Probiotics in Aquaculture

Subjects: Biotechnology & Applied Microbiology

Contributor: Hary L. Razafindralambo, Vijayaram Srirengaraj, Holy N. Rabetafika, Huu-Thanh Nguyen, Yun-Zhang Sun

The Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO) define probiotics as “Live microorganisms that, when administered in adequate amounts, confer a health benefit on the host”. Possible action modes of probiotics in aquaculture include the regulation of amino and fatty acid metabolisms, the excretion of digestive enzymes and vitamins or cofactors, the production of antagonistic compounds that inhibit bacteria, the enhancement of immune responses, the disruption of the quorum-sensing processes of pathogenic organisms, stress improvement, and heavy-metal detoxification.

Keywords: probiotics ; prebiotics ; synbiotics ; gut microbiota ; fishes

1. Definition and Characteristic Features

The Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO) define probiotics as “Live microorganisms that, when administered in adequate amounts, confer a health benefit on the host” [1]. Recently, the term probiotics has been associated with microbial feed additives that, when controlled in enough amounts, confer health and beneficial impacts on a host of aquatic animals [2].

Probiotics act as a defense system for the host against harmful microbes or foreign substances [3][4][5][6]. They also produce beneficial bioactive molecules such as enzymes, proteins, lipids, organic acids, and others. Some of these bioactive molecules improve binding to probiotics and reduce, therefore, the activity of pathogens in the gut region through the surface competition mechanism [7]. Probiotics play a significant role in strengthening the immune system of the host [8]. While earlier studies have noted the utilization of probiotics in pigs, poultry, cattle, and humans, their application in aquaculture is a relatively new idea [9][10]. Probiotics can be administered in two ways in aquaculture. They can be supplemented with feed to modulate gut microbes, or they can be directly added to the water, thereby inhibiting the growth of pathogens. These modes of administration are very critical in the utilization of probiotics in aquaculture [11][12]. Probiotics can have alive, dead, or microbial cell components and provide benefits to the host when added to feed or rearing water. This is achieved at least in part by improving the microbial balance of the host or ambient environment [12]. **Figure 1** summarizes the different entryways of probiotics and their benefits in the aquaculture system.

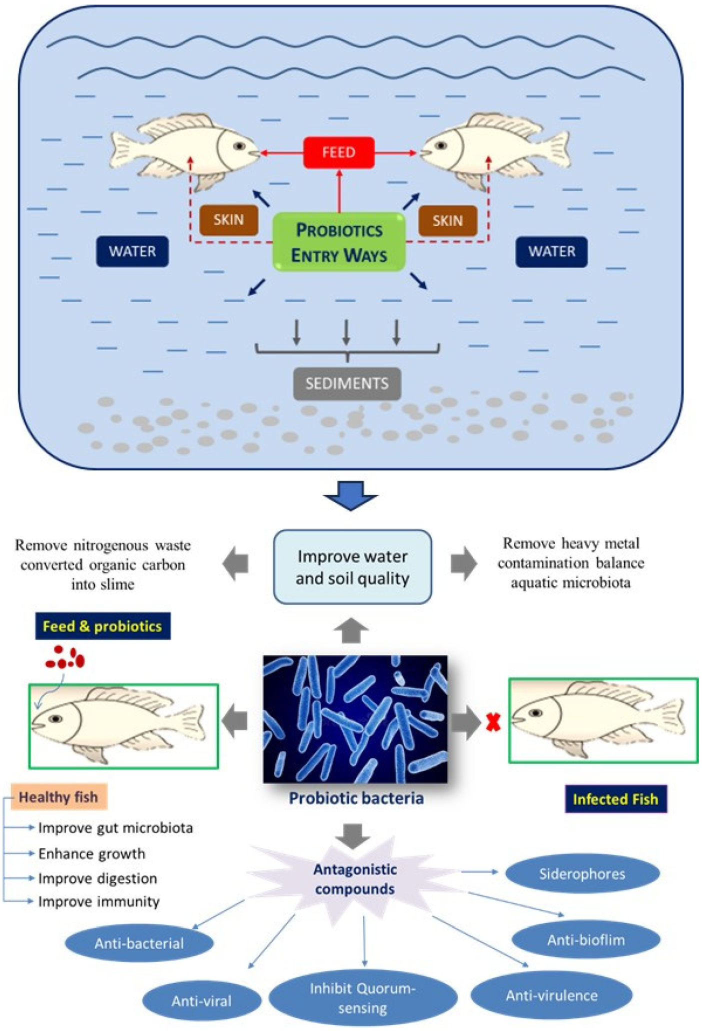

Figure 1. Illustration of the use and impact of probiotics in aquaculture systems.

Probiotics appear to be a new agent for the development of aquaculture systems, exerting several favorable effects on growth activity, immune systems, digestion, water quality, the inhibition of pathogens, and the regulation of the gut microbes of aquatic animals. The utilization of probiotics in aquaculture is a modern trend, although its effectiveness in the aquatic ecosystem has not been considered comprehensively. Probiotics are ubiquitous, commonly present in aquatic animals, and play an important protective role throughout the digestive system [13][14]. Mainly represented by Lactobacilli, these beneficial microorganisms are vital to preventing illnesses and improving aquatic animal GIT functions by excreting secondary metabolites such as lactic acid and other bioactive compounds [15][16]. These biomolecules, synthesized by probiotics, protect against inhibitory molecules from pathogens [17]. They can also be extracted from probiotics in terrestrial plants and marine life forms and then utilized to enhance disease resistance, develop the immune system, reduce environmental stress, and increase feed quality levels [18][19]. Advanced studies in this field have reported microbial by-product biomolecules such as enzymes, lipids, proteins, and immune toxins [20]. Nowadays, some probiotic products are commercially available and are already used in aquaculture as feed additives [21]. These microbial by-products are beneficial and are mainly helpful in enhancing the health status of aquatic animals.

Potential probiotic strains are assessed based on physiological, functional, and safety criteria such as stress resistance (e.g., acid and bile tolerance), gut epithelial adherence, survival rates, pathogen-inhibiting activities, large-scale cultivability, non-hemolytic activity, non-pathogenicity, the absence of plasmid-encoded antibiotic resistance genes, and beneficial effects on host animals. These include, for instance, their capacity as growth promoters and anti-inflammatory, antimutagenic, and immunostimulatory agents. Each new strain used for probiotic expansion mainly contains all the aforesaid features [22][23][24]. Current and potential probiotic species for use in aquaculture are listed in **Table 1**.

Table 1. A list of current probiotic strains for use in aquaculture.

Genus	Probiotics	Example of Target Fish Species	References
Bacillus	*Bacillus coagulans*	Common carp (*Cyprinus carpio*), turbot (*Scophthalmus Maximus*)	[25][26]
	Bacillus subtilis	Nile tilapia (*O. niloticus*)	[27]
	Bacillus licheniformis	Grass carp (*Ctenopharyngodon idella*)	[28]
	Bacillus cereus	Catfish (*Heteropneustes fossilis)*	[29]
Bifidobacterium	*Bifidobacterim bifidus*	Koi fish (*Cyprinus rubrofuscus*)	[30]
Carnobacterium	*Carnobacterium divergens*	Atlantic cod (*Gadus morhua*)	[31]
Enterococcus	*Enterococcus faecium*	Nile tilapia (*O. niloticus*)	[32]
Lactobacillus	*Lactobacillus casei*	Common carp (*Cyprinus carpio*)	[33]
	L. plantarum	Black sea bream (*Acanthopagrus schlegelii*)	[34]
	L. rhamnosus	Nile tilapia *(O. niloticus)*	[35]
Lactococcus	*L. lactis*	Mandarin fish *(Siniperca chuatsi)*	[36]
Pediococcus	*Pediococcus acidilactici*	Rainbow trout *(Oncorhynchus mykiss)*	[37]
Streptomyces	*Streptomyces sp.*	Zebrafish *(Danio rerio)*	[38]
Saccharomyces	*Saccharomyces cerevisiae*	Striped catfish (*Pangasianodon hypophthalmus*)	[39]
Weissella	*Weissella cibaria*	Common carp (*Cyprinus carpio*)	[40]

2. Possible Modes of Action of Probiotics in Aquaculture

The significant effects of probiotics, e.g., *Bacillus* spp. as feed supplements, include the improvement of growth performance, digestive enzyme activity, resistance to pathogens, and immune responses in aquatic animals [41][42]. Possible action modes of probiotics in aquaculture include the regulation of amino and fatty acid metabolisms, the excretion of digestive enzymes and vitamins or cofactors, the production of antagonistic compounds that inhibit bacteria, the enhancement of immune responses, the disruption of the quorum-sensing processes of pathogenic organisms, stress improvement, and heavy-metal detoxification.

2.1. Probiotics Act as Growth Enhancers in Aquaculture

Probiotics play a crucial role in digesting complex dietary macronutrients. Additionally, they contribute to the host's nutrient and vitamin supply and provide essential digestive enzymes, thereby enhancing feed utilization and digestion.

One of the mechanisms that regulates the metabolism of amino and fatty acids is the capacity of various probiotic strains to produce vitamin B12, as revealed by a study on carp guts [43][44]. In addition, this is helpful for enhancing fish growth and eradicating vitamin B12 deficiency in fish [45]. Also, essential macronutrients are usually supplied through feed. Various micronutrients such as amino acids, vitamins, and fatty acids are very important for physiological functions as nutrients in aquatic animals [46][47][48]. For instance, diverse fish species such as carp (*Cyprinus carpio*), rainbow trout (*Oncorhynchus mykiss*), channel catfish (*Ictalurus punctatus*), and tilapia (*Oreochromis niloticus*) have been found to synthesize vitamin B12 [49][50][51]. The growth and survival rates of juvenile black tiger shrimp (*Penaeus monodon*) were enhanced when they were fed for 100 days with a combination of *Lactobacillus* spp., previously isolated from the GITs of chickens [52]. In fact, probiotics improve the digestive function of aquatic animals by producing or inducing the secretion of different kinds of extracellular enzymes such as proteases, amylases, and lipases.

