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Sujita Balami
College of Aquaculture and Fisheries, Can Tho University, Can Tho, Vietnam

Krishna Paudel
University of the Highlands and Islands, SAMS-UHI, United Kingdom

Nisha Shrestha
University of Crete, Greece

Corresponding Author:
Sujita Balami
College of Aquaculture and Fisheries, Can Tho University, Can Tho, Vietnam

A review: Use of probiotics in striped catfish larvae culture

Sujita Balami, Krishna Paudel and Nisha Shrestha

Abstract
Intensive striped catfish farming has resulted in various health difficulties for the species and significant financial losses for farmers due to fish losses and high treatment costs for veterinary pharmaceuticals such as antibiotics. As such, these drugs increase the strain of drug-resistance pathogenic microbes and residual effect on fish muscles. Also, the larval survival of striped catfish is meager compared to other species. Diseases like *Edwardsiellosis* are prevalent in striped catfish, causing high mortality, which probiotics can reduce. Probiotics are live microbes added in feed or in water that can modify the host-associated microbial community. Probiotics reach the gut of fish, where they proliferate and either compete for the nutrients, act as a bactericide, or barrier against the growth of opportunistic bacteria. Probiotics promote the growth and survival of striped catfish larvae and other fish species by stimulating fish's non-specific or innate immune system and better feed utilization. As a result, striped catfish farmers should be encouraged to use probiotics, and researchers should conduct more research on this topic.

Keywords: Aquaculture, bacterial resistance, gut microflora, immune response, and lactic acid bacteria

Introduction
Recently, the striped catfish has been known as the "Princess of Vietnamese aquaculture" [1]. This fish species is famous worldwide due to the facultative air-breathing organ to breathe at low water quality, which other freshwater fish lack [2]. One of the critical factors for its successful farming is the seed production and associated hatchery techniques [3]. Anciently, striped catfish were cultured by capturing the wild seeds. Still, the Vietnamese government's ban on the capture of wild stocks led to a concerted effort to the art of propagating them. After that, the faster growth of striped catfish than other species made it an ideal candidate for intensive farming [4]. For striped catfish farming, there is an integration of production units such as seed, nursery and grow out dispersed all over the country. For instance, in Vietnam, seed production hatcheries are primarily located in Dong Thap and An Giang provinces, with fry and fingerling rearing facilities run in Dong Thap, An Giang, and Can Tho provinces grow-out farms distributed throughout all provinces [4].

Under a large-scale business in the aquaculture sector, it might be stressful for the fish when they are exposed to traumatic conditions and deteriorated environmental conditions. These conditions result in the frequent outbreak of the diseases causing mortality and high treatment costs during farming [5]. These may lead to severe economic losses to the farmers. Striped catfish larvae are cannibalistic and have meager survival due to bacterial disease outbreaks. As striped catfish are cultured in an intensive system at high densities, infectious disease agents are likely to be transmitted very easily between individuals [6]. A range of approaches is available to protect farmed aquatic animals against the effect of pathogens [7]. However, a significant issue for the loss of production in world aquaculture is disease outbreaks [8, 9]. Also, different gram-negative bacteria cause severe diseases to the striped catfish culture [10]. Other environmental factors, stocking density, quality and quantity of feed supply, and pond management, impact the growth and survival of the catfish [11, 12]. Therefore, probiotics are used as an incentive to solve larval mortality and antibiotic residue issues in striped catfish.

Good strategies should be developed for disease management to ensure good production and stable income for striped catfish farmers. The lack of disease diagnosis and treatment has caused substantial financial losses to farmers [2].

The most common treatment used by the farmers in Bangladesh is liming, followed by applying salt, potassium permanganate, antibiotics, pesticides, and insecticides [2]. Commercial approaches like anti-microbials and vaccination have been used. However, they have limited success in preventing and treating diseases. Antibiotics and other immunostimulants used in aquaculture can develop a drug-resistant strain of disease-causing agents [13].

