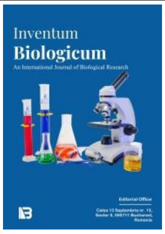
Inventum Biologicum: *An International Journal of Biological Research*
2022, Vol. 2, Issue 2, pp. 64-76

Inventum Biologicum

Journal homepage: www.worldbiologica.com/ib



Review paper

Perspectives and Prospects of Probiotics in Aquaculture: A Review

Dhruv Dave*, [a], Dhaval Prajapati [b], Dipika Pandya [a], Shreya Modi [c], Shreyas Bhatt [a]

[a] *Department of Life Sciences, Hemchandracharya North Gujarat University, Patan 384265, Gujarat, India*
[b] *Mehsana Urban Institute of Sciences, Ganpat University, Mahesana 384012, Gujarat, India*
[c] *Shri Sarvajanik Science College, Mehsana 384001, Gujarat, India*

ARTICLE INFO

Article history

Received 08 June 2022
Revised 23 June 2022
Accepted 24 June 2022
Published 26 June 2022

Keywords

Aquaculture
Colony forming units
Disease control
Growth
Probiotics
Survival

ABSTRACT

The use of probiotics in aquaculture is now generally acknowledged due to the rising need for environmentally friendly aquaculture. But it is obvious that we need to know more about gut microbiology, optimal probiotic production, and probiotic safety evaluation. Probiotics, which have long been used to raise animals, are now being employed in aquaculture. Live cells or a substrate that enhances immune function, improves digestion, and stimulates development are referred to as probiotics. Probiotics can help enhance the quality of water. Because of their significance and future potential in aquaculture systems, probiotics are already frequently used. Commercial and local fish growing facilities in aquaculture systems can be promoted by more up-to-date probiotic production, validation, and usage. This article provides an overview of current knowledge about the use of probiotics in aquaculture, including a description of their application, possibilities, and challenges. It also defines probiotics and explains how they work.

1. Introduction

Aquaculture represents a multi-billion sector that continually grows and expands in the aquaculture system. In 2018, aquaculture delivered around 178.5 million tons of fish to the world, and from Asia, inland production contributions were 66% of the whole world (FAO, 2020). Marine aquaculture accounted for around 84.4% of total capture fisheries, with 12% inland capture. Aquatic species are continually and inextricably linked to the compo--sition and changes in their surroundings. Microbial intervention might be critical in fisheries and aquaculture sector productivity, and efficient probiotic treatments may give a broad spectrum of nonspecific disease protection (Salunke et al., 2020, Rengpipat et al., 2003; Panigrahi and Azad, 2007). Several gram-positive bacterial species, gram-negative bacteria, some bacteriophages, yeasts, and some unicellular algae were the potent probiotic mic-

*Corresponding author: Dhruv Dave
E-mail: ddp02@ganpatuniversity.ac.in
redgarden2009@gmail.com

DOI https://doi.org/10.5281/zenodo.6750427

-robial species studied for use in aquaculture (Irianto and Austin, 2002).

Based on in vitro antagonism, bacterial species were selected as a probiotic (Verschuere et al., 2000) and on the capacity for adhesion and colonization, and growth in the mucus of the gut (Vine et al., 2004; Irianto and Austin, 2002). Probiotics or good bacteria that inhibit diseases in many ways are increasingly being explored as a substitute for chemical or antibiotic treatment. Probiotics have long been used in human and animal diets (Rinkinen et al., 2003; Fuller, 1992; Mulder et al., 1997), and they have been lately beginning to be used in fisheries and aquaculture sector (Bachere, 2003; Verschuere et al., 2000; Gomez et al., 2002, Gatesoupe, 2002; Irianto and Austin, 2002). Considering these problems and the potentially lethal effect of antibiotic residues in fish or aquaculture products on human health, the United States and the European Union have implemented bans or restrictions on antibiotics (Grenni et al., 2018; Capita and Alonso, 2013).

At the high population densities prevalent in aquaculture ponds, genetic transmission by plasmid transduction, virus transduction, or even direct transformation from DNA absorbed to particles in the water or on substrate surfaces can be viable options (Matias et al., 2002). Their pathogens are also supported by the water environment, where they can achieve species richness high enough to cause disease or make the host immune-compromised (Moriarty, 1999). Furthermore, intensive stocking or poor seed conditions contribute significantly to the breakdown of the "host-pathogen–environment" balance resulting in disease breakout. Antibiotics were widely used to control infections, and the uncontrolled chemical and antibiotic medicines use resulted in the growth of several antibiotic-resistant bacterial species. Production in many Asian countries fallen (Karunasagar et al., 1994). As a result, antibiotics are not effective against causative agents in treating luminous vibriosis (Defoirdt et al., 2007; Romero et al., 2012)., The effects of emerging antibiotic-resistant bacteria on aquaculture include the risk of harmful bacteria to humans. Antibiotics have put severe selection stress on specific bacteria, which had adapted to this condition mainly through a level to the level transfer of antibiotic resistance genes containing the plasmid. Some bacterial infections can produce plasmid-mediated resistance. In marine *Vibrio* species, antibiotic resistance gene-containing plasmids have been found, and they may be cross-exchanged. Several methods like water filtration and NaCl, ozonization, and UV radiation to lower harmful bacterial load in aquaculture are effective, although not as much as probiotics. The most successful strategy has been observed to be probiotics to supplement production. As a result, a continuing hunt for new and robust probiotic strains is required to tackle newly emerging diseases. The main goals of this study are to explain the concepts, modes of action, and selection criteria for probiotics and outline their uses in fisheries and aquaculture.

2. What is a Probiotic?

The name probiotic means "for life" and it is originally from the Greek terms "pro" and "bios" (Ebner et al., 2014). Parker (1974) coined the term "probiotic" which he defined as "organisms and chemicals that help for gut microbial equilibrium" Following this, various revisions were offered to shorten the original definition (Irianto and Austin, 2002; Salminen et al., 1998). Fuller (1992) defined it as "a live microbial feed additive that benefits the host animal by increasing its intestinal microbial balance". Verschuere et al. (2000) proposed a modified definition: "a live microbial adjunct that has a beneficial effect on the host by modifying the host-associated or ambient microbial community, ensuring improved use of the feed or enhancing its nutritional value, enhancing the host response to disease, or improving the quality of its ambient environment". A probiotic, by term, will help the host organism, moreover nutritionally or by altering its immediate surrounding atmosphere (Kesarcodi-Watson et al., 2008). Probiotics are bacteria or products from bacteria that support the physical condition of different other species. According to Lilley and Stillwell (1965), it is clear that the chemicals released by one microbe increase the host animal's growth animal. As per the World Health Organization/Food and Agriculture Organization of the United Nations (WHO/FAO), live probiotic bacteria taken in sufficient quantities give a health benefit to the host (Hotel and cordoba, 2001). A probiotic bacterial found in both indigenous and external microbiota of aquaculture species. Fighting bacterial pathogens for nutrition and preventing pathogen growth are feasible options for the prophylactic use of pesticides, antibiotics, chemicals, and biocides. The central indigenous Microbiota of many marine fish species is gram-negative, facultatively anaerobic bacteria like *Vibrio* and *Pseudomonas* (Onarheim et al., 1994). As in freshwater fish, indigenous microbiota dominant genera are *Aeromonas* and *Plesiomonas*, members of the family *Enterobacteriaceae* and obligate anaerobic bacteria from the genera *Bacteroides*, *Fusobacterium*, and *Eubacterium* (Sakata, 1990).