The function of probiotics results in abridged feed cost, which accounts for 60–70% of the contribution cost of fish production [53][54]. Both the maximum growth performance and best feed conversion ratio were detected when *O. niloticus* was fed with the probiotic *Micrococcus luteus* [55][56]. *Bacillus subtilis* improved feed digestibility; enhanced weight gain and feed conversion; and significantly increased the survival rate of bullfrogs (*Lithobates catesbeianus*) fed different doses (2.5, 5.0, and 10.0 g/kg) [57][58]. *Bacillus* species aid in the digestion of aquatic animals by supplying exoenzymes (proteases, lipases, and amylases) that enhance digestive enzymes [59]. The addition of probiotics (a mixture of

Streptococcus faecium, Lactobacillus acidophilus, and *Saccharomyces cerevisiae*) at a concentration of 0.1% to Nile tilapia fry diets was found to enhance animal growth and intestinal alkaline phosphatase activity [60].

2.2. Biocontrol of Bacterial Diseases in Aquaculture

In the past few decades, numerous studies have stated that probiotics synthesize different types of inhibitory substances responsible for antagonistic activity against pathogens. Two probiotic strains of LAB (*Lactococcus lactis* MM1 and *Enterococcus faecium* MM4) isolated from the intestine of the orange-spotted grouper (*E. coioides*) can secrete several inhibitory substances such as hydrogen peroxide and bacteriocin-like substances. These can be utilized to induce antimicrobial activity against different pathogens such as *Staphylococcus aureus*, *V. harveyi*, and *V. metschnikovi*, which affect groupers (*E. coioides*) [61][62]. The probiotic *B. pumilus* H2 has strong inhibitory activity against *Vibrio* spp. through its main mechanism of amicoumacin production, disrupting the cell membrane and cell lysis and thus showing anti-*Vibrio* activity [63][64]. The probiotic *Bacillus velezensis* cell-free supernatant contains different types of bioactive molecules that act against *A. salmonicida* infection [65]. The lipopeptide N3, synthesized by the probiotic *Bacillus amyloliquefaciens* M1, has strong antibacterial activity in the whole-cell membrane, which can exert significant effects from ion-conducting channels on the whole-cell membrane and membrane-active properties [66][67]. The probiotic species *Clostridium butyricum*, a culture supernatant, includes different types of inhibitory substances, mainly short-chain fatty acids (SCFAs); it can lower the pH of the intestine and thus decrease the growth of pathogens in fish intestinal epithelial cells [68]. The probiotic *E. faecium* was supplemented in the diets of Olive flounders and can enhance the antibacterial activity [69].

2.3. Biocontrol of Viral Diseases in Aquaculture

Microorganism strains with potential probiotic effects in aquaculture such as *Pseudomonas* spp., *Vibrios* spp., and *Aeromonas* spp. induce antiviral effects against hematopoietic necrosis virus (IHNV) infection [70][71]. Similarly, the potential probiotic strain *Pseudoalteromonas undina* VKM-124 has been used to improve Yellow Jack (*Carangoides bartholomaei*) larval survival and enhance antiviral effects against Neuro Necrosis Virus (SJNNV) infections [72][73].

2.4. Immunostimulant Agents in Aquaculture

Immunity development and modulation are among the various health benefits of probiotics in aquaculture. The majority of earlier studies have dealt with the health-boosting capabilities of probiotics in aquatic organisms. Currently, probiotics are significantly focused on the immunological development properties of the piscine immune system, including both innate and adaptive immunities [74]. Different types of probiotics improve various immunological properties, and notably, several fish use the efficiency of probiotics to vitalize teleost immunity in both in situ and ex situ conditions [75]. Although promising findings have been reported in previous studies, most immunostimulants do not progress to large-scale functions for fish. Since various immunostimulants in aquaculture produce similar effects, researchers have demonstrated the utilization of probiotics to enhance disease resistance and the immune system of carp fish species [76][77]. Several carp fish have shown an increase in the production of total serum protein, nitric oxide, lysozyme, albumin, and phagocytic activity via blood leucocytes; express IL-1b, superoxide anion, myeloperoxidase content, respiratory burst activity, and globulin levels; and complement C3, TNF-α, and lysozyme-C [76][78]. Current study reports indicate that probiotics (either single or mixed types) could enhance the immunological development of fish [79]. These reports have emphasized the immunomodulating properties of beneficial living cell organisms and the factors that facilitate the optimal induction of defense responses in the fish community. The probiotic strain *B. pumilus* SE5 has been isolated from the intestine of the fast-growing grouper, *E. coioides* [80][81], and subsequent studies have demonstrated that both viable and heat-inactivated *B. pumilus* SE5 could shape intestinal immunity and microbiota [82] and improve the growth performance and systemic immunity of *E. coioides* [83]. The dietary supplementation of the cell wall (CW), peptidoglycan (PG), and lipoteichoic acid (LTA) of the probiotic *B. pumilus* SE5 and its effect on intestinal immune-related gene expression and microbiota were evaluated in a 60-day feeding trial. The PG and LTA of the probiotic *B. pumilus* SE5 were more effective than the CW in shaping the intestinal immunity and microbiota of *E. coioides* [84], even though the mechanisms were largely unclear and needed further study.

2.5. Interference of Quorum Sensing in Aquaculture

Quorum sensing (QS) is a communication system among bacterial cells that is very useful in controlling different kinds of biological macromolecule expressions like virulence agents in cell-thickness-dependent comparative performance [85]. In this process, QS bacteria produce and generate tiny marker molecules called auto-inducers [86]. The disruption of the QS process in pathogenic organisms is a potential anti-infective strategy, and different types of methods have been used to investigate QS. These include the inhibition of signal molecule biosynthesis, the application of QS antagonists, the chemical inactivation of QS signals with oxidized halogen antimicrobials, signal molecule biodegradation with bacterial lactonases and bacterial and eukaryotic acylases, and the application of QS agonists in aquaculture [87][88]. N-acyl homoserine lactones (AHLs) are the most important family of QS auto-inducers utilized in Gram-negative bacteria, and their biodegradation is a potential way to interrupt QS [89]. *Bacillus* species were among the first bacteria documented to degrade AHLs through the production of lactonase enzymes. Probiotic *Bacillus* strains can effectively secrete quorum-quenching enzymes and could reduce the pathogenic activity of *A. hydrophila* YJ-1 and control gut microbiota [90][91]. The dietary supplementation of probiotics with quorum-quenching activity has been shown to increase the intestinal barrier function and enhance the immune system of crucian carp against *A. hydrophila* infection. The quorum-quenching bacteria increase the expression of the tight junction (TJ) proteins ZO-1 and Occludin, which control the permeability and absorption of the intestinal mucosal barrier of crucian carp [92]. *Bacillus* sp. QSI-1 has been reported to be a quorum quencher in virulence agent production and the biofilm arrangement of the zebrafish pathogen *A. hydrophila*. In experimental trials, fish fed with *Bacillus* sp. QSI-1 exhibited a relative survival percentage of 80.8% [93]. In another study, AHL-degrading *Bacillus* sp. was shown to protect shrimp (*Penaeus monodon*) against *Vibrio harveyi* infection [94]. Furthermore, *Enterobacter* sp. f003 and *Staphylococcus* sp. sw120, isolated from fish intestines and pond sediment, respectively, have demonstrated the ability to degrade acyl-homoserine lactones (AHLs) and protect against *A. hydrophila* infection in the cyprinid *Carassius auratus gibelio* [95]. In a biofilm system, bacteria are resistant to high temperatures, phagocytic cells, surfactants, antibiotics, and antibodies and can alter their vital transmissions via quorum-sensing signaling [96]. These findings suggest that bacteria capable of degrading AHLs should be considered an alternative to antibiotics in aquaculture for effectively controlling bacterial infections in fish.

2.6. Stress Improvement in the Aquaculture System

Stress in a fish's life cycle disrupts all production. The cultured species may be weakened and averse to taking feed [97]. In this condition, probiotics in culture farms can decrease stress levels and help to enhance the innate immune system against pathogens and environmental stressors [98][99]. Probiotic treatments are very helpful in increasing the production of fish within the given time, and they also reduce the stress level in normal aquaculture practices.

Studies have concluded that the use of some probiotic strains increases chronic stress resistance in zebrafish (*D. rerio*) [100][101]. Supplementation with an experimental nutritional probiotic, *Lactobacillus delbrueckii* sp. *Delbrueckii*, in sea bass led to a decrease in cortisol levels from 25 to 59 days, which, in fish tissue, is a stress indicator since it is directly engaged with the host's reaction to stress [102]. One more approach evaluated how fish treated with probiotics exhibited increased flexibility in stress tests when compared with a control group [54]. The antioxidative properties of the probiotic *Lactobacillus fermentum* induce protective action in the intestinal microbial ecosystem and help to overcome exo- and endogenous oxidative stress [103]. The probiotic strain *Bacillus coagulans* SCC-19 alleviates the nonspecific immune damage induced by cadmium in common carp while also relieving oxidative stress induced by cadmium in fish [104].