Similarly, continued use of anti-microbial agents increases the risk of antibiotic residues in muscle [5]. Almost 90% of the striped catfish cultured in Vietnam are exported in different product forms [4, 14]. Striped catfish fillet is one of the best-known products shipped from Vietnam [15], but antibiotics residues in these products are of grave concern to the food safety hazard [16]. When humans consume residue-laden meat, the drug builds up in their bodies, leading to drug resistance when antibiotics treat infections [17]. As such, scientists have directed their effort to investigate and develop a safe aqua product with probiotics. Probiotics can be taken as an alternative and effective way of maintaining fish fitness and preventing opportunistic pathogens which otherwise take advantage of immune-suppressed or stressed fish. Therefore, probiotics can be used as an incentive to solve the problem of larval survival of striped catfish by ensuring the high survival of larvae and avoiding the antibiotic residues and the transfer of antibiotic residues. More research should be focused on the early stages of the development, which is the best time for a probiotic introduction. Good strategies should be developed for disease management to ensure good production and stable income of striped catfish farmers.

Probiotics are the microbial assistants who can prevent pathogens from proliferating in cultured species' gastrointestinal tract and growing environment. They can further secure the feed's optimal use by aiding in its digestion, improving water quality, and stimulating the immune system [18]. The probiotics have the safety-enhancing property of not transferring the antibiotic-resistant genes to other bacteria [17]. They are also an alternative to reduce the abuse of antibiotics [19], making the product acceptable in the international market and providing better survival, growth, and some bacterial resistance from improved immunity in the fish. Many probiotic species have been experimented with and tested for various species to date in aquaculture. Many of them proved beneficial for improving survival, growth, immunity, and bacterial resistance [18, 20-24]. Thus, it can be used as a less harmful and environmentally friendly treatment in aquaculture management. *Lactobacillus* (Lactic acid bacteria), mostly separated from the fish GIT, are generally recognized as safe (GRAS) status, and it is recognized as a potential candidate to replace antibiotics and develop immune functions in the fish [25]. Specifically, in various experiments, *Lactobacillus plantarum*, a potential probiotic in aquaculture species, showed significant improvement in growth, survival, immune response, and bacterial resistance of fish [22, 26-28]. More research and experiment should be conducted to learn more about probiotics' effect on commercial aquaculture. So, this article aims to discuss the use of probiotics in aquaculture, the benefits of probiotics in the striped catfish larvae culture, and their importance.

Probiotics in Aquaculture

Probiotics can be defined as live microbes added as a feed supplement for beneficial effects on the host animal by improving its intestinal balance [29]. It is also defined as a live microbial adjunct that has a benefits animals, modifies the host-associated microbial community, and ensures improved feed use [18]. The probiotics usually used by the farmers of several countries like Bangladesh, Thailand, Vietnam, and China, primarily include a wide variety of formulations given as photosynthetic bacteria microorganisms for the nutritional and enzymatic acceleration of digestion and for improving water quality [30]. In aquaculture, probiotics can potentially be employed as a disease control method [31].

The field of probiotics is now attracting attention for aquaculture as an alternative to antibiotics for disease resistance and immune progress. The use of probiotics in aquaculture has shown the reduction of anti-microbial compounds (particularly antibiotics) and improvement in appetite and growth performance [20]. Microbes also play an important role in aquaculture both in the hatchery and grow-out level, as the water quality and disease control are openly affected by microbial activity [32]. Controlling these microbes in the water can be a challenge in the hatchery. So, probiotics may be useful for pre-emptively colonizing the water and fish gut to get benefits of growth, survival, and disease resistance [18] once they multiply on or in the host animal [9]. Bio-encapsulated probiotics with live food can also be offered/fed to larvae in the hatchery to increase the effectiveness of probiotics [33, 34].