In contrast to saltwater fish, freshwater fish species' indigenous microbiota is dominated by members of the genera Bacillus spp., a spore-forming bacteria, and *Saccharomyces cerevisiae*, a yeast, have both garnered a lot of attention. It seems to have the ability to adhesion ability to create bacteriocins. The yeast has been demonstrated to have immunological stimulatory activities and the creation of inhibitory chemicals.

3. Source of Probiotics

Many different probiotic candidates have been studied to determine their potential, including semi-intensive aquaculture systems, cage culture in the reservoir or rivers, farm pond culture, and natural lakes (Chantharasophon et al., 2011; Chemlal-Kherraz et al., 2012). Allochthonous or exogenous microbes are found outside the host, whereas autochthonous or indigenous microbes are found within the host. Various bacterial populations (10^2–10^{11} CFU/g) in living and non-living habitats have been found, such as aquatic animals, snow, humans, soils, groundwater, sediments, freshwater, and saltwater (Liu et al., 2010; Nimrat et al., 2012), There are generally 10^2–10^9 CFU/g of microbial burden in aquatic species' guts (Pond et al., 2006; Balcázar et al., 2007; Wu et al., 2010). Tilapia bacterial loads range from 10^4 to 10^9 CFU/g in the gut, from 10^5 to 10^8 CFU/g on the gills, to the 10^3–10^7 CFU/g in water culture, and from the 10^6–10^8 CFU/g in the pond sediment, whereas pathogenic bacterial loads were reported to be 10^1–10^3 CFU/g in the gut of the tilapia and water culture. In water environments, foreign bacteria (from human or animal sources, air or soil) can alter microbial populations, resulting in the colonization of aquatic animals guts with new strains of bacteria (Verschuere et al., 2000).

4. Mechanisms of Action

The valuable bacterial strains produce a wide range of enzymes such as protease, amylase, CGTase, and lipase, which help digest unconsumed feed and excrement in the ponds and are probable involvement in animal nutrition, boosting feed digestibility and feed utilization. The mode of probiotics action includes pathogen inhibition via competition for attachment sites. Also, it shows the production of bacteriocin-like compounds. Likewise, it involves nutrient competition for growth and survival (specifically iron in marine microbes). The Immune stimulatory actions with nutritional benefits also enhance digestion and absorption in pathogens used for enzymatic activity, which is altered by probiotic bacteria (Fuller, 1992; Kesarcodi-Watson et al., 2008). Probiotics have been demonstrated to improve colonization and have direct pathogen inhibitory effects. Probiotic bacteria can inhibit as a pathogen by generating an antagonistic effect with chemicals and competitive segregation (antagonism for attachment sites and nutrients). The bacterial species consume or degrade organic materials to improve the water quality in the aquatic ecosystem.

5. Competitive Exclusion

The microbial antagonism effect is expected in the environment, and microbial relationships play a crucial role in balancing competing for beneficial and potentially harmful pathogens. However, husbandry procedures and ecological factors that promote the expansion of specific probiotic bacterial species affect microbial communities' composition. It is generally recognized that the normal microflora of aquatic animals' gastrointestinal tracts is altered, for example, by intake of other microbes; thus, microbial treatment represents a possible method for reducing or eliminating the incidence of opportunist pathogens (Balcazar, 2002; Balcazar et al., 2006). A study of antibiotic-producing marine bacteria shown by Rosenfeld and Zobell (1947), explained study about biological control agents had begun. Inhibitory effects were seen against *Vibrio anguillarum* in aquaculture by *Thalassobacter utilis*. This strain improved the survival rate of crab larvae *Portunus trituberculatus* while simultaneously decreasing the amount of *Vibrio* sp. in the aquatic condition to grow the larvae (Nogami and Maeda, 1992; Nogami et al., 1997; Middlemiss et al., 2015). The fish pathogen *V.*

anguillarum growth is inhibited by the bacterial strains found in the intestinal and skin mucus of adult marine turbot *(Scophthalmus maximus*) and dab (*Limanda limanda*) (Vijayaram and Kannan, 2018; Olsson et al., 1992). *Vibrio alginolyticus* strains as probiotics in *Ecuadorian hatcheries* have been advocated to boost white shrimp's growth and survival rate (*Litopenaeus vannamei*) post-larvae. In intensive larviculture systems, competitive exclusion of possibly harmful bacteria effectively decreases or eliminates the requirement for antibiotic prophylaxis (Garriques, 1995). *Pseudomonas* I2 can control shrimp pathogenic *vibrios*, a marine bacterium strain obtained from estuarine environmental materials that recently generated inhibitory chemicals. This antibacterial compound is demonstrated for heat stable and low molecular weight, which is soluble in chloroform and resistant to proteolytic enzymes (Chythanya et al., 2002).

6. Source of Nutrients and Enzymatic Contribution to Digestion

According to several types of research, microorganisms are thought to have a significant part in the digestion process of aquatic animals. In fish, *Clostridium* sp. and *Bacteroides* have been found to aid in the host's nutrition, mainly by supplying fatty acids and vitamins (Sakata, 1990). Ring et al. (1995) found that *Pseudomonas* sp., *Microbacterium* sp., *Agrobacterium* sp., *Staphylococcus* sp., and *Brevibacterium* sp. all have a role in nutritional processes in arctic charr (*Salvelinus alpinus* L.). Furthermore, certain bacteria may help bivalve digestion by creating extracellular enzymes, including lipases and proteases, and providing essential growth factors (Prieur et al., 1990). Adult penaeid shrimp (*Penaeus chinensis*) have a comparable microbial flora, which supplies a complement of enzymes for digestion and the production of chemicals assimilated by the animal (Lara-Flores, 2011). Microbiota can be a source of vitamins or vital amino acids, and microbial activity in the digestive tract can be a source of additional food (Dall and Moriarty, 1983).

7. Improvement of Water Quality

Bacillus sp. in particular, has been associated with enhanced water quality. According to the research, gram-positive bacteria convert organic materials to CO_2 more efficiently than gram-negative bacteria. During the manufacturing process, high populations of gram-positive bacteria can aid in minimizing the formation of dissolved and particulate organic carbon. *Bacillus* sp. increased water quality, survival, and growth rates in young *Penaeus monodon* improved the fish's health state, and reduced pathogenic vibrios (Dalmin et al., 2001; Fdhila et al., 2017).

