lactic acid microbes are also mentioned as growth promoters due to their essence in the growth rate of juvenile fish (Alishahi et al., 2018). Probiotics may also improve appetite and lead to enhanced growth and better feed conversion and improved digestibility. It determines whether probiotics taste good for aquaculture species (A. Irianto and B. Austin, 2002).

The use of probiotics as growing promoters of palatable fishes and the diet of (Oreochromis niloticus) was edited with probiotics Streptococcus strain, significantly increasing the content of crude protein and crude lipid in the fish weight is increased from 0.154 g to 6.164 g in 9 weeks of culture (F. Lara et al., 2003). Due to the commercial importance of fish species, the effect of complementing the diet with probiotics shaped an increase of 115.3% when the commercial formulation was made at a concentration of 2% (E. Haroun, et al., 2006). Probiotics also have been tested successfully in shellfish culture. Macey and Coyne,(2005) isolated two yeasts and one bacterial strain from the digestive tract of abalone (Haliotis midae). A diet was formulated with a mixture of the three putative probiotics. The growth rate of small (20 mm) and large (67 mm) abalone was improved by 8% and 34%, cultures.

2.5 Probiotics and Disease Control

A current probiotic organism can simply achieve the desires of maintainable aquaculture development due to the main key factors of growth performance and disease resistance (Dawood MAO, Koshio S, 2016). Their products are beneficial effects on the host's gut defenses and disease prevention in the fish culture system. Probiotic bacteria discharge some biochemical substances in the intestinal tract of the host fish that inhibit the propagation of opportunistic pathogens (Martínez Cruz and Ibáñez, 2012). The management of probiotics to minimize the practice of antibiotics and synthetic chemicals in fish food (Dawood Mahmoud et al., 2019). Probiotics are currently increasing in popularity as valuable microbes candidates in cultured organisms to retain the health condition and happiness of different aquatic animals. The management of the gastrointestinal microbiota develops crucial since also guarantees the fight and prevention of diseases, and the digestibility, and absorption of nutrients, resulting in advanced product performance and the prevention of disease of the host (Ferreira, 2014). Probiotic organisms increase the resistance method of culture organisms, improving their disease and preventing the pathogenic organisms from disease formation in the host (Dawood and Koshio, 2016). Most survey probiotic applications in aquaculture consider the ability to inhibit or exclude pathogenic bacteria.

The mainstream studies addressing disease resistance use the in vitro assay to classify antagonistic effects as one of the greatest important selection criteria for applicants for the probiotic. According to Kuebutornye et al. (2019), the exercise of *Bacillus sp.* showed disease protection by introducing cellular and humoral immune resistances in tiger shrimp (*P. monodon*) more or less bacterial and fungal strains were mixed with feeding pellets and enhanced essential microbial flora of the gut (Prasad et al., 2003 and Nageswara and, Babu, 2006). Probiotics like lactic acid bacteria applied in the food of fry of Atlantic cold indicated suitable growth, survival, and immune response (Gildberg A., 1997). According to Prasad et al, (2003) report shows Lactic Acid Bacteria, a popular probiotic strain, can be purposeful to control bacterial infection. Several straining of *Aeromonas, Vibrio,Streptococcus, Yersinia, Pseudomonas, Clostridium, Acinetobacter, Edwardsiella, Flavobacterium,* white spot syndrome virus, and infectious hypodermal and hematopoietic necrosis virus has proven to be mitigated by Bacillus Kuebutornye, Felix KA, et al.,2020).

These probiotic organisms could be used in combination such as the incorporation of the individual supplementation of *Lactobacillus rhamnosus* and *Lactobacillus sporogenes* to enhance the health and disease resistance of common carp (Allameh, et al 2014, Chi, et al. 2014, Faramazi, et al., 2011 and. Harikrishnan . et al., and 2010). It also enhanced the resistance toward the pathogen expressed as a higher survival rate in different aquaculture species including tilapia (the Chu, et al., 2020) carp species (Feng, et al., 2019) rainbow trout (Ghosh, et al., 2016) cod (Puvanendran, et al ., 2021)and several other species.