Aquatic ecosystems contain many microorganisms around and within the water [35, 36]. The water can be preemptively colonized by adding probiotic bacteria to avoid the harmful effects of those microorganisms [18] or as feed additives [38, 18]. Another circumstance is when the host and its environment already have a well-established microbial community, the probiotic must be administered regularly to acquire and maintain artificial dominance [18]. As recognized by [37], an essential function of probiotics in aquaculture is the degradation of organic matter in the pond, reducing the sludge and formation of slime, thereby improving water quality.

Probiotic treatment is mainly applied during the larval stages [45] because the digestive tract is not yet fully developed [38]. In the study conducted for Japanese flounder by [47], it was observed that at larval and juvenile stages, the intestine consists of antibacterial producers against *P. piscicida*, i.e., Vibrio *spp* seems to be a candidate for the probiotic bacteria for marine fish. Various experiments can be seen with different fish, crustaceans, and mollusk sizes using probiotic bacterial strains. A study demonstrated that *Bacillus* probiotics could be found in the intestine of the fish even after 90 days of feeding [24].

Also, probiotics are prevalent in the culture of ornamental species where they show superior growth performance compared to the control diet-fed fishes and revealed that live-bearing fishes utilize dietary proteins more efficiently when feed was supplemented with probiotics [39]. The availability of probiotics in the water may stimulate endogenous digestive enzymes in shrimp larvae, enhancing digestion and increasing food absorption [40].

Threats on Larval Rearing

Larvae of striped catfish are small, about 0.9 mg at the start of exogenous feeding at 36 hours after hatching [41]. The larvae of uniform size that can swim actively and respond quickly to external stimuli are considered good quality [3]. Larval rearing of this species has always been problematic due to variable and low survival rates [42]. In Vietnam, the seeds are reared in specialized nursery facilities to a size of 1.0 to 8.5 cm as fry and 1.2 to 20 cm as fingerlings used for growing out [14]. Ponds for larval rearing are treated before stocking mainly by drying, sludge removal, application of quick lime, and salting, but very few farmers use screens in inlet water [3, 43]. The larvae are advised to be transferred to rearing tanks or ponds within 24 hours after hatching. The use of live food and releasing larvae into an earthen pond within a day of hatching can also be a technique to reduce mortality rates [38].

The primary cause of larval mortality in striped catfish is cannibalism [43]. Although the larvae of striped catfish are cannibalistic, the study conducted by [42] indicated that the survival rate of *P. hypophthalmus* larvae is influenced more by a bacterial disease. Bui *et al.* [43] also supported that the most common reason for mortality in fish larvae, juveniles, and fry is the occurrence of diseases in the wet season. Fish mortality increases as the temperature falls due to continuous rain, which is favorable for disease breakdown. According to Bui *et al.* [43], the survival rate of striped catfish larvae to fry was 15-80%, whereas fry to fingerling was 10-90%. This data indicates that the survival rates of striped catfish larvae must be given more importance. BNP is the most common disease in striped catfish nursery farms and a genuine cause of lower survival of striped catfish larvae. Therefore, larvae are the appropriate stage for the probiotics to be administered so that the undeveloped digestive system [44] can be colonized. The effects of probiotics on the health of larvae can be prominently witnessed. For this reason, beneficial bacterial products (or the larvae microbial-products) can be added into the pond at a rate of 30 g/1000 m^3 in addition to live food [42].

Probiotic Mode of Action

Numerous microorganisms in the environment can act as probiotic strains in aquaculture. They benefit the host species in several ways. Many researchers have conducted research and experiments to find the possible mode of action of the probiotic species. However, the precise mode of action is rarely explained fully. Strengthening the immune response, competition for binding sites, generation of anti-microbial compounds, and competition for nutrients are all plausible modes of action for probiotics [45]. As lactic acid bacteria became popular in humans and animals, people started using similar knowledge in aquaculture. The probiotic strain should pass in-vivo tests of bacterial dominance and in-vitro test of survival inside the host for being effective as a probiotic to fish [46]. The potential of probiotics can be explained by some of the selective ingestion and digestion features of aquatic animals. Another important criterion is the effective proliferation in the gastrointestinal tract of the fish, which serves a vital role in the efficacy of probiotics. Hence for the practical mode of action, there should be an indication that the probiotic can reach and proliferate in the fish gut. The possible mode of action as indicated by are the production of inhibitory compounds that have a bactericidal and bacteriostatic effect, competition for chemical, available energy, and adhesion sites, enhancement of the immune system, improvement of water quality, interaction with phytoplankton, source of macro-and micronutrients, and enzymatic contribution on digestion [18].