8. Selection of Probiotics

Pathogens are exposed to putative probiotics or their extracellular products in a liquid (Sotomayor and Balcazar, 2016; Nandi et al., 2017) or solid medium to identify probiotics (Dopazo et al., 1988; Chythanya et al., 2002). In vitro activity in well-diffusion experiments and broth cultures, however, cannot be used to predict potential in vivo effects, according to Gram et al. (1999). In vitro antagonism of *Pseudomonas fluorescens* against *Aeromonas monicida*, for example, does not protect Atlantic salmon against furunculosis but is an effective probiotic in rainbow trout, offering protection against vibriosis (Gram et al., 2001). As a result, knowing the strain's origin (it's best to use strains isolated from the host), safety (non-pathogenicity), and capacity to survive transfer through the host's gastrointestinal system is crucial (e.g., bile tolerance, acidic pH, and enzyme-like proteases). The ability of microorganisms to colonize is usually recognized as one of the primary selection criteria for potential probiotics, which is the ability of probiotics to adhere effectively to the intestinal wall to limit or protect against pathogen colonization (Khaneghah et al., 2020; Monteagudo et al., 2019). In addition, potential probiotics must positively impact the host (e.g., improved nutritional quality and a solid immunological response). Finally, the probiotic must survive in regular preservation conditions and be suitable for industrial use in terms of technology. To summarise, the following are the approaches for selecting probiotic bacteria for use in aquaculture:

i) obtaining basic information,
ii) obtaining possible probiotics,
iii) analyzing putative probiotics' ability to outcompete pathogenic strains,
iv) assessing the pathogenicity of potential probiotics, and

v) determining the host's reaction to possible probiotics.

Probiotics can be delivered to the host or introduced to its aquatic habitat in a variety of ways including live food:

i) live food (Gomez-Gil et al., 1998),
ii) bathing (Austin et al., 1995; Gram et al., 1999),
iii) an additive to culture freshwater (Spanggaard et al., 2001), and
iv) artificial foodstuffs (Spanggaard et al., 2001; Rengpipat et al., 2000).

For example, tanks inhibited harmful bacteria invasion by daily injection of probiotic bacteria at a density of 10^5 CFU ml^{-1} into larval white shrimp (*L. vannamei*) during larval culture (Ahmadifard et al., 2019).

9. Regulations on Probiotics are Being Considered

The foundation upon which feed additives in the European Union were built has evolved in recent years. In the case of feed additives, efforts have been made to ensure that human health, animal health and welfare, environmental users, and consumer interests are well protected. The European Parliament produced the White Paper on Food Safety and Regulation, EC-No. 178/2002, to develop a food safety policy for the European Union, and the European Food Safety Authority (EFSA) was founded (Regulation EC-No. 178/2002). From primary agriculture to animal feed safety to the consumer food supply, EFSA is involved in food production and delivery stages. Council Directive 70/524/EEC governs feed additives' licensing, marketing, and usage. Before a feed additive can be marketed or utilized, it must first be approved under the Directive's rules. To receive clearance, a manufacturer must submit a dossier with data and research demonstrating the product's efficacy and safety for animals, consumers, and the environment.

10. Factors Affecting the Efficiency of Probiotic Species

10.1 In vitro Trials

A few of the factors examined in these studies include hemolysis of the blood and antibiotic resistance, adherence assays, pH, and bile salt tolerance. Various sources have recommended various ways of selecting probiotics. Such activities as blood hemolysis and pathogenic inhibition are performed after the initial examination of pathogenic activities (Gram et al., 2001; Carnevali et al., 2004; Venkat et al., 2004; Balcázar et al., 2008; Zorriehzahra et al., 2016; Bentzon-Tilia et al., 2016, Cao et al., 2018; Kuebutornye et al., 2019; Kuebutornye et al., 2020; Noor et al., 2020; Dawood et al., 2020). Blood hemolysis and pathogenic activity inhibition (Gobinath and Ramanibai, 2012). *In vitro* investigations can save money by reducing the number of animals needed for *In vivo* testing and the number of samples required. To begin testing antagonistic activity, pathogen antagonism assays are frequently recommended (Balcázar et al., 2008; Chemlal-Kherraz et al., 2012). Pathogenic inhibition and adhesive potentials have been employed in specific research (Grześkowiak et al., 2012), while others solely used the bacterial aggregation feature (Etyemez and Balcazar, 2016). Probiotics' potential can be gauged by looking at the relationship between cell surfaces—hydrophobicity and auto-aggregation (Wang et al., 2007). Researchers have looked at various criteria when choosing probiotics, including the ability to produce lactic acid and pH and bile salt tolerances due to pathogenic antagonism and antibiotic susceptibility. Munoz-Atienza et al. (2013), described how to choose probiotics based on hemolysin synthesis, antibiotic susceptibility, bile salt deconjugation, mucin breakdown, enzymatic activity, and antibiotic resistance genes. Dhruv et al. (2021) revealed the probiotic potential of gut microflora of Indian Major Carps (IMC). In certain studies, the characteristics of each isolate, including cell surface properties, auto-aggregation and co-aggregation, and adhesiveness to various substrates, have been observed to be unique.

10.2 In vivo Trials

Fish were given intra peritoneal administered probiotic cells to see how many died without developing severe pathogenic signs (Alyet al., 2008; Abd El-Rhman et al., 2009). Probiotics for tilapia have been evaluated using several criteria, such as the growth rate, illness resistivity, and several characteristics in the gut, and for microbiological changes, histological analyses, and hematological testing.

11. Use of Bacterial Species as a Probiotic

Increased productivity, illness resistance, enhanced immune function, and increased number of helpful microbes in the stomach and water are just a few of the health benefits of employing probiotics in aquaculture. By utilizing probiotics in aquaculture, it is possible to prevent antibiotic-related side effects. Moreover, probiotic potential has been shown to produce high efficiency on low protein diets, thereby lowering production costs. Additionally, different probiotic characteristics (high adherence versus low adherence) had different effects on hybrid tilapia FCR and weight gain. On the other hand, probiotics are effective even under extreme stock density and protein levels (Lara-Flores et al., 2003). At the same time, it seems to negatively influence tilapia fry growth (He et al., 2013; Standen et al., 2013). According to several studies, probiotics are beneficial for growth, immunity, blood chemistry, hematological and antioxidant properties, as well as for the gut microbiome and general public health. Adding probiotics to feed supplements allows for proper digestion and nutritional availability. Probiotics can help improve immune responses by being added to fish meals. When added to fish meals, probiotics can help prevent or treat various fish ailments. Several studies have shown that probiotics can help with growth (Table 1).

12. Discussion

From the above, it is clear that more caution must be exercised during the actinobacterial probiotic selection process, as probiotic research requires many tests to find a good strain (Kesarcodi-Watson et al., 2008). Species, strain biotype, water activity, temperature, hydrogen-ion concentration (pH), osmotic pressure, mechanical friction, and oxygen affect probiotic stability. The enzymes produced by marine actinobacteria provide a vital niche for probiotics, prebiotics, or their combination (synbiotics) approaches in aquaculture, with the ever-increasing need for probiotics and prebiotics. For selection criteria of possible probiotics, it is necessary to understand the mechanisms of action. To better understand the composition and functions of the indigenous microbiota and microbial cultures of probiotics more information on host/microbe interactions in vivo and the development of monitoring methods (e.g., molecular biology) are still needed. Probiotics in aquaculture have mainly been based on historical and empirical evidence rather than scientific criteria. Probiotics are an essential management tool, but their effectiveness is contingent on knowledge of the nature of competition among species or strains.