2.6 Probiotics and Immune Response

Probiotics use in Aquaculture is growing with the demand for the environment–responsive sustainable aquaculture. The benefits of such supplements are probiotics improve feed value, enzymatic contribution to digestion, inhibition of pathogenic bacteria, anti-mutagenic activity increased immune response (Van Hai; Ngo,2015). According to Michael *et al.* (2014) Among the numerous valuable effects of probiotics, modulation of the immune system is one of the most commonly purported benefits of probiotics. The reports show that fish larvae, shrimps, and other aquatic animals have immune systems that are dependent mostly on non-specific immune responses for their confrontation with infection. Akhter et al. (2015) demonstrated that oral administration of *Clostridium butyricum* bacteria to rainbow trout improved their resistance to vibriosis by emerging phagocytosis of leucocytes. On indirect, immunostimulation, includes lysozyme, serum peroxidase, alternate peroxidase, phagocytosis, and breathing burst activities. Interestingly, probiotics also motivate the immune response, with an intensification in exact antibody production. These antibodies show a critical role in decreasing the range of spread of pathogenic bacteria to the liver and the spleen after infection with the pathogen. Probiotics are inoffensive bacteria that assist the well-being of the host animal and contribute, directly or indirectly to protecting the host animal against destructive bacterial pathogens (Van Hai; Ngo, 2015).

3. Prebiotics

Prebiotics are indigestible feed components that motivate the activity of favorable gut commensal organisms in the host thus improving the health of fish (Guerreiro et al., 2016).The feed component which acts as a prebiotic essential possesses the following criteria such as showing resistance to intestinal acidity, hydrolysis by digestive enzyme, fermentation by gastrointestinal microflora, and growth in the abundance of intestinal bacteria associated with health (Das, et al., 2017).

3.1 Prebiotic Organisms

Sugars are the greatest effective prebiotics which could be categorized based on the step of polymerization (Akhter et al., 2015). According to Mahious and Ollivier (2005), several food substances such as non-palatable Sugars, smaller proteins, peptides, and certain fatty acids act as prebiotic constituents. Prebiotic combinations like fructose, mannan oligosaccharides, and B-glucan are considered the greatest operative prebiotics in culture fish (Guerreiro, 2016). Prebiotics mostly **digest dietary fiber or** fermentation by *Bifidobacteria*, *Lactobacillus,* and *Bacteroides* (Yousefianl and Amiri, 2009).

3.2 Prebiotics and Growth of fish

Prebiotics is made as feed supplements that succeed in enhancing growth performance. Growth factors differ based on aquatic bacteria as well as prebiotic supplements. A food containing 20 g kg^{-1} oligofructose engineered by incomplete enzymatic hydrolysis of inulin, better for the growth of fish species larvae, but 20 g kg^{-1} inulin itself did not distress growth (Mahious et al., 2006).

3.3 Prebiotics and fish Health

A prebiotic is a non-consumable feed ingredient that helpfully upsets the host by select inspiring the growth and action of a limited number of microorganisms in the colony. Even though the potential benefits to health and performance as well-known in various terrestrial animals, the use of prebiotics in the farming of fish and shellfish has been less investigated (Ringø, E., et al. 2010). According to Yousefian and Amiri (2009), antibiotics regulate bacterial diseases but a kind of chemical substance is sensible to avoid in culture fish. In the aquaculture industry, other policies developed for disease control as well as the decrease in the widespread use of antibiotics. Prebiotics are a famous group of these policies which strengthen, non-specific immune responses. The increased interest in food fish consumption, together with the prohibition of antibiotics for fish growth raise and greater public awareness of healthy fish production, led to an augmented interest in the potential benefit of feeds as health developers. Prebiotics are focused fixings that are made in fish, existence reported to be related to improvements in growth, feed competence, gut microbiota, intestinal enzyme actions, gut morphology, immune position, disease resistance, intermediate metabolism, and stress responses(inês Guerreiro, 2017).