The presence of inhibitory compounds in the intestine, on its surface, or in the culture medium may act as a barrier against the growth of opportunistic bacteria [7, 18]. Lactic acid bacteria have been found to create bacteriocins, which hinder the growth of other bacteria [47]. Inhibitory chemicals can operate as a barrier against the proliferation of opportunistic pathogens in the host's intestine, on its surface, or in the culture media [18]. Organic acids, hydrogen peroxide, lactoferrin, and bacteriocin are produced by probiotic bacteria and may have bactericidal or bacteriostatic effects [48, 49].

The external environment has a specific impact on aquatic species' gastrointestinal microbiota as there is a flow of water from the environment to the digestive tract. [50]. According to Balcázar *et al*. [47], microbial communities can be stimulated to proliferate in the gastrointestinal tract by ingestion of other microorganisms in the early stage. The creation of normal gut microbiota is complementary to establishing the digestive system, and it functions as a barrier against invading pathogens under normal conditions [18]. Thus, probiotics can compete with opportunist pathogens and eliminate them. The proliferation can be possible only after birth with high doses of probiotics to provoke its dominance. Probiotics modify the intestinal microbiota and compete with pathogens to prevent their adhesion to the intestine, competing for nutrients necessary for pathogen survival [50]. Pathogens that cannot adhere and colonize in the digestive tract are released by excretion, which results in a microbial balance in the digestive tract and leads to better fish performances [51].

Probiotics can modulate and stimulate the non-specific immune system [47, 50]. The increase in cellular components like red blood cells (RBCs) indicates the physiological state of the fish [52] and oxygen-carrying capacity [53]. An increase in white blood cells (WBCs) indicates the good activatory response of fish immunity. Furthermore, an increase in monocytes and granulocytes [54] suggests incrementing a non-specific immune response. These all are proven to increase via probiotic supplementation by various experiments. Therefore, immune-stimulation or enhancement of an organism's immune response seems to be the most promising method of probiotics showing their action [55].

Probiotic species are more efficient at converting organic matter to carbon dioxide (CO_2), resulting in a higher percentage of organic carbon being converted to bacterial biomass or slime. Thus, using a high amount of probiotics in production ponds is recommended to minimize organic carbon load and improve water quality [56].

Some bacteria are used in digestion processes by producing cellular enzymes such as proteases and lipases and providing necessary growth factors [50]. Greater lactic acid production decreases toxic amines and increases the availability of amino acids at absorption sites [57] which improves the energy economy and the availability of vitamins and enzymes [58]. Moreover, probiotics also enhance the synthesis of growth factors such as vitamins, co-factors, fatty acids, and amino acids which increase the nutrient absorption in the host's body [47, 59, 60].

Potential use of probiotics in striped catfish larvae

While most of the research focused on probiotic supplementation on fish juveniles, attention has been directed to the larvae of fish, shellfish, and live food organisms. The use of probiotics might help larvae's undeveloped intestinal system be colonized with the probiotic bacterial strain, which can benefit the fish's growth, survival, and immunity [18]. Probiotics have been used in human food for a long time and have been favorable in various aspects. Slowly the use of probiotics increased, and now its use is being experimented on in fish and animals. Many experiments have reported multiple benefits of probiotics on different fish and shellfish. However, scanty investigations can be seen conducted for striped catfish larvae.