13. Conclusion

The review of literature uncovered the promising impacts of probiotics in aquaculture. Aquaculture has arisen as a quickest developing approach as it offers a great animal protein that upholds the nutritional and food security. This developing aquaculture creation has number of imperatives as disease outbreak, high pressure condition, deficiency of fish feast for protein sources and so forth. The application of probiotics in aquaculture has acquired main focus as microbial candidates to maintain the health and wellbeing of number of fishes and other aquaculture animals. As compared to other physical and chemical methods, use of probiotics in aquaculture have been proved as a good alternative to improve feed utilization, stress response, maintenance of tissue integrity, disease resistance, and also to improve the quality of water for sustainable aquaculture. Therefore, the review implies that, probiotics has given new direction in modern aquaculture as a viable alternative for sustainable aquaculture.

Funding Information

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Conflict

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to thank Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, for providing infrastructure and library facility.

Table 1 Applications of some selected bacterial species as a probiotic in aquaculture

Probiotic bacteria	Probiotics are used on aquatic organisms	Beneficial effects	References
Aeromonas hydrophila	*Oncorhynchus mykiss* (Rainbow trout)	Reduces *Aeromonas salmonicida* infection	Irianto and Austin, 2002a, 2002b
Aeromonas media A199	*Crassostrea gigas* (Pacific oyster)	*Vibrio tubiashii* infection Reduced	Gibson 1999, 1998
Aeromonassobria GC2	Rainbow trout	Protection against Infection of *Lactococcus garvieae* pro and *Streptococcus iniae*. Similarly protects against *Aeromonas bestiarum* (causative of fin rot) and Ichthyophthirius	Pieters et al., 2008; Brunt and Austin, 2005
Agarivorans albus F1-UMA	*Haliotis rufescens* (Abalone)	Viability has improved.	Silva-Aciareset al., 2011
Alteromonas CA2	Pacific oyster	Viability has improved.	Douillet and Langdon, 1994
Alteromonas macleodii 0444	*Perna canaliculus* (Greenshell mussel) *Pecten maximus* (Scallop)	*Vibrio splendidus* infection Control *Vibrio coralliilyticus* and *V.splendidus infection* Control	Kesarcodi-Watson et al., 2010, 2012
*Burkholderiacepacia*Y021	*Crassostreacorteziensis* (Cortezoyster)	Viability has improved, and the growth rate	Granados et al., 2012
Enterobacter amnigenus	Rainbow trout	Resistance to *Flavobacterium psychrophilum* has increased.	Burbank et al., 2011
Neptunomonas 0536	*Perna canaliculus* (Greenshell mussel)	*Infection with V. splendidus is under control.*	Kesarcodi-Watson et al., 2010, 2012
Pseudomonas aeruginosa, *Pseudomonas synxantha*	*Penaeuslatisulcatus* (Western king prawns)	The state of my health and the immune system has improved.	Hai et al., 2009
Shewanella putrefaciens	*Sparusaurata L.* (Gilthead seabream)	Juvenile growth has improved.	De la Banda et al., 2012;
Arthrobacter XE-7	*L. vannamei* (Pacific white shrimp)	Microbes in the intestine are altered.	Li et al., 2008
Bacillus circulans PB7	*Labeo rohita* (Rohu)	It protects against *A. hydrophila* and acts as an immunological booster.	Bandyopadhyay and Mohapatra, 2009
Bacillus subtilis and *Bacillus licheniformis*	Trout	Protects against *Yersinia ruckeri*, as well as bacterial pathogens.	Raida et al., 2003 Muras et al., 2021
Bacillus subtilis	*Labeo rohita* (Indian major carp) White shrimp *Ictalurus punctatus* (Channel catfish) and *Pangasianodon hypophthalmus* (Striped catfish)	*A. hydrophila* is controlled. Immunity to *V. harveyi* has improved, as has resistance to it. Due to Infection of *Edwardsiell aictaluri,* the mortality rate has decreased	Kumar et al., 2006 Zokaeifar et al., 2012 Zokaeifar et al., 2014 Ran et al., 2012
Bacillus subtilis UTM 126	*Litopenaeus vannamei* (Whiteshrimp)	Protection against vibriosis	Das et al., 2006
Lactococcuslactis	*Cyprinus carpio* (Common carp)	against *Aeromonashydrophila* performance, innate immune response and disease resistance increases	Feng et al., 2019
Paenibacillusehimensis NPUST1	*Oreochromis niloticus* (Nile tilapia)	bacteriocin-like activity improves growth performance and immunity against *Aeromonas hydrophila* and *Streptococcus iniae*	Chen et al., 2019
Arthrobacter XE-7	*Penaeus vannamei* (shrimp larvae culture)	improved survival and growth rates, phenoloxidase activity, phagocytic activity, and clearance efficiency of hemocyte	Xia et al., 2014
Roseobacter sp. BS107	Scallop larvae	Pathogen inhibition	Ruiz et al., 1999

Flavobacterium sasangense BA-3	Carp Culture	affected the innate immune parameters in a beneficial way	Chi et al., 2014
Saccharomyces cerevisiae	Tilapia	increase gut microvilli length and trypsin activity	Ran et al., 2016
Bacillus baekryungensis	Sea cucumber (*Apostichopus japonicus*)	Improves growth has been reported in sea cucumber	Yan et al., 2014
Bacillus pumilus	*Epinephelus coioides*	improved antagonistic activity	Sun et al., 2016
Bacillus clausii	*Epinephelus coioides*	improves feed utilization	Wang et al., 2018
Bacillus coagulans	*Oreochromis niloticus* (Tilapia) *Penaeus vannamei*	Improves immune response and growth performance The activity of digestive enzymes rises.	Zhou et al., 2010 Xu et al., 2014 Zhou et al., 2009
Bacillus velezensis	*Carassius auratus*	Antimicrobial action against microorganisms that cause disease in fish.	Yi et al., 2018
Clostridium butyricum	-	Influence of growth factor supplements	Vandak et al., 1995
Lactobacillus rhamnosus	*Danio rerio*	Improves reproduction	Gioacchini et al., 2010
Lactobacillus delbrueckii	*Cyprinus carpio*	enhanced immunity	Zhang et al., 2017
Lactobacillus casei BL23	*Danio rerio*	significantly increase fecundity rate	Qin et al., 2017
Lactobacillus plantarum	Pacific white shrimp	Increase growth and anti-stress capacity	Zheng et al., 2017 Xie et al., 2018
Weissella confusa LS13	sea cucumber	Increase growth performance	Chen et al., 2018
Pseudomonas stutzeri	-	improved both water quality and works as a denitrifying bacteria	Gaoet al., 2019
Pseudoalteromonas elyakovii HS1	sea cucumber	Increase the number of total coelomocytes, respiratory burst activity, lysozyme activity, and ACP activity.	Chi et al., 2014
Rhodopseudomonas palustris G06	white shrimp	Improves the performance of juvenile white shrimp in terms of growth.	Wang and Gu, 2010