2.7. Reducing Heavy Metals in Aquaculture

Heavy metals such as lead (Pb), cadmium (Cd), silver (Ag), chromium (Cr), mercury (Hg), cobalt (Co), zinc (Zn), iron (Fe), and copper (Cu) are present in the soil, water, and atmosphere [105][106][107]. These metals can have toxic effects on all organisms and pose a huge risk to food quality, crops, and environmental quality. Heavy metals are mainly connected to anthropogenic action in the ecosystem [108]. Aqueous release from metal industries (steel, mining, and electroplating) contains elevated levels of heavy metals that end up in water bodies, and they are then also utilized for aquacultural action [109][110]. These heavy metals accumulate in fish tissue, and this is a matter of great concern with regard to humans consuming them via the food chain and breathing [108][110][111]. Their elimination is very helpful in reducing the toxic effects of the aquatic environment and outflow is, subsequently, imperative [112]. Among all the recommended methods of eliminating heavy metals is the process of utilizing microbes, which is cost-effective [113]. The action mechanisms of probiotics in detoxifying heavy metals can be classified into metabolically independent processes that do not require cellular energy, such as biosorption, and cellular-energy-dependent processes, namely, bioaccumulation and bioprecipitation [114].

Biosorption relies on a physicochemical process wherein cell-surface structures bind heavy metals through physical interactions. For example, *Lactobacillus acidophilus* and *Bifidobacterium angulatum* are effective in removing Cd, Pb, and As through electrostatic interactions between heavy-metal cations and the anionic functional groups of cell wall membranes [115]. Some probiotics release exopolysaccharides (EPSs), which can sequester heavy metals and reduce their bioavailability. The mechanisms underlying EPS-metal binding are mainly related to negatively charged acidic groups and steric structures on the surface of EPSs [116].

In bioaccumulation processes, probiotics accumulate heavy metals within their cells through energy-dependent processes. This can involve the synthesis and use of metal-binding proteins, such as metallothionein. For instance, *Bacillus cereus* can produce metallothionein in order to accumulate Pb [117].

Bioprecipitation involves the conversion of free metals into insoluble complexes, thereby reducing their bioavailability. Bacteria can catalyze oxidative and reductive processes to facilitate the precipitation of heavy metals. *Micrococcus* spp. have been demonstrated to be able to sequestrate heavy metals such as Zn, Cd, Pb, and Fe via calcite precipitation [118]

Generally, heavy metals activate the sporulation development of *Bacillus* species and thus decrease heavy metal absorption [109][119]. In addition, probiotic strains from aquatic farming sediments can be utilized as dietary supplements and help to remove heavy metals and metal-resistant microbes from the intestines of aquatic organisms, particularly fish, to control the progress of heavy metal accumulation [120].

3. Major Probiotic Genera as Biocontrol Agents in Aquaculture

The major probiotic genera used in aquaculture are *Lactobacillus* and *Bacillus* [121]. In most cases, *Bacillus*, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Pediococcus*, and *Weissella* are isolated from fish and shellfish guts [122][123][124][125][126]. Supplementation in aquaculture feed is achieved using single-strain probiotics or associations of various bacteria as multi-strain probiotics (MSPs), which have been reported to have more beneficial effects on hosts owing to synergistic effects between various strains [127]. **Table 2** lists some examples of probiotic-based functional feed additives for aquatic animals.

Table 2. Functional feed additives of major probiotics in aquatic animals.

Probiotics Organisms	Functions	Aquatic Organisms	References
Bacillus			
***B. licheniformis* HGA8B**	**↑ growth performance and ↓ feed conversion ratio** **Up-regulation of immune genes**	***O. niloticus***	[128]
***B. cereus* G19** ***B. cereus* BC-01**	**↑ growth and immunity**	***Apostichopus japonicus***	[129]
***B. cereus* EN25**	**Immunity and resistance against *Vibrio splendidus***	***A. japonicus***	[130]
***B. pumilus* SE5**	**↑ growth and immunity**	***L. vannamei***	[131]
***B. subtilis* AB1**	**Bactericidal activity against *Aeromonas* infection**	***O. mykiss***	[132]
Bifidobacterium			
***Bifidobacterium animalis* PTCC-1631**	**↑ growth performance, digestion, and nutrient utilization**	***O. mykiss***	[133]
***B. lactis* PTCC-1736**	**↑ growth, nutrient digestibility, and carcass composition**	***O. mykiss***	[133]
Carnobacterium			
C. divergens ***C. maltaromaticum***	**Antagonistic effects against *V. anguillarum*, *V. viscosus*, and *A. salmonicida***	**-**	[134][135]
Lactobacillus			
***L. plantarum* CLFP**	**↓ mortality against harmful strain *L. garvieae***	***O. mykiss***	[136]
L. acidophilus	**Survival against *Staphylococcus xylosus*, *Aeromonas hydrophila* gr.2, and *Streptococcus agalactiae* infection**	***Clarias gariepinus***	[137]
L. pentosus	**↑ growth performance and feed conversion ratio** **↑ survival against *Vibrio* species**	***L. vannamei***	[138]
Lactococcus			
***Lactococcus lactis* BFE920**	**Activation of nonspecific immune system** **Bactericidal activity against *S. iniae***	***Paralichthys olivaceus***	[139]
Leuconostoc			

Probiotics Organisms	Functions	Aquatic Organisms	References
Lc. Mesenteroides CLFP 196	↑ survival against *A. salmonicida* infection	*Salmo trutta*	[140]
Pediococcus			
P. pentosaceus HN10	↑ feed utilization, digestive enzyme activity, and anti-Vibrio activity	*L. vannamei*	[141]
Enterococcus			
E. casseliflavus CGMCC1.2136	↑ growth performance, immunity, and digestive enzyme activity	*Rutilus rutilus caspicus*	[142]
E. casseliflavus	↑ growth performance and disease resistance against *S. iniae*	*O. mykiss*	[143]
E. durans	↑ growth performance and survival rate	*O. mykiss*	[144]
Clostridium			
C. butyricum	↑ antibacterial activity against *Vibriosis* infection	*O. mykiss*	[145]
C. butyricum	↑ immunity; regulation of gut microbiota; antagonistic effects against *Aeromonas* sp., *Vibrio* sp., and *Pseudomonas* sp.	*C. carpio*	[146]
Weissella			
W. confusa	↑ growth performance	*O. mykiss*	[147]
W. confusa	↑ growth performance and antibacterial activity against *A. hydrophila*	*Lates calcarifer*	[148]
Other strains			
A. veronii BA-1	↑ immune system and antibacterial activity	*C. carpio*	[149]
Micrococcus luteus	↑ growth performance and feed conversion ratio	*O. niloticus*	[150]
Pseudoalteromonas undina VKM-124	↑ survival and antiviral activity	*Carangoides bartholomaei*	[72]
Yeast			
S.cerevisiae	↑ growth performance and resistance against waterborne Cu toxicity	*Sarotherodon galilaeus*	[151]
S. cerevisiae	↑ immunity and ↓ mortality against *P. fluorescens*	*Mystus cavasius*	[152]
Yarrowia lipolytica	↑ immune response, antioxidant status, and disease resistance against *V. parahaemolyticus* infection	*Lutjanus peru*	[153]
Multi-strain			
B. subtilis and *Bacillus licheniformis* (BioPlus2B)	↑ resistance against *Y. ruckeri*	*O. mykiss*	[154]
Lactobacillus delbrueckii *Lactobacillus rhamnosus* *L. plantarum* *B. bifidum*	↑ growth performance and immunity	*Acipenser baerii*	[155]
Lactobacillus plantarum (STBL1), *Saccharomyces cerevisiae* (STBS1), and *Bacillus safensis* (SQVG18)	↑ growth, antioxidant capacity, digestion, and gut microflora	*P. vannamei*	[156]

↓ decrease or reduction; ↑, increase or improvement.