3.4 Prebiotics and Microbes

Prebiotics could change microorganisms of the intestinal tract by developing immune responses (Frei, *et al*. 2015). The digestive tract of all invertebrates and vertebrates aquatic animals plays a vital role in if habitat for different kinds of microbes (Das et al., 2017). Several prebiotic oligosaccharides are ferment in the colon where they react to the growth of bacterial populations connected to a well-functioning colon and oligosaccharides are willingly fermented by favorable bacteria and they are not made effectively by pathogenic bacterial species (Yousefianl and Amiri, 2009).

4. Constraints in the application of probiotics and prebiotics:

The practice of probiotics and prebiotics receive excessive consideration as a beneficial line in the aquaculture scheme but sometimes due to inadequate information on their modes of action, the application was hampered (Sutriana, 2017). According to Verschuere *et al.*(2000), the practice of probiotics as organic control agents could be preserved as a kind of risk coverage which should not provide any remarkable benefit when the aquaculture is performed below optimal conditions and in the nonappearance of pathogens. Once cultivating the aquatic species, bacterial inhabitants in the gastrointestinal fillings are abundant higher than in the surrounding water (Denev et al., 2009). Injecting probiotics inside aquatic animals has been used to motivate a fish's immune response against bacterial pathogenic disease (Sahoo and Mukherjee 1999). When to inoculate probiotics into aquatic animals, especially into fish species, and to treat a large number of fish (Tuan et al., 2013). According to Hoseinifar et al., 2016,) Developments of the strategy have been suggested and practiced as an alternative to antibiotic administration in aquaculture of *Lactobacillus lactis* on *the* hematological parameter of *Acipenser persicus* demonstrated that the number of blood lymphocytes reduces and granulocytes improved. The consequence of prebiotics on fish *modification of the immune response* is partial. In the case of the beluga whale, prebiotics similar to dietary oligofructose didn't show any significant effect on serum glucose, total protein, RBC counts, mean cell hemoglobin concentration, and corpuscular volume, or different enzyme activities like alkaline phosphatase, alanine aminotransferase and serum lactate dehydrogenase (Adel et al., 2016). The effective fructooligosaccharide on haemato-immunological parameters of stellate sturgeon juvenile (Hoseinifar and Seyed Hossein, 2014), after eleven weeks of management, revealed that haemato-immunological levels (RBC, WBC, hemoglobin, hematocrit and lymphocyte levels) were meaningfully advanced, whereas respiratory rupture activity of leucocytes was not significantly developed by the food supplement. Very limited studies have been showing constraints in the practice of probiotics and prebiotics in culture fish systems.

5. Conclusion

The application of probiotics and prebiotics has developed a crucial part of aquaculture practices for improving growth performance levels and disease tolerance. Probiotics are imperative in water quality improvement, feed value, increasing growth rates, weight improvement, immune response, and disease prevention of fish. The prebiotic system similarly has numerous helpful effects essentially in disease tolerance and nutrient obtainability to fish. The use of probiotics and prebiotics improves the existence and establishment of the live bacterial dietary supplement in the gut tract of the host. The biotic practices are critical for developing the health ranks and the production of fish, in place of more traditional immunological and disease control methods such as vaccinations, antimicrobials, and immunostimulants. The important difference in growth, and feed utilization, in addition to health benefits with the dietary use of these biotics, is maybe dependent on the fish species, the extent of feeding, and supplement dosage.

Compliance with ethical standards

Acknowledgments

First of all, we would like thanks God to make healthful with his grace. Additionally our great respect was goes to my institute Animal Health Institute to being with has during manuscript preparation to allow library, materials we request.

Disclosure of conflict of interest

No conflict of interest.

References

[1] A. Irianto and B. Austin, "Probiotics in aquaculture," Journal of Fish Diseases, vol. 25, no. 11, pp. 633–642, 2002. "Probiotics in aquaculture," Journal of Fish Diseases, vol. 25, no. 11, pp. 633–642, 2002.