References

1. Abd El-Rhman, A. M., Khattab, Y. A., & Shalaby, A. M. (2009). Micrococcus luteus and Pseudomonas species as probiotics for promoting the growth performance and health of Nile tilapia, Oreochromis niloticus. *Fish & Shellfish Immunology*, *27*(2), 175-180.
2. Ahmadifard, N., Aminlooi, V. R., Tukmechi, A., & Agh, N. (2019). Evaluation of the impacts of long-term enriched Artemia with Bacillus subtilis on growth performance, reproduction, intestinal microflora, and resistance to Aeromonas hydrophila of ornamental fish Poecilia latipinna. *Probiotics and antimicrobial Proteins*, *11*(3), 957-965.
3. Aly, S. M., Abd-El-Rahman, A. M., John, G., & Mohamed, M. F. (2008). Characterization of some bacteria isolated from Oreochromis niloticus and their potential use as probiotics. *Aquaculture*, *277*(1-2), 1-6.
4. Aly, S. M., Mohamed, M. F., & John, G. (2008).Effect of probiotics on the survival, growth and challenge Infection in Tilapia nilotica (*Oreochromis niloticus*). *Aquaculture research*, *39*(6), 647-656.
5. Austin, B., Stuckey, L. F., Robertson, P. A. W., Effendi, I., & Griffith, D. R. W. (1995). A probiotic strain of Vibrio alginolyticus effective in reducing diseases caused by Aeromonas salmonicida, Vibrio anguillarum and Vibrio ordalii. *Journal of fish diseases*, *18*(1), 93-96.
6. Bachère, E. (2003). Anti-infectious immune effectors in marine invertebrates: potential tools for disease control in larviculture. *Aquaculture*, *227*(1-4), 427-438.
7. Balcazar, J. L. (2002). Use of probiotics in aquaculture: general aspects. In *Memoriasdel Primer CongresoIberoamericano Virtual de Acuicultura, Zaragoza, Spain* (pp. 877-881).
8. Balcázar, J. L., De Blas, I., Ruiz-Zarzuela, I., Cunningham, D., Vendrell, D., &Múzquiz, J. L. (2006).The role of probiotics in aquaculture. *Veterinary microbiology*, *114*(3-4), 173-186.
9. Balcázar, J. L., De Blas, I., Ruiz-Zarzuela, I., Vendrell, D., Calvo, A. C., Márquez, I., ...& Muzquiz, J. L. (2007). Changes in intestinal microbiota and humoral immune response following probiotic administration in brown trout (Salmo trutta). *British journal of nutrition*, *97*(3), 522-527.
10. Balcázar, J. L., Vendrell, D., de Blas, I., Ruiz-Zarzuela, I., Muzquiz, J. L., & Girones, O. (2008). Characterization of probiotic properties of lactic acid bacteria isolated from intestinal microbiota of fish. *Aquaculture*, *278*(1-4), 188-191.
11. Bentzon-Tilia, M., Sonnenschein, E. C., & Gram, L. (2016). Monitoring and managing microbes in aquaculture–Towards a sustainable industry. *Microbial biotechnology*, *9*(5), 576-584.
12. Cao, J., Zhang, J., Ma, L., Li, L., Zhang, W., & Li, J. (2018). Identification of fish source Vibrio alginolyticus and evaluation of its bacterial ghosts vaccine immune effects. *MicrobiologyOpen*, *7*(3), e00576.
13. Capita, R., & Alonso-Calleja, C. (2013). Antibiotic-resistant bacteria: a challenge for the food industry. *Critical reviews in food science and nutrition*, *53*(1), 11-48.
14. Carnevali, O., Zamponi, M. C., Sulpizio, R., Rollo, A., Nardi, M., Orpianesi, C., ...& Cresci, A. (2004). Administration of probiotic strain to improve sea bream wellness during development. *Aquaculture International*, *12*(4), 377-386.
15. Chantharasophon, K., Warong, T., Mapatsa, P., & Leelavatcharamas, V. (2011).High potential probiotic Bacillus species from gastrointestinal tract of Nile tilapia (Oreochromis niloticus). *Biotechnology*, *10*(6), 498-505.
16. Chemlal-Kherraz, D., Sahnouni, F., Matallah-Boutiba, A., & Boutiba, Z. (2012). The probiotic potential of lactobacilli isolated from Nile tilapia (Oreochromis niloticus) 's intestine. *African Journal of Biotechnology*, *11*(68), 13220-13227.
17. Chemlal-Kherraz, D., Sahnouni, F., Matallah-Boutiba, A., & Boutiba, Z. (2012). The probiotic potential of lactobacilli isolated from Nile tilapia (Oreochromis niloticus) 's intestine. *African Journal of Biotechnology*, *11*(68), 13220-13227.
18. Chen, J., Ren, Y., Wang, G., Xia, B., & Li, Y. (2018). Dietary supplementation of biofloc influences growth performance, physiological stress, antioxidant status and immune response of juvenile sea cucumber Apostichopus japonicus (Selenka). *Fish & shellfish immunology*, *72*, 143-152.
19. Chen, S. W., Liu, C. H., & Hu, S. Y. (2019). Dietary administration of probiotic Paenibacillus ehimensis NPUST1 with bacteriocin-like activity improves growth performance and immunity against Aeromonas hydrophila and Streptococcus iniae in Nile tilapia (Oreochromis niloticus). *Fish & shellfish immunology*, *84*, 695-703.
20. Chi, C., Jiang, B., Yu, X. B., Liu, T. Q., Xia, L., & Wang, G. X. (2014). 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 immunology*, *36*(1), 9-18.
21. Chi, C., Liu, J. Y., Fei, S. Z., Zhang, C., Chang, Y. Q., Liu, X. L., & Wang, G. X. (2014). Effect of intestinal autochthonous probiotics isolated from the gut of sea cucumber (*Apostichopus japonicus*) on immune

response and growth of A. japonicus. *Fish & shellfish immunology*, *38*(2), 367-373.