References

1. FAO/WHO Expert Consultation. Health and Nutritional Properties of Probiotics in Food Including Powder Milk with Live Lactic Acid Bacteria; World Health Organization: Córdoba, Spain, 2001.
2. Adel, M.; Dawood, M.A. Probiotics Application: Implications for Sustainable Aquaculture. In Probiotic Bacteria and Postbiotic Metabolites: Role in Animal and Human Health; Springer: Berlin/Heidelberg, Germany, 2021; pp. 191–219.
3. Guardiola, F.A.; Porcino, C.; Cerezuela, R.; Cuesta, A.; Faggio, C.; Esteban, M.A. Impact of Date Palm Fruits Extracts and Probiotic Enriched Diet on Antioxidant Status, Innate Immune Response and Immune-Related Gene Expression of European Seabass (Dicentrarchus labrax). Fish Shellfish Immunol. 2016, 52, 298–308.
4. Van Doan, H.; Hoseinifar, S.H.; Ringø, E.; Ángeles Esteban, M.; Dadar, M.; Dawood, M.A.; Faggio, C. Host-Associated Probiotics: A Key Factor in Sustainable Aquaculture. Rev. Fish. Sci. Aquac. 2020, 28, 16–42.
5. Morshedi, V.; Bojarski, B.; Hamedi, S.; Torahi, H.; Hashemi, G.; Faggio, C. Effects of Dietary Bovine Lactoferrin on Growth Performance and Immuno-Physiological Responses of Asian Sea Bass (Lates calcarifer) Fingerlings. Probiotics Antimicrob. Proteins 2021, 13, 1790–1797.
6. Mirbakhsh, M.; Ghaednia, B.; Zorriehzahra, M.J.; Esmaeili, F.; Faggio, C. Dietary Mixed and Sprayed Probiotic Improves Growth Performance and Digestive Enzymes of Juvenile Whiteleg Shrimp (Litopenaeus vannamei, Boone, 1931). J. Appl. Aquac. 2022, 35, 823–836.
7. Misra, S.; Pandey, P.; Mishra, H.N. Novel Approaches for Co-Encapsulation of Probiotic Bacteria with Bioactive Compounds, Their Health Benefits and Functional Food Product Development: A Review. Trends Food Sci. Technol. 2021, 109, 340–351.
8. El-Kady, A.A.; Magouz, F.I.; Mahmoud, S.A.; Abdel-Rahim, M.M. The Effects of Some Commercial Probiotics as Water Additive on Water Quality, Fish Performance, Blood Biochemical Parameters, Expression of Growth and Immune-Related Genes, and Histology of Nile Tilapia (Oreochromis niloticus). Aquaculture 2022, 546, 737249.
9. Vijayaram, S.; Kannan, S. Probiotics: The Marvelous Factor and Health Benefits. Biomed. Biotechnol. Res. J. BBRJ 2018, 2, 1–8.
10. Cıl, G.I.; Bulut, G.; Budak, D.; Camkerten, G.; Camkerten, I. Probiotics and Functional Feed. In Probiotics, the Natural Microbiota in Living Organisms; CRC Press: Boca Raton, FL, USA, 2021; pp. 315–342. ISBN 1-351-02754-9.
11. Foysal, M.J.; Alam, M.; Kawser, A.R.; Hasan, F.; Rahman, M.M.; Tay, C.-Y.; Prodhan, M.S.H.; Gupta, S.K. Meta-Omics Technologies Reveals Beneficiary Effects of Lactobacillus plantarum as Dietary Supplements on Gut Microbiota, Immune Response and Disease Resistance of Nile Tilapia (Oreochromis niloticus). Aquaculture 2020, 520, 734974.
12. Zaineldin, A.I.; Hegazi, S.; Koshio, S.; Ishikawa, M.; Dawood, M.A.; Dossou, S.; Yukun, Z.; Mzengereza, K. Singular Effects of Bacillus Subtilis C-3102 or Saccharomyces Cerevisiae Type 1 on the Growth, Gut Morphology, Immunity, and Stress Resistance of Red Sea Bream (Pagrus major); Mzuzu University: Mzuzu, Malawi, 2021.
13. Kong, Y.; Gao, C.; Du, X.; Zhao, J.; Li, M.; Shan, X.; Wang, G. Effects of Single or Conjoint Administration of Lactic Acid Bacteria as Potential Probiotics on Growth, Immune Response and Disease Resistance of Snakehead Fish (Channa argus). Fish Shellfish Immunol. 2020, 102, 412–421.
14. Kord, M.I.; Maulu, S.; Srour, T.M.; Omar, E.A.; Farag, A.A.; Nour, A.A.M.; Hasimuna, O.J.; Abdel-Tawwab, M.; Khalil, H.S. Impacts of Water Additives on Water Quality, Production Efficiency, Intestinal Morphology, Gut Microbiota, and Immunological Responses of Nile tilapia Fingerlings under a Zero-Water-Exchange System. Aquaculture 2022, 547, 737503.
15. Ayivi, R.D.; Gyawali, R.; Krastanov, A.; Aljaloud, S.O.; Worku, M.; Tahergorabi, R.; da Silva, R.C.; Ibrahim, S.A. Lactic Acid Bacteria: Food Safety and Human Health Applications. Dairy 2020, 1, 202–232.
16. Feng, T.; Wang, J. Oxidative Stress Tolerance and Antioxidant Capacity of Lactic Acid Bacteria as Probiotic: A Systematic Review. Gut Microbes 2020, 12, 1801944.
17. Tiwari, S.K.; Dicks, L.M.; Popov, I.V.; Karaseva, A.; Ermakov, A.M.; Suvorov, A.; Tagg, J.R.; Weeks, R.; Chikindas, M.L. Probiotics at War against Viruses: What Is Missing from the Picture? Front. Microbiol. 2020, 11, 1877.
18. Govindaraj, K.; Samayanpaulraj, V.; Narayanadoss, V.; Uthandakalaipandian, R. Isolation of Lactic Acid Bacteria from Intestine of Freshwater Fishes and Elucidation of Probiotic Potential for Aquaculture Application. Probiotics Antimicrob. Proteins 2021, 13, 1598–1610.
19. Khalid, F.; Khalid, A.; Fu, Y.; Hu, Q.; Zheng, Y.; Khan, S.; Wang, Z. Potential of Bacillus velezensis as a Probiotic in Animal Feed: A Review. J. Microbiol. 2021, 59, 627–633.
20. Vallesi, A.; Pucciarelli, S.; Buonanno, F.; Fontana, A.; Mangiagalli, M. Bioactive Molecules from Protists: Perspectives in Biotechnology. Eur. J. Protistol. 2020, 75, 125720.

21. Butt, U.D.; Lin, N.; Akhter, N.; Siddiqui, T.; Li, S.; Wu, B. Overview of the Latest Developments in the Role of Probiotics, Prebiotics and Synbiotics in Shrimp Aquaculture. Fish Shellfish Immunol. 2021, 114, 263–281.

22. Al-Shawi, S.G.; Dang, D.S.; Yousif, A.Y.; Al-Younis, Z.K.; Najm, T.A.; Matarneh, S.K. The Potential Use of Probiotics to Improve Animal Health, Efficiency, and Meat Quality: A Review. Agriculture 2020, 10, 452.

23. Labba, I.-C.M.; Andlid, T.; Lindgren, Å.; Sandberg, A.-S.; Sjöberg, F. Isolation, Identification, and Selection of Strains as Candidate Probiotics and Starters for Fermentation of Swedish Legumes. Food Nutr. Res. 2020, 64.

24. Rajyalakshmi, K.; Babu, M.K.; Shabana, S.; Satya, A.K. Identification and Screening of Probiotics as a Biocontrol Agent against Pathogenic Vibriosis in Shrimp Aquaculture. Ann. Rom. Soc. Cell Biol. 2021, 25, 12292–12305.

25. Chang, X.; Kang, M.; Shen, Y.; Yun, L.; Yang, G.; Zhu, L.; Meng, X.; Zhang, J.; Su, X. Bacillus Coagulans SCC-19 Maintains Intestinal Health in Cadmium-Exposed Common Carp (Cyprinus carpio L.) by Strengthening the Gut Barriers, Relieving Oxidative Stress and Modulating the Intestinal Microflora. Ecotoxicol. Environ. Saf. 2021, 228, 112977.

26. Zhao, C.; Guo, G.; Li, Z.; Chen, J.; Ren, Y. Effects of Probiotics (Bacillus coagulans) Supplementation after Antibiotic Administration on Growth, Immunity, and Intestinal Microflora in Turbot Scophthalmus maximus. Aquac. Int. 2023.

27. Galagarza, O.A.; Smith, S.A.; Drahos, D.J.; Eifert, J.D.; Williams, R.C.; Kuhn, D.D. Modulation of Innate Immunity in Nile tilapia (Oreochromis niloticus) by Dietary Supplementation of Bacillus subtilis Endospores. Fish Shellfish Immunol. 2018, 83, 171–179.

28. Qin, L.U.; Xiang, J.; Xiong, F.; Wang, G.; Zou, H.; Li, W.; Li, M.; Wu, S. Effects of Bacillus Licheniformis on the Growth, Antioxidant Capacity, Intestinal Barrier and Disease Resistance of Grass Carp (Ctenopharyngodon idella). Fish Shellfish Immunol. 2020, 97, 344–350.

29. Das, S.; Mondal, K.; Sengupta, C. Evaluation of the Probiotic Potential of Streptomyces antibioticus and Bacillus cereus on Growth Performance of Freshwater Catfish Heteropneustes Fossilis. Aquac. Rep. 2021, 20, 100752.

30. Loghmani, H.; Khalili Hadad, B.; Kazempoor, R.; Sh, A.S. Investigation of the Effects of Bifidobacterium Bifidum as a Probiotic on Liver Function Enzymes Due to Exposure to E. Coli. O157H7 in Koi Fish (Cyprinus rubrofuscus). J. Surv. Fish. Sci. 2022, 5, 27-3.

31. Puvanendran, V.; Rud, I.; Breiland, M.S.W.; Arnesen, J.-A.; 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.

32. Tachibana, L.; Telli, G.S.; de Carla Dias, D.; Goncalves, G.S.; Ishikawa, C.M.; Cavalcante, R.B.; Natori, M.M.; Hamed, S.B.; Ranzani-Paiva, M.J.T. Effect of Feeding Strategy of Probiotic Enterococcus Faecium on Growth Performance, Hematologic, Biochemical Parameters and Non-Specific Immune Response of Nile Tilapia. Aquac. Rep. 2020, 16, 100277.

33. Tian, J.-X.; Kang, Y.-H.; Chu, G.-S.; Liu, H.-J.; Kong, Y.-D.; Zhao, L.-H.; Kong, Y.-X.; Shan, X.-F.; Wang, G.-Q. Oral Administration of Lactobacillus Casei Expressing Flagellin A Protein Confers Effective Protection against Aeromonas Veronii in Common Carp, Cyprinus carpio. Int. J. Mol. Sci. 2019, 21, 33.

34. Sagada, G.; Gray, N.; Wang, L.; Xu, B.; Zheng, L.; Zhong, Z.; Ullah, S.; Tegomo, A.F.; Shao, Q. Effect of Dietary Inactivated Lactobacillus plantarum on Growth Performance, Antioxidative Capacity, and Intestinal Integrity of Black Sea Bream (Acanthopagrus schlegelii) Fingerlings. Aquaculture 2021, 535, 736370.

35. Noshair, I.; Kanwal, Z.; Jabeen, G.; Arshad, M.; Yunus, F.-U.-N.; Hafeez, R.; Mairaj, R.; Haider, I.; Ahmad, N.; Alomar, S.Y. Assessment of Dietary Supplementation of Lactobacillus rhamnosus Probiotic on Growth Performance and Disease Resistance in Oreochromis niloticus. Microorganisms 2023, 11, 1423.