[2] Adel, Milad, et al. "Effects of dietary Spirulina platensis on growth performance, humoral and mucosal immune responses and disease resistance in juvenile great sturgeon (Huso huso Linnaeus, 1754)." *Fish & Shellfish Immunology* 56 (2016): 436-444.

[3] Akhter, Najeeb, et al. (2015): "Probiotics and prebiotics associated with aquaculture: a review." *Fish & shellfish immunology* 45.2 733-741.

[4] Akrami R, Iri Y, Rostamy HK, Razeghi Mansour M. Effect of dietary supplementation of fructooligosaccharide (FOS) on growth performance, survival, lactobacillous bacteria population and hematoimmunological parameters of stellate sturgeoan (Acipenser stellatus) juvenile. Fish Shellfish Immunol. 2013; 35:1235-9.

[5] Alemayehu, Tewodros Abate, Akwake Geremew, and Abebe Getahun. "The role of functional feed additives in tilapia nutrition." *Fisheries and Aquaculture Journal* 9.2 (2018): 1g-1g.

[6] Alishahi, Mojtaba, et al. "Effect of dietary chitosan on immune response and disease resistance in Cyprinus carpio." *Iranian Journal of Veterinary Medicine* 8.2 (2014): 125-133.

[7] Alishahi, Mojtaba, et al. "Effects of two probiotics, Lactobacillus plantarum and Lactobacillus bulgaricus on growth performance and intestinal lactic acid bacteria of Cyprinus Carpio." *Iranian Journal of Veterinary Medicine* 12.3 (2018): 207-218. 218.

[8] Allameh SK, Yusoff FM, Ringo E, Daud HM, Saad CR, Ideris A. Effects of dietary mono and multi probiotic strains on growth performance, gut bacteria and body composition of Javanese carp (Puntius gonionotus, Bleeker 1850). Aquac Nutr. 2014. v.12265vv.

[9] B. M. Macey and V. E. Coyne, "Improved growth rate and disease resistance in farmed Haliotis midae through probiotic treatment," Aquaculture, vol. 245, no. 1–4, pp. 249–261, 2005.

[10] Chi C, Jiang B, Yu XB, Liu TQ, Xia L, Wang GX et al. Effects of three strains of intestinal autochthonous bacteria and their extracellular products on the immune response and disease resistance of common carp, Cyprinus carpio. Fish Shellfish Immunol. 2014; 36:9-18.

[11] Chu, T.-W.; Chen, C.-N.; Pan, C.-Y. Antimicrobial status of tilapia (Oreochromis niloticus) fed Enterococcus avium originally isolated from goldfish intestine. Aquac. Rep. 2020, 17, 100397.

[12] Das, Susmita, Kausik Mondal, and Salma Haque. "A review on application of probiotic, prebiotic and synbiotic for sustainable development of aquaculture." *growth* 14 (2017): 15..

[13] Dawood MAO, Koshio S. Recent advances in the role of probiotics and prebiotics in carp aquaculture: a review. Aquacult. 2016; 454:243-251.

[14] Dawood, Mahmoud AO, et al. "Probiotic application for sustainable aquaculture." *Reviews in Aquaculture* 11.3 (2019): 907-924.

[15] Denev S, Staykov Y, Moutafchieva R, Beev G. Microbial ecology of the gastrointestinal tract of fish and the potential application of probiotics and prebiotics in finfish aquaculture. Int Aquat Res. 2009; 1:1-29.

[16] Denev SA. Ecological alternatives of antibiotic growth promoters in animal husbandry and aquaculture. DSc. Thesis. Starajagora, Bulgaria. Department of Biochemistry Microbiology, Trakia University, 2008; 294.

[17] E. Haroun, A. Goda, and M. Kabir, "Effect of dietary probiotic Biogen supplementation as a growth promoter on growth performance and feed utilization of Nile tilapia Oreochromis niloticus (L.)," Aquaculture Research, vol. 37, no. 14, pp. 1473–1480, 2006.