22. Chythanya, R., Karunasagar, I., & Karunasagar, I. (2002).Inhibition of shrimp pathogenic vibrios by a marine Pseudomonas I-2 strain. *Aquaculture*, *208*(1-2), 1-10.
23. Dall, W. I. L. L. I. A. M., & Moriarty, D. J. (1983).Functional aspects of nutrition and digestion. *The biology of Crustacea*, *5*, 215-261.
24. Dalmin, G., Kathiresan, K., & Purushothaman, A. (2001).Effect of probiotics on bacterial population and health status of shrimp in culture pond ecosystem.
25. Dawood, M. A., Abo-Al-Ela, H. G., & Hasan, M. T. (2020). Modulation of transcriptomic profile in aquatic animals: Probiotics, prebiotics and synbiotics scenarios. *Fish & shellfish immunology*, *97*, 268-282.
26. Defoirdt, T., Boon, N., Sorgeloos, P., Verstraete, W., & Bossier, P. (2007). Alternatives to antibiotics to control bacterial infections: luminescent vibriosis in aquaculture as an example. *Trends in biotechnology*, *25*(10), 472-479.
27. Dhruv, D., Pandya, D., Prajapati, C., & Bhatt, S. (2021). Assessing Probiotic Potential of Gut Microflora from Indian Major Carps.
28. Dopazo, C. P., Lemos, M. L., Lodeiros, C., Bolinches, J., Barja, J. L., & Toranzo, A. E. (1988).Inhibitory activity of antibiotic-producing marine bacteria against fish pathogens. *Journal of Applied Bacteriology*, *65*(2), 97-101.
29. Ebner, S., Smug, L. N., Kneifel, W., Salminen, S. J., & Sanders, M. E. (2014). Probiotics in dietary guidelines and clinical recommendations outside the European Union. *World Journal of Gastroenterology: WJG*, *20*(43), 16095.
30. Etyemez, M., & Balcazar, J. L. (2016).Isolation and characterization of bacteria with antibacterial properties from Nile tilapia (Oreochromis niloticus). *Research in veterinary science*, *105*, 62-64.
31. Fdhila, K., Haddaji, N., Chakroun, I., Dhiaf, A., Macherki, M. E. E., Khouildi, B., ...& Missaoui, H. (2017). Culture conditions improvement of *Crassostrea gigas* using a potential probiotic *Bacillus* sp strain. *Microbial pathogenesis*, *110*, 654-658.
32. C, J., Chang, X., Zhang, Y., Yan, X., Zhang, J., & Nie, G. (2019).Effects of Lactococcus lactis from Cyprinus carpio L. as probiotics on growth performance, innate immune response and disease resistance against Aeromonas hydrophila. *Fish & shellfish immunology*, *93*, 73-81.
33. Food and Agriculture Organization (2020). Sustainability in action. *State of World Fisheries and Aquaculture.Rome*, *200*.
34. Fuller, R. (1992). History and development of probiotics.In *Probiotics* (pp. 1-8).Springer, Dordrecht.
35. Gao, F., Liao, S., Liu, S., Bai, H., Wang, A., & Ye, J. (2019). The combination use of Candida tropicalis HH8 and Pseudomonas stutzeri LZX301 on nitrogen removal, biofloc formation and microbial communities in aquaculture. *Aquaculture*, *500*, 50-56.
36. Garriques, D. (1995). An evaluation of the Production and use of a live bacterial isolate to manipulate the microbial flora in the commercial Production of Penaeus vennamei postlarvae in Ecuador. *Swimming through troubled water.Proceedings of the special session on shrimp farming, Aquaculture'95. World Aquaculture Societ*, 53-59.
37. Gatesoupe, F. J. (2002). Probiotic and formaldehyde treatments of Artemianauplii as food for larval pollack, Pollachiuspollachius. *Aquaculture*, *212*(1-4), 347-360.
38. Gobinath, J., & Ramanibai, R. (2012). Effect of probiotic bacteria culture on pathogenic bacteria from fresh water fish Oreochromis massambicus. *J Mod Biotechnol*, *1*(1), 50-54.
39. Gomez-Gil, B., Herrera-Vega, M. A., Abreu-Grobois, F. A., & Roque, A. (1998).Bioencapsulation of two different Vibrio species in nauplii of the brine shrimp (*Artemia franciscana*). *Applied and environmental microbiology*, *64*(6), 2318-2322.
40. Gram, L., Løvold, T., Nielsen, J., Melchiorsen, J., & Spanggaard, B. (2001). In vitro antagonism of the probiont Pseudomonas fluorescens strain AH2 against Aeromonas salmonicida does not confer protection of salmon against furunculosis. *Aquaculture*, *199*(1-2), 1-11.
41. Gram, L., Melchiorsen, J., Spanggaard, B., Huber, I., & Nielsen, T. F. (1999).Inhibition of Vibrio anguillarum by Pseudomonas fluorescens AH2, a possible probiotic treatment of fish. *Applied and environmental microbiology*, *65*(3), 969-973.
42. Grenni, P., Ancona, V., &Caracciolo, A. B. (2018). Ecological effects of antibiotics on natural ecosystems: A review. *Microchemical Journal*, *136*, 25-39.
43. Grześkowiak, Ł., Collado, M. C., & Salminen, S. (2012). Evaluation of aggregation abilities between commensal fish bacteria and pathogens. *Aquaculture*, *356*, 412-414.
44. He, S., Zhang, Y., Xu, L., Yang, Y., Marubashi, T., Zhou, Z., & Yao, B. (2013).Effects of dietary Bacillus subtilis C-3102 on the Production, intestinal cytokine expression and autochthonous bacteria of hybrid tilapia Oreochromis niloticus♀× Oreochromis aureus♂. *Aquaculture*, *412*, 125-130.
45. Hotel, A. C. P., & Cordoba, A. (2001). Health and nutritional properties of probiotics in food including

powder milk with live lactic acid bacteria. *Prevention*, *5*(1), 1-10.