36. Zhu, C.-Z.; Li, D.; Chen, W.-J.; Ban, S.-N.; Liu, T.; Wen, H.; Jiang, M. Effects of Dietary Host-Associated Lactococcus lactis on Growth Performance, Disease Resistance, Intestinal Morphology and Intestinal Microbiota of Mandarin Fish (Siniperca chuatsi). Aquaculture 2021, 540, 736702.

37. Al-Hisnawi, A.; Rodiles, A.; Rawling, M.D.; Castex, M.; Waines, P.; Gioacchini, G.; Carnevali, O.; Merrifield, D.L. Dietary Probiotic Pediococcus acidilactici MA18/5M Modulates the Intestinal Microbiota and Stimulates Intestinal Immunity in Rainbow Trout (Oncorhynchus mykiss). J. World Aquac. Soc. 2019, 50, 1133–1151.

38. Liang, Q.; Liu, G.; Guo, Z.; Wang, Y.; Xu, Z.; Ren, Y.; Zhang, Q.; Cui, M.; Zhao, X.; Xu, D. Application of Potential Probiotic Strain Streptomyces sp. SH5 on Anti-Aeromonas Infection in Zebrafish Larvae. Fish Shellfish Immunol. 2022, 127, 375–385.

39. Boonanuntanasarn, S.; Ditthab, K.; Jangprai, A.; Nakharuthai, C. Effects of Microencapsulated Saccharomyces cerevisiae on Growth, Hematological Indices, Blood Chemical, and Immune Parameters and Intestinal Morphology in Striped Catfish, Pangasianodon hypophthalmus. Probiotics Antimicrob. Proteins 2019, 11, 427–437.

40. Zamini, A.; Tehranifard, A. Effects of Lactococcus lactis and Weissella Cibaria as Probiotic on Growth Performance, Intestinal Bacterial Flora, Digestive Enzymes and Intestinal Histology in Common Carp (Cyprinus Carpio). J. Aquac. Dev. 2021, 15, 13–29.

41. Mingmongkolchai, S.; Panbangred, W. Bacillus Probiotics: An Alternative to Antibiotics for Livestock Production. J. Appl. Microbiol. 2018, 124, 1334–1346.

42. Ringø, E. Probiotics in Shellfish Aquaculture. Aquac. Fish. 2020, 5, 1–27.

43. Xia, Y.; Yu, E.; Lu, M.; Xie, J. Effects of Probiotic Supplementation on Gut Microbiota as Well as Metabolite Profiles within Nile tilapia, Oreochromis niloticus. Aquaculture 2020, 527, 735428.

44. Yukgehnaish, K.; Kumar, P.; Sivachandran, P.; Marimuthu, K.; Arshad, A.; Paray, B.A.; Arockiaraj, J. Gut Microbiota Metagenomics in Aquaculture: Factors Influencing Gut Microbiome and Its Physiological Role in Fish. Rev. Aquac. 2020, 12, 1903–1927.

45. Wu, G. Nutrition and Metabolism: Foundations for Animal Growth, Development, Reproduction, and Health. In Recent Advances in Animal Nutrition and Metabolism; Springer: Berlin/Heidelberg, Germany, 2022; pp. 1–24.

46. LeBlanc, J.G.; Chain, F.; Martín, R.; Bermúdez-Humarán, L.G.; Courau, S.; Langella, P. Beneficial Effects on Host Energy Metabolism of Short-Chain Fatty Acids and Vitamins Produced by Commensal and Probiotic Bacteria. Microb. Cell Factories 2017, 16, 79.

47. Morais, T.; Inácio, A.; Coutinho, T.; Ministro, M.; Cotas, J.; Pereira, L.; Bahcevandziev, K. Seaweed Potential in the Animal Feed: A Review. J. Mar. Sci. Eng. 2020, 8, 559.

48. Hardy, R.W.; Kaushik, S.J.; Mai, K.; Bai, S.C. Fish Nutrition—History and Perspectives. In Fish Nutrition; Elsevier: Amsterdam, The Netherlands, 2022; pp. 1–16.

49. Uma, A.; Subash, P.; Abraham, T.J. Importance of Gut Microbiota in Fish–A Review. Indian J. Anim. Health 2020, 59, 181–194.

50. Singh, S.K.; Bhandari, M.P.; Shrestha, S.; Koirala, U.; Gurung, G.B. Supplementation of Commercial Probiotics in Feed for Growth and Survival of Rainbow Trout (Oncorhynchus mykiss). In Proceedings of the National Workshop on Livestock and Fisheries Research in Nepal, Kathmandu, Nepal, 3–4 March 2021; Volume 3, p. 275.

51. Chen, J.; Sun, D.; Cui, H.; Rao, C.; Li, L.; Guo, S.; Yang, S.; Zhang, Y.; Cao, X. Toxic Effects of Carbon Quantum Dots on the Gut–Liver Axis and Gut Microbiota in the Common Carp Cyprinus carpio. Environ. Sci. Nano 2022, 9, 173–188.

52. Phianphak, W.; Rengpipat, S.; Piyatiratitivorakul, S.; Menasveta, P. Probiotic Use of Lactobacillus spp. for Black Tiger Shrimp, Penaeus monodon. J. Sci. Res. Chula Univ. 1999, 24, 41–58.

53. Tuan, T.N.; Duc, P.M.; Hatai, K. Overview of the Use of Probiotics in Aquaculture. Int. J. Res. Fish. Aquac. 2013, 3, 89–97.

54. El-Saadony, M.T.; Alagawany, M.; Patra, A.K.; Kar, I.; Tiwari, R.; Dawood, M.A.; Dhama, K.; Abdel-Latif, H.M. The Functionality of Probiotics in Aquaculture: An Overview. Fish Shellfish Immunol. 2021, 117, 36–52.

55. Yassir, R.Y.; Adel, M.E.; Azze, A. Use of Probiotic Bacteria as Growth Promoters, Antibacterial and the Effect on Physiological Parameters of Orechromis niloticus. J. Fish Dis. 2002, 22, 633–642.

56. Swain, S.; Hauzoukim, S.K.G.; Das, S.K.; Roy, A. Application of Probiotics in Aquaculture. Pharma innov. 2021, 10, 146–149. Available online: https://www.thepharmajournal.com/archives/2021/vol10issue7S/PartC/S-10-6-136-245.pdf (accessed on 1 November 2023).

57. Franca, F.M.; Danielle de Carla, D.; Teixeira, P.C.; Marcantonio, A.S.; de Stefani, M.V.; Antonucci, A.; Da Rocha, G.; Ranzani-PAIVA, M.J.T.; Ferreira, C.M. Efeito Do Probiótico Bacillus Subtilis No Crescimento, Sobrevivência e Fisiologia de Rãs-Touro (Rana catesbeiana). Bol. Inst. Pesca 2008, 34, 403–412.

58. Wang, Z.; Yang, M.; Wang, L.; Lu, K.; Song, K.; Zhang, C. Bacillus Subtilis LCBS1 Supplementation and Replacement of Fish Meal with Fermented Soybean Meal in Bullfrog (Lithobates catesbeianus) Diets: Effects on Growth Performance, Feed Digestibility and Gut Health. Aquaculture 2021, 545, 737217.

59. Assan, D.; Kuebutornye, F.K.A.; Hlordzi, V.; Chen, H.; Mraz, J.; Mustapha, U.F.; Abarike, E.D. Effects of Probiotics on Digestive Enzymes of Fish (Finfish and Shellfish); Status and Prospects: A Mini Review. Comp. Biochem. Physiol. B Biochem. Mol. Biol. 2022, 257, 110653.

60. Lara-Flores, M.; Olivera-Castillo, L.; Olvera-Novoa, M.A. Effect of the Inclusion of a Bacterial Mix (Streptococcus faecium and Lactobacillus acidophilus), and the Yeast (Saccharomyces cerevisiae) on Growth, Feed Utilization and Intestinal Enzymatic Activity of Nile Tilapia (Oreochromis niloticus). Int. J. Fish. Aquac. 2010, 2, 93–101.

61. Carnevali, O.; Sun, Y.-Z.; Merrifield, D.L.; Zhou, Z.; Picchietti, S. Probiotic Applications in Temperate and Warm Water Fish Species. In Aquaculture Nutrition: Gut Health, Probiotics and Prebiotics; Wiley: New York, NY, USA, 2014; pp.

253–289.