[18] E. Haroun, A. Goda, and M. Kabir, "Effect of dietary probiotic Biogen supplementation as a growth promoter on growth performance and feed utilization of Nile tilapia Oreochromis niloticus (L.)," Aquaculture Research, vol. 37, no. 14, pp. 1473–1480, 2006.

[19] El-Saadony, Mohamed T., et al. "The functionality of probiotics in aquaculture: an overview." *Fish & Shellfish Immunology* 117 (2021): 36-52.

[20] F. Lara, N. Olvera, M. Guzman, and M. L ´ opez, "Use of the ´ bacteria Streptococcus faecium and Lactobacillus acidophilus, and the yeast Saccharomyces cerevisiae as growth promoters in Nile tilapia (Oreochromis niloticus)," Aquaculture, vol. 216, no. 1–4, pp. 193–201, 2003.

[21] Faramazi M, Kiaalvandi S, Lashkarbolooki M, Iranshahi F. The investigation of Lactobacillus acidophilus as probiotics on growth performance and disease resistance of rainbow trout (Oncorhychus mykiss). Am-Eurasian J Sci Res 2011; 6(1): 32-38.

[22] Feng, J.; Chang, X.; Zhang, Y.; Yan, X.; Zhang, J.; Nie, G. Effects of Lactococcus lactis from

[23] Cyprinus carpio L. as probiotics on growth performance, innate immune response and disease resistance against Aeromonas hydrophila. Fish Shellfish. Immunol. 2019, 93, 73–81.

[24] FERREIRA, G. S.. Disbiose intestinal: aplicabilidade dos prebióticos e dos probióticos na recuperação e manutenção da microbiota intestinal. Monografia (Bacharelado) - Centro Universitário Luterano, Palmas, 2014.

[25] Frei, Remo, Mübeccel Akdis, and Liam O'Mahony. "Prebiotics, probiotics, synbiotics, and the immune system: experimental data and clinical evidence." *Current opinion in gastroenterology* 31.2 (2015): 153-158.

[26] Fuller R. Probiotic in man and animals. J Appl Bacteriol. 1989; 66:365-378.

[27] Ghosh, B.; Cain, K.D.; Nowak, B.F.; Bridle, A.R. Microencapsulation of a putative probiotic Enterobacter species, C6-6, to protect rainbow trout, Oncorhynchus mykiss (Walbaum), against bacterial coldwater disease. J. Fish Dis. 2016, 39, 1–11.

[28] Gildberg A, Mikkelsen H, Sandaker E, Ringo E. Probiotic effect of lactic acid bacteria in the feed on growth and survival of fry of Atlantic cod (Gadus morhua). Hydrobiologia. 1997; 352:279-285

[29] Guerreiro I, Couto A, Machado M, Castro C, PousaoFerreira P, Oliva-Teles A et al. Probiotics effect on immune and hepatic oxidative status and gut morphology of white sea bream (Diplodus sargus). Fish Shellfish Immunol. 2016; 50:168-174.

[30] Harikrishnan R, Balasundaram C, Heo MS. Potential use of probiotic- and triherbal extract-enriched diets to control Aeromonas hydrophila infection in carp. Dis Aquat Org. 2010; 92:41-49.

[31] Harris, Suvi J., Martin Cormican, and Enda Cummins. "Antimicrobial residues and antimicrobial-resistant bacteria: impact on the microbial environment and risk to human health—a review." *Human and Ecological Risk Assessment: An International Journal* 18.4 (2012): 767-809.

[32] Hodar, A. R., et al. "Fish meal and fish oil replacement for aqua feed formulation by using alternative sources: A review." *J. Exp. Zool. India* 23.1 (2020): 13-21.

[33] Hoseinifar, Seyed Hossein, et al. "Probiotic, prebiotic and synbiotic supplements in sturgeon aquaculture: a review." *Reviews in Aquaculture* 8.1 (2016): 89-102.

[34] Hoseinifar, Seyed Hossein, Narges Soleimani, and Einar Ringø. "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 (2014): 1296-1302.