Probiotics on fish survival and growth performance

Survival is an essential factor to be considered in the aquaculture business. The larvae of *P. hypophthalmus* reared in water-containing antibiotics (oxytetracycline) demonstrated higher survival [42]. Probiotics have mostly supplanted antibiotics in treating bacterial infections [47, 61] due to the antibiotic resistance and residual effect in fish muscle [42]. When juveniles of *Penaeus indicus* were administered orally with four lactic acid bacteria (LAB) probiotics for four weeks gave improved survival (56 to 72%) [62]. Improved survival was observed in the larval crab (*Portunus pelagicus*) fed with bio encapsulated live prey (Rotifers and *Artemia*) with LAB (*Lactobacillus. plantarum, L. rhamnosus, and L. salivarius*) than the untreated control group [33]. In research conducted by Hai *et al.* [63], it is observed that probiotic supplementation in feed (*Pseudomonas synxantha* and *P. aeruginuosa*) resulted in higher survival (73%) compared to the control group without probiotic supplementation (60%) on juvenile western king prawns (*Penaeus latisulcatus*). The survival rate was significantly increased (7-13.10%) in comparison to control groups when probiotics, *Bacillus. coagulans* SC8168 were applied to the treatment tanks for *Penaeus. vannamei* [40]. *Labeo rohita* juveniles were fed *L. plantarum* increased the survival post-challenge with *A. hydrophila* from 14.8% in control diets to 77.7% in 10^8 CFU m/L of *L. plantarum* after 60 days of feeding [28]. *L. plantarum* supplemented fish diet was known to decrease the mortality from 50% in the control group to 0% in the treated group in hybrid catfish challenged with *A. hydrophila* [25]. The highest survival rate of striped catfish juveniles was 74.2% observed when they were fed with 50 ppm of heat-killed (HK) *L. plantarum* than control diets which showed the lowest survival of 41.8% only [22].

The better growth performance of African catfish (*Clarius gariepinus*) in terms of specific growth rate (SGR) and relative growth rate (RGR) when maintained on the probiotic-supplemented diet indicated that *Lb. acidophilus* could be an excellent probiotic agent. This study also indicated that white blood cells, total serum protein, and total immunoglobins concentrations relating to the immune system were significantly better in fish fed with probiotics than in the control group [64]. Vaseeharan and Ramasamy [9] concluded that the antagonistic probiotic must be present at significantly higher levels than the pathogen and supplied regularly. The study conducted for common snook (*Centropomus undecimalis*) showed a 20% higher survival after one week of transport than control groups when supplemented with mixed Bacillus as probiotics [65]. The growth performance of *P. hypophthalmus* juveniles fed with *Lb. acidophilus* was significantly higher than the control group. The SGR of the control group was only 0.92%, while fish fed with 10^7 CFU/g probiotics was 1.35% [21]. A significantly higher final weight, weight gain, and specific growth rate of experimental striped catfish juveniles were observed when fed with 20 and 50 ppm of the HK *L. plantarum* [22].

The enhancement of the growth parameters can be the reason for some functions provided by the probiotics, such as improvement in feed utilization by synthesis of some growth factors such as vitamins, co-factors, fatty acids, and amino acids and augment of digestive activity of the fed animal which increases the nutrient absorption [47, 66]. In addition, a more significant population of lactic acid bacteria decreases the production of toxic amines increases the availability of amino acids at absorption sites [57], which can further improve the energy economy and availability of vitamins and enzymes [58], resulting in higher growth performance. Probiotics can also alter the architecture of the gut epithelium [67], improving nutrient absorption by increasing the absorptive surface area [68], and also the production of endogenous digestive enzymes enhances digestion of food [40] which may affect the increment of growth parameters [67]. Pathogens that cannot bind to and colonize the digestive tract are released through excretion due to *L. plantarum* colonization, resulting in microbial equilibrium and improved fish growth efficiency [51]. Also, the probiotic supplemented group can have better growth due to good health conditions and appetite [22].