62. Loh, J.Y.; Chan, H.K.; Yam, H.C.; In, L.L.A.; Lim, C.S.Y. An Overview of the Immunomodulatory Effects Exerted by Probiotics and Prebiotics in Grouper Fish. Aquac. Int. 2020, 28, 729–750.
63. Gao, X.-Y.; Liu, Y.; Miao, L.-L.; Li, E.-W.; Hou, T.-T.; Liu, Z.-P. Mechanism of Anti-Vibrio Activity of Marine Probiotic Strain Bacillus Pumilus H2, and Characterization of the Active Substance. AMB Express 2017, 7, 23.
64. Kuebutornye, F.K.; Abarike, E.D.; Lu, Y.; Hlordzi, V.; Sakyi, M.E.; Afriyie, G.; Wang, Z.; Li, Y.; Xie, C.X. Mechanisms and the Role of Probiotic Bacillus in Mitigating Fish Pathogens in Aquaculture. Fish Physiol. Biochem. 2020, 46, 819–841.
65. Emam, A.M.; Dunlap, C.A. Genomic and Phenotypic Characterization of Bacillus velezensis AMB-Y1; a Potential Probiotic to Control Pathogens in Aquaculture. Antonie Leeuwenhoek 2020, 113, 2041–2052.
66. Xu, H.-M.; Rong, Y.-J.; Zhao, M.-X.; Song, B.; Chi, Z.-M. Antibacterial Activity of the Lipopetides Produced by Bacillus Amyloliquefaciens M1 against Multidrug-Resistant Vibrio spp. Isolated from Diseased Marine Animals. Appl. Microbiol. Biotechnol. 2014, 98, 127–136.
67. Chau, K.M.; Van, T.T.H.; Quyen, D.V.; Le, H.D.; Phan, T.H.T.; Ngo, N.D.T.; Vo, T.D.T.; Dinh, T.T.; Le, H.T.; Khanh, H.H.N. Molecular Identification and Characterization of Probiotic Bacillus Species with the Ability to Control Vibrio spp. in Wild Fish Intestines and Sponges from the Vietnam Sea. Microorganisms 2021, 9, 1927.
68. Yin, Z.; Liu, Q.; Liu, Y.; Gao, S.; He, Y.; Yao, C.; Huang, W.; Gong, Y.; Mai, K.; Ai, Q. Early Life Intervention Using Probiotic Clostridium butyricum Improves Intestinal Development, Immune Response, and Gut Microbiota in Large Yellow Croaker (Larimichthys crocea) Larvae. Front. Immunol. 2021, 12, 640767.
69. Li, C.; Zhang, B.; Liu, C.; Zhou, H.; Wang, X.; Mai, K.; He, G. Effects of Dietary Raw or Enterococcus faecium Fermented Soybean Meal on Growth, Antioxidant Status, Intestinal Microbiota, Morphology, and Inflammatory Responses in Turbot (Scophthalmus maximus L.). Fish Shellfish Immunol. 2020, 100, 261–271.
70. Kamei, Y.; Yoshimizu, M.; Ezura, Y.; Kimura, T. Screening of Bacteria with Antiviral Activity from Fresh Water Salmonid Hatcheries. Microbiol. Immunol. 1988, 32, 67–73.
71. Hasan, K.N.; Banerjee, G. Recent Studies on Probiotics as Beneficial Mediator in Aquaculture: A Review. J. Basic Appl. Zool. 2020, 81, 53.
72. Maeda, M.; Nogami, K.; Kanematsu, M.; Hirayama, K. The Concept of Biological Control Methods in Aquaculture. Hydrobiologia 1997, 358, 285–290.
73. Mondal, H.; Chandrasekaran, N.; Mukherjee, A.; Thomas, J. Viral Infections in Cultured Fish and Shrimps: Current Status and Treatment Methods. Aquac. Int. 2022, 30, 227–262.
74. Tran, N.T.; Yang, W.; Nguyen, X.T.; Zhang, M.; Ma, H.; Zheng, H.; Zhang, Y.; Chan, K.-G.; Li, S. Application of Heat-Killed Probiotics in Aquaculture. Aquaculture 2022, 548, 737700.
75. De Andrade Belo, M.A.; Charlie-Silva, I. Teleost Fish as an Experimental Model for Vaccine Development. In Vaccine Design: Methods and Protocols, Volume 2. Vaccines for Veterinary Diseases; Springer: Berlin/Heidelberg, Germany, 2022; pp. 175–194.
76. Dawood, M.A.; Koshio, S. Recent Advances in the Role of Probiotics and Prebiotics in Carp Aquaculture: A Review. Aquaculture 2016, 454, 243–251.
77. Akbari, H.; Shekrabi, S.P.H.; Soltani, M.; Mehrgan, M.S. Effects of Potential Probiotic Enterococcus Casseliflavus (EC-001) on Growth Performance, Immunity, and Resistance to Aeromonas Hydrophila Infection in Common Carp (Cyprinus carpio). Probiotics Antimicrob. Proteins 2021, 13, 1316–1325.
78. Rachmawati, R.A.; Mulyani, Y.; Rochima, E.; Grandiosa, R. The Effect of Induction of Bacteria Bacillus Subtilis in Feed on the Immune System of Carp (Cyprinus carpio Linnaeus, 1758). World Sci. News 2021, 160, 203–216.
79. Shah, S.; Chesti, A.; Rather, M.; Manzoor, S.; Malik, R.; Khan, J. Effect of Probiotic (Bacillus Subtilis) on the Immune System of Fingerlings of Grass Carp, Ctenopharyngodon idella. Pharma Innov. J. 2021, 10, 769–772.
80. Yan, Y.-Y.; Xia, H.-Q.; Yang, H.-L.; Hoseinifar, S.H.; Sun, Y.-Z. Effects of Dietary Live or Heat-inactivated Autochthonous Bacillus pumilus SE 5 on Growth Performance, Immune Responses and Immune Gene Expression in Grouper Epinephelus coioides. Aquac. Nutr. 2016, 22, 698–707.
81. Liu, Z.-Y.; Yang, H.-L.; Hu, L.-H.; Yang, W.; Ai, C.-X.; Sun, Y.-Z. Dose-Dependent Effects of Histamine on Growth, Immunity and Intestinal Health in Juvenile Grouper (Epinephelus coioides). Front. Mar. Sci. 2021, 8, 685720.
82. Yang, H.-L.; Xia, H.-Q.; Ye, Y.-D.; Zou, W.-C.; Sun, Y.-Z. Probiotic Bacillus Pumilus SE5 Shapes the Intestinal Microbiota and Mucosal Immunity in Grouper Epinephelus coioides. Dis. Aquat. Organ. 2014, 111, 119–127.
83. Yang, H.-L.; Hu, X.; Ye, J.-D.; Seerengaraj, V.; Yang, W.; Ai, C.-X.; Sun, Y.-Z. Cell Wall Components of Bacillus Pumilus SE5 Improved the Growth, Digestive and Immunity of Grouper (Epinephelus coioides). Curr. Chin. Sci. 2021, 1, 231–

239.

84. Yang, H.-L.; Sun, Y.-Z.; Hu, X.; Ye, J.; Lu, K.-L.; Hu, L.-H.; Zhang, J.-J. Bacillus Pumilus SE5 Originated PG and LTA Tuned the Intestinal TLRs/MyD88 Signaling and Microbiota in Grouper (Epinephelus coioides). Fish Shellfish Immunol. 2019, 88, 266–271.
85. Boo, A.; Amaro, R.L.; Stan, G.-B. Quorum Sensing in Synthetic Biology: A Review. Curr. Opin. Syst. Biol. 2021, 28, 100378.
86. Saeki, E.K.; Kobayashi, R.K.T.; Nakazato, G. Quorum Sensing System: Target to Control the Spread of Bacterial Infections. Microb. Pathog. 2020, 142, 104068.
87. Defoirdt, T.; Boon, N.; Bossier, P.; Verstraete, W. Disruption of Bacterial Quorum Sensing: An Unexplored Strategy to Fight Infections in Aquaculture. Aquaculture 2004, 240, 69–88.
88. Alexpandi, R.; Abirami, G.; Satish, L.; Swasthikka, R.P.; Krishnaveni, N.; Jayakumar, R.; Pandian, S.K.; Ravi, A.V. Tocopherol and Phytol Possess Anti-Quorum Sensing Mediated Anti-Infective Behavior against Vibrio campbellii in Aquaculture: An in Vitro and in Vivo Study. Microb. Pathog. 2021, 161, 105221.
89. Samrot, A.V.; Abubakar Mohamed, A.; Faradjeva, E.; Si Jie, L.; Hooi Sze, C.; Arif, A.; Chuan Sean, T.; Norbert Michael, E.; Yeok Mun, C.; Xiao Qi, N. Mechanisms and Impact of Biofilms and Targeting of Biofilms Using Bioactive Compounds—A Review. Medicina 2021, 57, 839.
90. Hoseinifar, S.H.; Sun, Y.-Z.; Wang, A.; Zhou, Z. Probiotics as Means of Diseases Control in Aquaculture, a Review of Current Knowledge and Future Perspectives. Front. Microbiol. 2018, 9, 2429.
91. Wang, A.; Ran, C.; Wang, Y.; Zhang, Z.; Ding, Q.; Yang, Y.; Olsen, R.E.; Ringø, E.; Bindelle, J.; Zhou, Z. Use of Probiotics in Aquaculture of China—A Review of the Past Decade. Fish Shellfish Immunol. 2019, 86, 734–755.
92. Jiang, Y.; Zhou, S.; Sarkodie, E.K.; Chu, W. The Effects of Bacillus cereus QSI-1 on Intestinal Barrier Function and Mucosal Gene Transcription in Crucian Carp (Carassius auratus gibelio). Aquac. Rep. 2020, 17, 100356.
93. Chu, W.; Zhou, S.; Zhu, W.; Zhuang, X. Quorum Quenching Bacteria Bacillus Sp. QSI-1 Protect Zebrafish (Danio rerio) from Aeromonas hydrophila Infection. Sci. Rep. 2014, 4, 5446.
94. Shaheer, P.; Sreejith, V.N.; Joseph, T.C.; Murugadas, V.; Lalitha, K.V. Quorum Quenching Bacillus spp.: An Alternative Biocontrol Agent for Vibrio harveyi Infection in Aquaculture. Dis. Aquat. Organ. 2021, 146, 117–128.
95. Li, M.; Xi, B.; Qin, T.; Chen, K.; Xie, J. Isolation and Characterization of AHL-Degrading Bacteria from Fish and Pond Sediment. J. Oceanol. Limnol. 2019, 37, 1460–1467.
96. Mamun, M.A.A.; Nasren, S.; Abhiman, P.B.; Rathore, S.S.; Sowndarya, N.S.; Ramesh, K.S.; Shankar, K.M. Investigation of Production, Formation and Characterization of Biofilm Cells of Aeromonas hydrophila for Oral Vaccination of Fish. J. Exp. Zool. India 2019, 22, 1115–1123.
97. Assan, D.; Huang, Y.; Mustapha, U.F.; Addah, M.N.; Li, G.; Chen, H. Fish Feed Intake, Feeding Behavior, and the Physiological Response of Apelin to Fasting and Refeeding. Front. Endocrinol. 2021, 12, 798903.
98. Mohapatra, S.; Chakraborty, T.; Kumar, V.; DeBoeck, G.; Mohanta, K.N. Aquaculture and Stress Management: A Review of Probiotic Intervention. J. Anim. Physiol. Anim. Nutr. 2013, 97, 405–430.
99. Hoseinifar, S.H.; Yousefi, S.; Van Doan, H.; Ashouri, G.; Gioacchini, G.; Maradonna, F.; Carnevali, O. Oxidative Stress and Antioxidant Defense in Fish: The Implications of Probiotic, Prebiotic, and Synbiotics. Rev. Fish. Sci. Aquac. 2020, 29, 198–217.
100. Vianello, S.; Brazzoduro, L.; Dalla Valle, L.; Belvedere, P.; Colombo, L. Myostatin Expression during Development and Chronic Stress in Zebrafish (Danio rerio). J. Endocrinol. 2003, 176, 47–60.
101. Lutfi, E.; Basili, D.; Falcinelli, S.; Morillas, L.; Carnevali, O.; Capilla, E.; Navarro, I. The Probiotic Lactobacillus Rhamnosus Mimics the Dark-Driven Regulation of Appetite Markers and Melatonin Receptors' Expression in Zebrafish (Danio Rerio) Larvae: Understanding the Role of the Gut Microbiome. Comp. Biochem. Physiol. B Biochem. Mol. Biol. 2021, 256, 110634.
102. Carnevali, O.; de Vivo, L.; Sulpizio, R.; Gioacchini, G.; Olivotto, I.; Silvi, S.; Cresci, A. Growth Improvement by Probiotic in European Sea Bass Juveniles (Dicentrarchus labrax, L.), with Particular Attention to IGF-1, Myostatin and Cortisol Gene Expression. Aquaculture 2006, 258, 430–438.
103. Castex, M.; Lemaire, P.; Wabete, N.; Chim, L. Effect of Dietary Probiotic Pediococcus Acidilactici on Antioxidant Defences and Oxidative Stress Status of Shrimp Litopenaeus Stylirostris. Aquaculture 2009, 294, 306–313.
104. Chang, X.; Chen, Y.; Feng, J.; Huang, M.; Zhang, J. Amelioration of Cd-Induced Bioaccumulation, Oxidative Stress and Immune Damage by Probiotic Bacillus coagulans in Common Carp (Cyprinus carpio L.). Aquac. Rep. 2021, 20, 100678.