[35] inês Guerreiro, Cláudia R. Serra, Aires Oliva-Teles, Paula Enes, Short communication: gut microbiota of European sea bass (Dicentrarchus labrax) is modulated by short-chain fructooligosaccharides and xylooligosaccharides, Aquaculture International, 10.1007/s10499-017-0220-4, 26, 1, (279-288), (2017)

[36] Irianto A, Austin B. Use of probiotics to control furunculosis in rainbow trout, Oncorhynchus mykiss (Walbaum). J Fish Dis. 2002; 25:1-10.

[37] J. L. Balcazar, I. D. Blas, I. Ruiz-Z, D. Cunningham, D. ´ Vendrell, and J. L. Muzquiz, "The role of probiotics in ´ aquaculture," Veterinary Microbiology, vol. 114, no. 3-4, pp. 173–186, 2006.

[38] Kuebutornye, Felix KA, Emmanuel Delwin Abarike, and Yishan Lu. "A review on the application of Bacillus as probiotics in aquaculture." *Fish & shellfish immunology* 87 (2019): 820-828.

[39] Kuebutornye, Felix KA, et al. "Mechanisms and the role of probiotic Bacillus in mitigating fish pathogens in aquaculture." *Fish physiology and biochemistry* 46.3 (2020): 819-841.Ma GW, Cho YS, Oh KH. Removal of pathogenic bacteria and nitrogen by Lactobacillus spp. JK-8- JK-11. Aquacult. 2009; 287:266-270.

[40] Mahious AS, Gatesoupe FJ, Hervi M, Metailler R, Ollevier F. Effect of dietary inulin and oligosaccharides as prebiotics for weaning turbot, Psetta maxima (Linnaeus,C.1758). Aquac Int. 2006; 14(3):219-229

[41] Mahious AS, Ollevier F. Probiotics and Prebiotics in Aquaculture. 1st Regional Workshop on Techniques for Enrichment of Live Food for Use in Larviculture-2005, AAARC, Urmia, Iran. 2005; p. 67

[42] Mamun MAA, Nasren S, Rathore SS, Sidiq MJ, Dharmakar P, Anjusha KV. Assessment of Probiotic in Aquaculture: Functional Changes and Impact on Fish Gut. Microbiology Research Journal International 2019; 1-10.

[43] Martínez Cruz P, Ibáñez AL, Monroy Hermosillo OA, Ramírez Saad HC. Use of probiotics in aquaculture. ISRN Microbiol 2012, 916845.

[44] Michael ET, Amos SO, Hussaini LT ,2014 Ma GW, Cho YS, Oh KH.,2009 Stanier RY, Doudoroff M, Adelberg EA,1963

[45] Michael ET, Amos SO, Hussaini LT. A review on probiotics application in aquaculture. Fish Aquac J. 2014; 5:4.

[46] Moriarty DJW. Control of luminous vibrio species in penaeid aquaculture ponds. Aquacult. 1998; 164(1- 4):351-358.

[47] Mukherjee A, Dutta D, Banerjee S, Ringo E, Breines EM, Hareide E et al. Potential probiotics from Indian major carp, Cirrhinus mrigala. Characterization, pathogen inhibitory activity, partial characterization of bacteriocin and production of coenzymes. Res Vet Sci. 2016; 108:76-84.

[48] Nageswara PV, Babu DE. Probiotics as an alternative therapy to minimize or avoid antibiotics use in aquaculture. Fishing Chimes. 2006; 26(1):112-114.

[49] Ngan PTT, Phu TQ. Effects of Bacillus bacteria (B8, B37, B38) on water quality of black tiger shrimp (Penaeus monodon) cultured tanks. Proceedings of the 4th aquaculture and fisheries conference, 2011; 28-41.

[50] Pandiyan P, Balaraman D, Thirunavukkarasu R, George EGJ, Subaramaniyam K, Manikkam S et al. Probiotics in aquaculture. Drug Invent Today. 2013; 5:55-59.

[51] Parker RB. Probiotics:the other half of the antibiotics story. Anim Nutr Health. 1974; 29:4-8.