46. Irianto, A., & Austin, B. (2002).Probiotics in aquaculture. *Journal of fish diseases*, *25*(11), 633-642.
47. Karunasagar, I., Pai, R., Malathi, G. R., &Karunasagar, I. (1994).Mass mortality of Penaeus monodon larvae due to antibiotic-resistant Vibrio harveyi infection. *Aquaculture*, *128*(3-4), 203-209.
48. Kesarcodi-Watson, A., Kaspar, H., Lategan, M. J., & Gibson, L. (2008). Probiotics in aquaculture: the need, principles and mechanisms of action and screening processes. *Aquaculture*, *274*(1), 1-14.
49. Khaneghah, A. M., Abhari, K., Eş, I., Soares, M. B., Oliveira, R. B., Hosseini, H., ...& Sant'Ana, A. S. (2020). Interactions between probiotics and pathogenic microorganisms in hosts and foods: A review. *Trends in Food Science & Technology*, *95*, 205-218.
50. Kuebutornye, F. K., Abarike, E. D., & Lu, Y. (2019).A review on the application of Bacillus as probiotics in aquaculture. *Fish & shellfish immunology*, *87*, 820-828.
51. Kuebutornye, F. K., Abarike, E. D., Lu, Y., Hlordzi, V., Sakyi, M. E., Afriyie, G., ...& Xie, C. X. (2020). Mechanisms and the role of probiotic Bacillus in mitigating fish pathogens in aquaculture. *Fish physiology and biochemistry*, 1-23.
52. Lang, J. C., & Chornesky, E. A. (1990). Competition between scleractinian reef corals-a review of mechanisms and effects. *Ecosystems of the world*, *25*, 209-252.
53. Lara-Flores, M. (2011). The use of probiotic in aquaculture: an overview. *Int Res J Microbiol*, *2*(12), 471-478.
54. Lara-Flores, M., Olvera-Novoa, M. A., Guzmán-Méndez, B. E., & López-Madrid, W. (2003).Use of the bacteria Streptococcus faecium and Lactobacillus acidophilus, and the yeast Saccharomyces cerevisiae as growth promoters in Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, *216*(1-4), 193-201.
55. Lewin, C. S. (1992). Mechanisms of resistance development in aquatic microorganisms. *Chemotherapy in Aquaculture: from Theory to Reality. Office International des Epizooties, Paris, France*, 288-301.
56. Liu, K. F., Chiu, C. H., Shiu, Y. L., Cheng, W., & Liu, C. H. (2010). Effects of the probiotic, Bacillus subtilis E20, on the survival, development, stress tolerance, and immune status of white shrimp, Litopenaeus vannamei larvae. *Fish & shellfish immunology*, *28*(5-6), 837-844.
57. Matias, H. B., Yusoff, F. M., Shariff, M., &Azhar, O. (2002). Effects of commercial microbial products on water quality in tropical shrimp culture ponds. *Asian Fisheries Science*, *15*(3), 239-248.
58. Middlemiss, K. L., Daniels, C. L., Urbina, M. A., & Wilson, R. W. (2015).Combined effects of UV irradiation, ozonation, and the probiotic Bacillus spp. on growth, survival, and general fitness in European lobster (Homarusgammarus). *Aquaculture*, *444*, 99-107.
59. Monteagudo-Mera, A., Rastall, R. A., Gibson, G. R., Charalampopoulos, D., & Chatzifragkou, A. (2019). Adhesion mechanisms mediated by probiotics and prebiotics and their potential impact on human health. *Applied microbiology and biotechnology*, *103*(16), 6463-6472.
60. Moriarty, D. J. (1999).Disease control in shrimp aquaculture with probiotic bacteria.In *Proceedings of the 8th international symposium on microbial ecology* (pp. 237-243).Atlantic Canada Society for Microbial EcologyHalifax.
61. Mulder, R. W. A. W., Havenaar, R., & Huis, J. H. J. (1997). Intervention strategies: the use of probiotics and competitive exclusion microfloras against contamination with pathogens in pigs and poultry. In *Probiotics 2* (pp. 187-207). Springer, Dordrecht.
62. Muñoz-Atienza, E., Gómez-Sala, B., Araújo, C., Campanero, C., Del Campo, R., Hernández, P. E., ...& Cintas, L. M. (2013). Antimicrobial activity, antibiotic susceptibility and virulence factors of lactic acid bacteria of aquatic origin intended for use as probiotics in aquaculture. *BMC microbiology*, *13*(1), 1-22.
63. Nandi, A., Dan, S. K., Banerjee, G., Ghosh, P., Ghosh, K., Ringø, E., & Ray, A. K. (2017). Probiotic potential of autochthonous bacteria isolated from the gastrointestinal tract of four freshwater teleosts. *Probiotics and antimicrobial proteins*, *9*(1), 12-21.
64. Nimrat, S., Suksawat, S., Boonthai, T., & Vuthiphandchai, V. (2012). Potential Bacillus probiotics enhance bacterial numbers, water quality and growth during early development of white shrimp (*Litopenaeus vannamei*). *Veterinary microbiology*, *159*(3-4), 443-450.
65. Nogami, K., & Maeda, M. (1992).Bacteria as biocontrol agents for rearing larvae of the crab Portunustrituberculatus. *Canadian Journal of fisheries and aquatic sciences*, *49*(11), 2373-2376.
66. Nogami, K., Hamasaki, K., Maeda, M., & Hirayama, K. (1997). Biocontrol method in aquaculture for rearing the swimming crab larvae Portunustrituberculatus.In *Live food in aquaculture* (pp. 291-295). Springer, Dordrecht.
67. Noor, Z., Noor, M., Khan, I., & Khan, S. A. (2020). Evaluating the lucrative role of probiotics in the aquaculture using microscopic and biochemical techniques. *Microscopy research and technique*, *83*(3), 310-317.

68. Olsson, J. C., Westerdahl, A. L. L. A. N., Conway, P. L., &Kjelleberg, S. T. A. F. F. A. N. (1992). Intestinal colonization potential of turbot (Scophthalmus maximus)-and dab (Limandalimanda)-associated bacteria with inhibitory effects against Vibrio anguillarum. *Applied and Environmental Microbiology*, *58*(2), 551-556.
69. Onarheim, A. M., Wiik, R., Burghardt, J., &Stackebrandt, E. (1994). Characterization and identification of two Vibrio species indigenous to the intestine of fish in cold sea water; description of Vibrio iliopiscarius sp. nov. *Systematic and Applied Microbiology*, *17*(3), 370-379.
70. Panigrahi, A., & Azad, I. S. (2007). Microbial intervention for better fish health in aquaculture: the Indian scenario. *Fish physiology and biochemistry*, *33*(4), 429-440.
71. Parker, R. B. (1974). Probiotics, the other half of the antibiotic story. *AnimNutr Health*, *29*, 4-8.
72. Pond, M. J., Stone, D. M., & Alderman, D. J. (2006).Comparison of conventional and molecular techniques to investigate the intestinal microflora of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, *261*(1), 194-203.
73. Prieur, D., Mevel, G., Nicolas, J. L., Plusquellec, A., & Vigneulle, M. (1990).Interactions between bivalve molluscs and bacteria in the marine environment. *Oceanogr. Mar. Biol. Annu. Rev*, *28*, 277-352.
74. Qin, C., Zhang, Z., Wang, Y., Li, S., Ran, C., Hu, J., ...& Zhou, Z. (2017). EPSP of L. casei BL23 Protected against the Infection Caused by Aeromonas veronii via Enhancement of Immune Response in Zebrafish. *Frontiers in microbiology*, *8*, 2406.
75. Ran, C., Huang, L., Liu, Z., Xu, L., Yang, Y., Tacon, P., ...& Zhou, Z. (2016). Correction: A Comparison of the Beneficial Effects of Live and Heat-Inactivated Baker's Yeast on Nile Tilapia: Suggestions on the Role and Function of the Secretory Metabolites Released from the Yeast. *PloS one*, *11*(3), e0151207.
76. Rengpipat, S., Rukpratanporn, S., Piyatiratitivorakul, S., & Menasaveta, P. (2000). Immunity enhancement in black tiger shrimp (Penaeus monodon) by a probiont bacterium (*Bacillus* S11). *Aquaculture*, *191*(4), 271-288.
77. Rengpipat, S., Tunyanun, A., Fast, A. W., Piyatiratitivorakul, S., &Menasveta, P. (2003). Enhanced growth and resistance to Vibrio challenge in pond-reared black tiger shrimp Penaeus monodon fed a Bacillus probiotic. *Diseases of aquatic organisms*, *55*(2), 169-173.
78. Ringø, E., Strøm, E., & Tabachek, J. A. (1995). Intestinal microflora of salmonids: a review. *Aquaculture Research*, *26*(10), 773-789.
79. Rinkinen, M., Jalava, K., Westermarck, E., Salminen, S., &Ouwehand, A. C. (2003). Interaction between probiotic lactic acid bacteria and canine enteric pathogens: a risk factor for intestinal Enterococcus faecium colonization?. *Veterinary microbiology*, *92*(1-2), 111-119.
80. Romero, J., Feijoó, C. G., & Navarrete, P. (2012).Antibiotics in aquaculture–use, abuse and alternatives. *Health and environment in aquaculture*, *159*.
81. Rosenfeld, W. D., &ZoBell, C. E. (1947).Antibiotic Production by marine microorganisms. *Journal of bacteriology*, *54*(3), 393-398.
82. Sakata, T. (1990).Microflora in digestive tract of fish and shell fish. *Microbiology in Poeciloterms*.
83. Salminen, S., Bouley, C., Boutron, M. C., Cummings, J. H., Franck, A., Gibson, G. R., ...& Rowland, I. (1998). Functional food science and gastrointestinal physiology and function. *British journal of nutrition*, *80*(S1), S147-S171.
84. Salunke, M., Kalyankar, A., Khedkar, C. D., Shingare, M., &Khedkar, G. D. (2020). A review on shrimp aquaculture in India: historical perspective, constraints, status and future implications for impacts on aquatic ecosystem and biodiversity. *Reviews in Fisheries Science & Aquaculture*, *28*(3), 283-302.
85. Sotomayor, M. A., & Balcázar, J. L. (2016).Inhibición de vibrios patógenos de camarón por mezclas de cepas probióticas. *Revista AquaTIC*, (19).
86. Spanggaard, B., Huber, I., Nielsen, J., Sick, E. B., Pipper, C. B., Martinussen, T., ...& Gram, L. (2001). The probiotic potential against vibriosis of the indigenous microflora of rainbow trout. *Environmental microbiology*, *3*(12), 755-765.
87. Standen, B. T., Rawling, M. D., Davies, S. J., Castex, M., Foey, A., Gioacchini, G., ...& Merrifield, D. L. (2013). Probiotic Pediococcus acidilactici modulates both localised intestinal-and peripheral-immunity in tilapia (*Oreochromis niloticus*). *Fish & shellfish immunology*, *35*(4), 1097-1104.
88. Sun, W., Liang, J., Yang, Y., Wu, Y., Yan, T., & Song, R. (2016).Investigating aging-related changes in the coordination of agonist and antagonist muscles using fuzzy entropy and mutual information. *Entropy*, *18*(6), 229.
89. Vandak, D., Telgarský, M., & Šturdík, E. (1995). Influence of growth factor supplements on butyric acid production from sucrose byClostridium butyricum. *Folia microbiologica*, *40*(6), 669-672.
90. Venkat, H. K., Sahu, N. P., & Jain, K. K. (2004). Effect of feeding Lactobacillus-based probiotics on the gut microflora, growth and survival of postlarvae of