105. Merola, C.; Bisegna, A.; Angelozzi, G.; Conte, A.; Abete, M.C.; Stella, C.; Pederiva, S.; Faggio, C.; Riganelli, N.; Perugini, M. Study of Heavy Metals Pollution and Vitellogenin Levels in Brown Trout (Salmo trutta trutta) Wild Fish Populations. Appl. Sci. 2021, 11, 4965.

106. Jyoti, D.; Sinha, R.; Faggio, C. Advances in Biological Methods for the Sequestration of Heavy Metals from Water Bodies: A Review. Environ. Toxicol. Pharmacol. 2022, 94, 103927.

107. Shahjahan, M.; Taslima, K.; Rahman, M.S.; Al-Emran, M.; Alam, S.I.; Faggio, C. Effects of Heavy Metals on Fish Physiology–A Review. Chemosphere 2022, 300, 134519.

108. Zaynab, M.; Al-Yahyai, R.; Ameen, A.; Sharif, Y.; Ali, L.; Fatima, M.; Khan, K.A.; Li, S. Health and Environmental Effects of Heavy Metals. J. King Saud Univ.-Sci. 2022, 34, 101653.

109. Stefanescu, I.A. Bioaccumulation of Heavy Metals by Bacillus megaterium from Phosphogypsum Waste. Sci. Study Res. Chem. Chem. Eng. Biotechnol. Food Ind. 2015, 16, 93.

110. Sonone, S.S.; Jadhav, S.; Sankhla, M.S.; Kumar, R. Water Contamination by Heavy Metals and Their Toxic Effect on Aquaculture and Human Health through Food Chain. Lett. Appl. NanoBioSci. 2020, 10, 2148–2166.

111. Fatima, S.; Muzammal, M.; Rehman, A.; Rustam, S.A.; Shehzadi, Z.; Mehmood, A.; Waqar, M. Water Pollution on Heavy Metals and Its Effects on Fishes. Int. J. Fish Aquat. Stud. 2020, 8, 6–14.

112. Moiseenko, T.I.; Gashkina, N.A. Distribution and Bioaccumulation of Heavy Metals (Hg, Cd and Pb) in Fish: Influence of the Aquatic Environment and Climate. Environ. Res. Lett. 2020, 15, 115013.

113. Rahman, Z.; Singh, V.P. Bioremediation of Toxic Heavy Metals (THMs) Contaminated Sites: Concepts, Applications and Challenges. Environ. Sci. Pollut. Res. 2020, 27, 27563–27581.

114. Wróbel, M.; Śliwakowski, W.; Kowalczyk, P.; Kramkowski, K.; Dobrzyński, J. Bioremediation of Heavy Metals by the Genus Bacillus. Int. J. Environ. Res. Public. Health 2023, 20, 4964.

115. Elsanhoty, R.M.; Al-Turki, I.A.; Ramadan, M.F. Application of Lactic Acid Bacteria in Removing Heavy Metals and Aflatoxin B1 from Contaminated Water. Water Sci. Technol. 2016, 74, 625–638.

116. Wang, Y.; Han, J.; Ren, Q.; Liu, Z.; Zhang, X.; Wu, Z. The Involvement of Lactic Acid Bacteria and Their Exopolysaccharides in the Biosorption and Detoxication of Heavy Metals in the Gut. Biol. Trace Elem. Res. 2023.

117. Murthy, S.; Bali, G.; Sarangi, S.K. Effect of Lead on Metallothionein Concentration in Leadresistant Bacteria Bacillus cereus Isolated from Industrial Effluent. Afr. J. Biotechnol. 2011, 10, 15966–15972.

118. Gomaa, E.Z. Biosequestration of Heavy Metals by Microbially Induced Calcite Precipitation of Ureolytic Bacteria. Rom. Biotechnol. Lett. 2018, 24, 147–153.

119. Fakhar, A.; Gul, B.; Gurmani, A.R.; Khan, S.M.; Ali, S.; Sultan, T.; Chaudhary, H.J.; Rafique, M.; Rizwan, M. Heavy Metal Remediation and Resistance Mechanism of Aeromonas, Bacillus, and Pseudomonas: A Review. Crit. Rev. Environ. Sci. Technol. 2022, 52, 1868–1914.

120. Rekadwad, B. Microbial Systematics; CRC Press: Boca Raton, FL, USA, 2021.

121. Ringø, E.; Van Doan, H.; Lee, S.H.; Soltani, M.; Hoseinifar, S.H.; Harikrishnan, R.; Song, S.K. Probiotics, Lactic Acid Bacteria and Bacilli: Interesting Supplementation for Aquaculture. J. Appl. Microbiol. 2020, 129, 116–136.

122. Valipour, A.; Nedaei, S.; Noori, A.; Khanipour, A.A.; Hoseinifar, S.H. Dietary Lactobacillus Plantarum Affected on Some Immune Parameters, Air-Exposure Stress Response, Intestinal Microbiota, Digestive Enzyme Activity and Performance of Narrow Clawed Crayfish (Astacus leptodactylus, Eschscholtz). Aquaculture 2019, 504, 121–130.

123. Yi, Y.; Zhang, Z.; Zhao, F.; Liu, H.; Yu, L.; Zha, J.; Wang, G. Probiotic Potential of Bacillus velezensis JW: Antimicrobial Activity against Fish Pathogenic Bacteria and Immune Enhancement Effects on Carassius auratus. Fish Shellfish Immunol. 2018, 78, 322–330.

124. Huang, J.-B.; Wu, Y.-C.; Chi, S.-C. Dietary Supplementation of Pediococcus Pentosaceus Enhances Innate Immunity, Physiological Health and Resistance to Vibrio anguillarum in Orange-Spotted Grouper (Epinephelus coioides). Fish Shellfish Immunol. 2014, 39, 196–205.

125. Dejene, F.; Regasa Dadi, B.; Tadesse, D. In Vitro Antagonistic Effect of Lactic Acid Bacteria Isolated from Fermented Beverage and Finfish on Pathogenic and Foodborne Pathogenic Microorganism in Ethiopia. Int. J. Microbiol. 2021, 2021, 5370556.

126. Huy, N.D.; Ngoc, L.M.T.; Loc, N.H.; Lan, T.T.; Quang, H.T.; Dung, T. Isolation of Weissella Cibaria from Pacific White Shrimp (Litopenaeus vannamei) Gastrointestinal Tract and Evaluation of Its Pathogenic Bacterial Inhibition. Indian J. Sci. Technol. 2020, 13, 1200–1212.

127. Puvanasundram, P.; Chong, C.M.; Sabri, S.; Yusoff, M.S.; Karim, M. Multi-Strain Probiotics: Functions, Effectiveness and Formulations for Aquaculture Applications. Aquac. Rep. 2021, 21, 100905.

128. Midhun, S.J.; Neethu, S.; Arun, D.; Vysakh, A.; Divya, L.; Radhakrishnan, E.K.; Jyothis, M. Dietary Supplementation of Bacillus Licheniformis HGA8B Improves Growth Parameters, Enzymatic Profile and Gene Expression of Oreochromis niloticus. Aquaculture 2019, 505, 289–296.

129. Yang, G.; Tian, X.; Dong, S.; Peng, M.; Wang, D. Effects of Dietary Bacillus Cereus G19, B. Cereus BC-01, and Paracoccus marcusii DB11 Supplementation on the Growth, Immune Response, and Expression of Immune-Related Genes in Coelomocytes and Intestine of the Sea Cucumber (Apostichopus japonicus selenka). Fish Shellfish Immunol. 2015, 45, 800–807.