[52] Peng, Mengfei, et al. "Effectiveness of probiotics, prebiotics, and prebiotic-like components in common functional foods." *Comprehensive reviews in food science and food safety* 19.4 (2020): 1908-1933.

[53] Prasad L, Baghel DS, Kumar V. Role and prospects of probiotics use in aquaculture. Aquacult. 2003; 4(2):247-251.

[54] Puvanendran, V.; Rud, I.; Msw, B.; Arnesen, J.; Axelsson, L. Probiotic Carnobacterium divergens increase growth parameters and disease resistance in farmed Atlantic cod (Gadus morhua) larvae without influencing the microbiota. Aquaculture 2021, 532, 736072

[55] Ray, A. K., K. Ghosh, and E. J. A. N. Ringø. "Enzyme-producing bacteria isolated from fish gut: a review." *Aquaculture Nutrition* 18.5 (2012): 465-492.

[56] Ringø, E., et al. "Prebiotics in aquaculture: a review." *Aquaculture Nutrition* 16.2 (2010): 117-136.

[57] Ringø, E., Hoseinifar, S. H., Ghosh, K., Van Doan, H., Beck, B. R., & Song, S. K. (2018). Lactic acid bacteria in the finfish-an update. *Frontiers in Microbiology*, *9*, 1818.

[58] Rodiles, A. *et al.* (2018). Probiotic Applications for Finfish Aquaculture. In: Di Gioia, D., Biavati, B. (eds) Probiotics and Prebiotics in Animal Health and Food Safety. Springer, Cham. https://doi.org/10.1007/978-3-319-71950-4_8

[59] Sahoo PK, Mukherjee SC. Influence of the immunostimulant, chitosan on immune responses of healthy and cortisol treated rohu (Labeo rohita). J Aqua Trop. 1999; 14:209-215.

[60] Sayes, Camila, Leyton, Yanett, Riquelme, Carlos. "Probiotic Bacteria as an Healthy Alternative for Fish Aquaculture" In Antibiotic Use in Animals, edited by Sara Savic. London: IntechOpen, 2017. 10.5772/intechopen.71206

[61] Stanier RY, Doudoroff M, Adelberg EA. The microbial world. Prentice- Hall Inc., Englewood Cliffs. N.J. 1963; 153-156.

[62] Stentiford, G. D., et al. "Disease will limit future food supply from the global crustacean fishery and aquaculture sectors." *Journal of invertebrate pathology* 110.2 (2012): 141-157.

[63] Sutriana, A. M. A. L. I. A. *The use of selected prebiotics and probiotic in feed development for striped catfish (Pangasianodon hypophthalmus, Sauvage, 1878) juveniles: effects on growth parameters and health status*. Diss. Ph. D. dissertation, Universiti Sains Malaysia, Malaysia, 2017.

[64] Tuan TN, Duc PM, Hatai K. Overview of the use of probiotics in aquaculture. Int J Res Fish Aquacult. 2013; 3(3):89-97.

[65] Van Hai, Ngo. "Research findings from the use of probiotics in tilapia aquaculture: a review." *Fish & shellfish immunology* 45.2 (2015): 592-597.

[66] YANG, G.; JIAN, S. Q.; CAO, H.; WEN, C.; Hu, B.; PENG, M.; PENG, L.; YUAN, J.. Lifeng Liange Changes in microbiota along the intestine of grass carp (Ctenopharyngodon Idella): Community, interspecific interactions, and functions. Aquaculture, v.498, p.146-156, 2019.

[67] Yassir AL, Adel ME, Azze A. Use of probiotic bacteria as growth promoters, antibacterial and the effect on physiological parameters of Oreochromis niloticus. J Fish Dis. 2002; 25: 633-642.

[68] Yousefianl M, Amiri MS. A review of the use of prebiotic in aquaculture for fish and shrimp. Afr J Biotechnol. 2009; 8(25):7313-7318.

[69] Zorriehzahra, Mohammad Jalil, et al. "Probiotics as beneficial microbes in aquaculture: an update on their multiple modes of action: a review." *Veterinary quarterly* 36.4 (2016): 228-241.