Effect of probiotics on fish immunity

The immune system is a body function comprising a complex network of cells and proteins with defensive mechanisms against infection. It is a physiological mechanism in animals to protect against disease infection and preserve internal homeostasis [69]. The immune system keeps track of every antigen it has ever defeated to recognize and destroy it swiftly if it resurfaces in the body. It also functions in resistance against diseases and protection against neoplastic cells. The immune system is present to protect itself from being attacked by a broad spectrum of invading microorganisms. It uses specialized organs which filter out and respond to microbes entering the body's tissue and force the molecules and cells in the bloodstream to respond quickly to the attack [69]. The fish immune system equals other vertebrates, but there is a difference, especially in histopathology and the location of critical immune-competent cells [70]. The immune organs of fish include the thymus, kidney, intestinal tract, liver, and spleen [71].

The immune system comprises various types of cells and subpopulations found in circulation or organized in lymphoid tissues of the kidney, spleen, and thymus. Erythrocytes (red blood cells) are the circulatory cells that contain hemoglobin that carries oxygen to body tissues. It is ovoid in shape and nucleate (72). A rise in erythrocytes indicates that the blood has a high oxygen-carrying capacity [53]. Leukocytes (white blood cells) are a large group of colorless, circulatory cells, including lymphocytes, granulocytes, monocytes, and their precursors, primarily involved in defensive mechanisms [72]. An increase in the number WBCs indicates the strengthening of the immunity in fish [73]. Lymphocytes make up most of the leukocytes population, i.e., greater than 90%, followed by others [70]. Neutrophils, a form of granulocyte found in fish, are phagocytic cells that play a crucial role in infection defense [74]. The non-specific defense mechanism is against microorganisms already in place in fish, without stimulating an antigen, e.g., mucous layer, hardened scales, blood lysozymes, neutrophils, and phagocytic cells function independently the antibody production [72]. It is also known as the innate immune system [75].

Probiotics stimulate the non-specific immune system in fish [47]. The immune parameters like serum globulins, white blood cell counts, phagocytic activities, and phagocytic indices can be investigated to determine the innate immune system of fish [76]. Also, the study in Rainbow trout showed that *Bacillus subtilis* stimulated both cellular and humoral innate immune responses [77]. The study also concluded that stress conditions should be induced during the experiment to demonstrate the positive effects of probiotic bacteria [78]. In the study conducted in Rainbow trout, the heightened immune response was observed with supplementation of *L. rhamnosus*, which improved the performance of non-specific immune parameters like phagocytosis, lysozyme, and complement activities [79]. Adding probiotics in water and feed during the culture of common snook larvae boosted immunity from decreased superoxide dismutase (SOD) activity, increased lysozyme activity, and reduced oxidative stress [65].

The physiological state of fish health is indicated by the hematological parameter of the fish [52]. The increased number of erythrocytes or RBCs demonstrates that the blood has a high oxygen-carrying capacity, typical of fish with aerial respiration, increased activity levels [53], and O_2 absorption within living cells [73]. A decrease in the RBCs may signify the fish's anemic conditions, which leads to immunosuppression. The immunosuppression can cause the infection to grow faster, resulting in fish mortality [53]. Fish with fewer RBC counts can become frail and die [73]. So, a higher number of RBCs in the fish blood can indicate the enhanced health status of the fish. Still, much research needs to be conducted to determine the mode of action of probiotics in increasing RBCs and their role in fish health.

The immune cells like thrombocytes and monocytes are found to be more abundant in the blood of catfish raised in tidal areas during the rainy season, indicating an increase of these cells with high suspended solids by monsoon runoffs coastal upwelling. The experiment demonstrates that the immunity and physiology of striped catfish are influenced by environmental factors [80]. A collection of *Bacillus* strains were identified to be antagonistic to the primary pathogens of catfish. They are also proved to be beneficial to both channel catfish and striped catfish to control (Enteric Septicemia of Catfish) ESC and BNP, respectively, when administered on feed [81]. In a survey conducted by Rico *et al*. [30], 38% of Vietnamese striped catfish farmers used probiotics to improve health and prevent disease outbreaks. The study on *P. hypophthalmus* showed that dietary supplementation of *B. amyloliquefaciens* 54A and *B. pumilus* 47B protected the fish from *E. ictaluri* infection [24].