130. Zhao, Y.; Yuan, L.; Wan, J.; Sun, Z.; Wang, Y.; Sun, H. Effects of Potential Probiotic Bacillus Cereus EN25 on Growth, Immunity and Disease Resistance of Juvenile Sea Cucumber Apostichopus Japonicus. Fish Shellfish Immunol. 2016, 49, 237–242.

131. Zhang, J.-J.; Yang, H.-L.; Yan, Y.-Y.; Zhang, C.-X.; Ye, J.; Sun, Y.-Z. Effects of Fish Origin Probiotics on Growth Performance, Immune Response and Intestinal Health of Shrimp (Litopenaeus vannamei) Fed Diets with Fish Meal Partially Replaced by Soybean Meal. Aquac. Nutr. 2020, 26, 1255–1265.

132. Newaj-Fyzul, A.; Adesiyun, A.A.; Mutani, A.; Ramsubhag, A.; Brunt, J.; Austin, B. Bacillus Subtilis AB1 Controls Aeromonas Infection in Rainbow Trout (Oncorhynchus mykiss, Walbaum). J. Appl. Microbiol. 2007, 103, 1699–1706.

133. Sahandi, J.; Jafaryan, H.; Soltani, M.; Ebrahimi, P. The Use of Two Bifidobacterium Strains Enhanced Growth Performance and Nutrient Utilization of Rainbow Trout (Oncorhynchus mykiss) Fry. Probiotics Antimicrob. Proteins 2019, 11, 966–972.

134. Ringø, E.; Seppola, M.; Berg, A.; Olsen, R.E.; Schillinger, U.; Holzapfel, W. Characterization of Carnobacterium divergens Strain 6251 Isolated from Intestine of Arctic Charr (Salvelinus alpinus L.). Syst. Appl. Microbiol. 2002, 25, 120–129.

135. Ringø, E. The Ability of Carnobacteria Isolated from Fish Intestine to Inhibit Growth of Fish Pathogenic Bacteria: A Screening Study. Aquac. Res. 2008, 39, 171–180.

136. Vendrell, D.; Balcazar, J.L.; de Blas, I.; Ruiz-Zarzuela, I.; Gironés, O.; Muzquiz, J.L. Protection of Rainbow Trout (Oncorhynchus mykiss) from Lactococcosis by Probiotic Bacteria. Comp. Immunol. Microbiol. Infect. Dis. 2008, 31, 337–345.

137. Al-Dohail, M.A.; Hashim, R.; Aliyu-Paiko, M. Evaluating the Use of Lactobacillus acidophilus as a Biocontrol Agent against Common Pathogenic Bacteria and the Effects on the Haematology Parameters and Histopathology in African Catfish Clarias gariepinus Juveniles: L. Acidophilus as a Probiotic in African Catfish. Aquac. Res. 2011, 42, 196–209.

138. Zheng, C.N.; Wang, W. Effects of Lactobacillus Pentosus on the Growth Performance, Digestive Enzyme and Disease Resistance of White Shrimp, Litopenaeus vannamei (Boone, 1931). Aquac. Res. 2017, 48, 2767–2777.

139. Lee, S.H.; Beck, B.R.; Hwang, S.-H.; Song, S.K. Feeding Olive Flounder (Paralichthys olivaceus) with Lactococcus lactis BFE920 Expressing the Fusion Antigen of Vibrio OmpK and FlaB Provides Protection against Multiple Vibrio Pathogens: A Universal Vaccine Effect. Fish Shellfish Immunol. 2021, 114, 253–262.

140. Balcázar, J.L.; Vendrell, D.; De Blas, I.; Ruiz-Zarzuela, I.; Múzquiz, J.L. Effect of Lactococcus lactis CLFP 100 and Leuconostoc mesenteroides CLFP 196 on Aeromonas salmonicida Infection in Brown Trout (Salmo trutta). Microb. Physiol. 2009, 17, 153–157.

141. Thao, T.T.P.; Lan, T.T.P.; Phuong, T.V.; Truong, H.T.H.; Khoo, K.S.; Manickam, S.; Hoa, T.T.; Tram, N.D.Q.; Show, P.L.; Huy, N.D. Characterization Halotolerant Lactic Acid Bacteria Pediococcus pentosaceus HN10 and in Vivo Evaluation for Bacterial Pathogens Inhibition. Chem. Eng. Process.-Process Intensif. 2021, 168, 108576.

142. Tarkhani, R.; Imani, A.; Hoseinifar, S.H.; Moghanlou, K.S.; Manaffar, R. The Effects of Host-Associated Enterococcus faecium CGMCC1. 2136 on Serum Immune Parameters, Digestive Enzymes Activity and Growth Performance of the Caspian Roach (Rutilus rutilus caspicus) Fingerlings. Aquaculture 2020, 519, 734741.

143. Safari, R.; Adel, M.; Lazado, C.C.; Caipang, C.M.A.; Dadar, M. Host-Derived Probiotics Enterococcus casseliflavus Improves Resistance against Streptococcus Iniae Infection in Rainbow Trout (Oncorhynchus mykiss) via Immunomodulation. Fish Shellfish Immunol. 2016, 52, 198–205.

144. Ali, M.; Soltanian, S.; Mirghaed, A.T.; Akhlaghi, M.; Hoseinifar, S.H.; Esmailnejad, A. The Effect of Oral Administration of Lactic Acid Bacteria Isolated from Kefir on Intestinal Microbiota, Growth Performance and Survival in Juvenile Rainbow Trout, Oncorhynchus mykiss. Int. J. Aquat. Biol. 2020, 8, 35–49.

145. Sakai, M.; Yoshida, T.; Atsuta, S.; Kobayashi, M. Enhancement of Resistance to Vibriosis in Rainbow Trout, Oncorhynchus mykiss (Walbaum), by Oral Administration of Clostridium butyricum Bacterin. J. Fish Dis. 1995, 18, 187–190.

146. Meng, X.; Wu, S.; Hu, W.; Zhu, Z.; Yang, G.; Zhang, Y.; Qin, C.; Yang, L.; Nie, G. Clostridium butyricum Improves Immune Responses and Remodels the Intestinal Microbiota of Common Carp (Cyprinus carpio L.). Aquaculture 2021, 530, 735753.

147. Kahyani, F.; Pirali-Kheirabadi, E.; Shafiei, S.; Shenavar Masouleh, A. Effect of Dietary Supplementation of Potential Probiotic Weissella Confusa on Innate Immunity, Immune-related Genes Expression, Intestinal Microbiota and Growth Performance of Rainbow Trout (Oncorhynchus mykiss). Aquac. Nutr. 2021, 27, 1411–1420.

148. Rengpipat, S.; Rueangruklikhit, T.; Piyatiratitivorakul, S. Evaluations of Lactic Acid Bacteria as Probiotics for Juvenile Seabass Lates calcarifer. Aquac. Res. 2008, 39, 134–143.

149. Jinendiran, S.; Archana, R.; Sathishkumar, R.; Kannan, R.; Selvakumar, G.; Sivakumar, N. Dietary Administration of Probiotic Aeromonas veronii V03 on the Modulation of Innate Immunity, Expression of Immune-Related Genes and Disease Resistance against Aeromonas Hydrophila Infection in Common Carp (Cyprinus carpio). Probiotics Antimicrob. Proteins 2021, 13, 1709–1722.

150. Abd El-Rhman, A.M.; Khattab, Y.A.E.; Shalaby, A.M.E. Micrococcus Luteus and Pseudomonas Species as Probiotics for Promoting the Growth Performance and Health of Nile Tilapia, Oreochromis niloticus. Fish Shellfish Immunol. 2009, 27, 175–180.

151. ABdel-Tawwab, M.; Mousa, M.A.A.; Mohammed, M.A. Use of Live Baker’s Yeast, Saccharomyces Cerevisiae, in Practical Diet to Enhance the Growth Performance of Galilee Tilapia, Sarotherodon galilaeus (L.), and Its Resistance to Environmental Copper Toxicity. J. World Aquac. Soc. 2010, 41, 214–223.

152. Banu, M.R.; Akter, S.; Islam, M.R.; Mondol, M.N.; Hossain, M.A. Probiotic Yeast Enhanced Growth Performance and Disease Resistance in Freshwater Catfish Gulsa Tengra, Mystus Cavasius. Aquac. Rep. 2020, 16, 100237.

153. Reyes-Becerril, M.; Alamillo, E.; Angulo, C. Probiotic and Immunomodulatory Activity of Marine Yeast Yarrowia lipolytica Strains and Response against Vibrio parahaemolyticus in Fish. Probiotics Antimicrob. Proteins 2021, 13, 1292–1305.

154. Raida, M.K.; Larsen, J.L.; Nielsen, M.E.; Buchmann, K. Enhanced Resistance of Rainbow Trout, Oncorhynchus mykiss (Walbaum), against Yersinia Ruckeri Challenge Following Oral Administration of Bacillus subtilis and B. licheniformis (BioPlus2B). J. Fish Dis. 2003, 26, 495–498.

155. Sayed Hassani, M.H.; Jourdehi, A.Y.; Zelti, A.H.; Masouleh, A.S.; Lakani, F.B. Effects of Commercial Superzist Probiotic on Growth Performance and Hematological and Immune Indices in Fingerlings Acipenser baerii. Aquac. Int. 2020, 28, 377–387.

156. Zhang, M.; Pan, L.; Fan, D.; He, J.; Su, C.; Gao, S.; Zhang, M. Study of Fermented Feed by Mixed Strains and Their Effects on the Survival, Growth, Digestive Enzyme Activity and Intestinal Flora of Penaeus vannamei. Aquaculture 2021, 530, 735703.