Macrobrachium rosenbergii (de Man). *Aquaculture Research*, *35*(5), 501-507.

91. Verschuere, L., Rombaut, G., Sorgeloos, P., &Verstraete, W. (2000). Probiotic bacteria as biological control agents in aquaculture. *Microbiology and molecular biology reviews*, *64*(4), 655-671.
92. Vijayaram, S., & Kannan, S. (2018). Probiotics: The marvelous factor and health benefits. *Biomedical and Biotechnology Research Journal (BBRJ)*, *2*(1), 1.
93. Wang, J., Yang, H. L., Xia, H. Q., Ye, J. D., Lu, K. L., Hu, X., ... & Sun, Y. Z. (2018). Supplementation of heat-inactivated Bacillus clausii DE 5 in diets for grouper, Epinephelus coioides, improves feed utilization, intestinal and systemic immune responses and not growth performance. *Aquaculture Nutrition*, *24*(2), 821-831.
94. Wang, Y. B., & Han, J. Z. (2007).The role of probiotic cell wall hydrophobicity in bioremediation of aquaculture. *Aquaculture*, *269*(1-4), 349-354.
95. Wang, Y., &Gu, Q. (2010). Effect of probiotics on white shrimp (Penaeus vannamei) growth performance and immune response. *Marine Biology Research*, *6*(3), 327-332.
96. Wu, S., Gao, T., Zheng, Y., Wang, W., Cheng, Y., & Wang, G. (2010). Microbial diversity of intestinal contents and mucus in yellow catfish (Pelteobagrus fulvidraco). *Aquaculture*, *303*(1-4), 1-7.
97. Xia, Z., Zhu, M., & Zhang, Y. (2014). Effects of the probiotic A rthrobacter sp. CW 9 on the survival and immune status of white shrimp (*P. enaeus vannamei*). *Letters in applied microbiology*, *58*(1), 60-64.
98. Xie, S., Zheng, L., Wan, M., Niu, J., Liu, Y., & Tian, L. (2018). Effect of deoxynivalenol on growth performance, histological morphology, anti-oxidative ability and immune response of juvenile Pacific white shrimp, *Litopenaeus vannamei*. *Fish & shellfish immunology*, *82*, 442-452.
99. Xu, Y., Wang, Y., & Lin, J. (2014).Use of Bacillus coagulans as a Dietary Probiotic for the Common Carp, Cyprinus carpio. *Journal of the World Aquaculture society*, *45*(4), 403-411.
100. Yan, F., Tian, X., & Dong, S. (2014). Effect of Bacillus baekryungensis YD13 supplemented in diets on growth performance and immune response of sea cucumber (Apostichopus japonicus). *Journal of Ocean University of China*, *13*(5), 805-810.
101. Yi, Y., Zhang, Z., Zhao, F., Liu, H., Yu, L., Zha, J., & Wang, G. (2018). Probiotic potential of Bacillus velezensis JW: antimicrobial activity against fish pathogenic bacteria and immune enhancement effects on Carassius auratus. *Fish & shellfish immunology*, *78*, 322-330.
102. Zhang, C. N., Zhang, J. L., Guan, W. C., Zhang, X. F., Guan, S. H., Zeng, Q. H., ... & Cui, W. (2017). Effects of *Lactobacillus delbrueckii* on immune response, disease resistance against *Aeromonas hydrophila*, antioxidant capability and growth performance of Cyprinus carpio Huanghe var. *Fish & shellfish immunology*, *68*, 84-91.
103. Zheng, X., Duan, Y., Dong, H., & Zhang, J. (2017). Effects of dietary Lactobacillus Plantarum in different treatments on growth performance and immune gene expression of white shrimp Litopenaeus vannamei under normal condition and stress of acute low salinity. *Fish & shellfish immunology*, *62*, 195-201.
104. Zhou, X. X., Wang, Y. B., & Li, W. F. (2009). Effect of probiotic on larvae shrimp (Penaeus vannamei) based on water quality, survival rate and digestive enzyme activities. *Aquaculture*, *287*(3-4), 349-353.
105. Zhou, X., Tian, Z., Wang, Y., & Li, W. (2010).Effect of treatment with probiotics as water additives on tilapia (*Oreochromis niloticus*) growth performance and immune response. *Fish physiology and biochemistry*, *36*(3), 501-509.
106. Zorriehzahra, M. J., Delshad, S. T., Adel, M., Tiwari, R., Karthik, K., Dhama, K., & Lazado, C. C. (2016). Probiotics as beneficial microbes in aquaculture: an update on their multiple modes of action: a review. *Veterinary quarterly*, *36*(4), 228-241.