Lysozyme is a defense molecule of the fish's innate immune system. It is an antibacterial agent that attacks and destroys the outer cell wall of bacteria [22]. Therefore higher lysozyme activity can lead to protection against pathogenic bacteria. It is an anti-microbial protein associated with front-line innate immunity invertebrates. This enzyme breaks the bond in the cell wall of gram-positive bacteria, and its association with complement components also affects the gram-positive bacteria [82]. It is a mucolytic enzyme of leucocytic origin that mediates protection against microbial invasion [69]. Recent research claims that lysozyme has anti-oxidant properties, although others say it boosts complement activity [82]. The study findings conducted by Van Doan *et al*. [26] showed that fish fed a diet containing 2g/kg Low Molecular Weight Agar (LMWA) and 10^8 CFU LP/g, either singly or in combination, had significantly higher serum lysozyme levels. When *P. bocourti* was fed with *L. plantarum*, the probiotic-fed group had substantially higher lysozyme activity than the control group [83]. Measurement of lysozyme activity is also a way of determining whether non-specific immunity could be improved by probiotic feeding. A comparable increase in lysozyme activity was seen in Rainbow trout fed with a diet supplemented with *L. plantarum* [67]. The range of immune effector activities like serum lysozyme is 192 - 387.78 Units per mL (U/mL) in healthy fish [84].

Phagocytosis is an activity where the phagocytes internalize, kill, and digest invading microorganisms. It initiates the processing and presentation of foreign antigens and the induction of cytokine secretion leading to lymphocyte activation [75]. The teleost fish possess a complement system with a functional antibody-mediated pathway and alternative pathway for complement activation [70]. Activation of the complement system helps develop acquired immunity [85]. Complement can eliminate pathogens in the inflammatory process by lysis cell membranes and activation of non-specific mediators [86]. Antibodies and antigen-carrying foreign cells activate complement system proteins in the plasma, which initiate a cascade of enzyme reactions that damage and eventually kill antibody-covered cells [87]. So, an increase in the complement activity may indicate enhanced immunity in the fish. Similar indifferent complement activity was seen in the experiment [67] in rainbow trout with *L. plantarum* supplemented diet.

Probiotics on bacterial resistance

The study conducted by Ran *et al*. [88] was the first to select the probiotic bacteria to control the Enteric Septicemia of Catfish (ESC) and other pathogens in catfish and evaluate the biocontrol efficacy via feed administration. The study conducted by Vine *et al*. [89] concluded that the probiotics isolated from the intestine of adult common clownfish have the power of colonization in intestinal mucus and serve as a prophylactic and therapeutic agent. *B. aerius* strain B81e, isolated from the intestine of healthy catfish, showed broad-spectrum antibacterial activity and the ability to suppress fish pathogens *Aeromonas hydrophila* and *Streptococcus agalactiae* by producing bacteriocin-like material [61]. *Bacillus* S11 protected *P. monodon* against pathogenic bacterial infection by competitive exclusion [90]. It was investigated that *Bacillus spp* co-culture of density 10^7-10^9 CFU m/L was required to inhibit the pathogenic *Vibrio harveyi* in *P. monodon* [9]. The stabilized community of *Bacillus* strains prevented the proliferation of opportunists (r-strategists), allowing a stable microbiota over time and protecting the common snook larvae from pathogenic host-microbe interactions [65]. The beneficial properties of LAB, like improved immune response and bacterial resistance in hybrid catfish, have brought them to the point of attention as a bio-control agent against the bacteria *A. hydrophila* [25].

Conclusion

Pangasianodon hypophthalmus (striped catfish) is one of the most important fish for culture worldwide. The breeding and nursing techniques have been improving a lot. Many technologies have been developed for breeding, nursing, and grow-out worldwide. Low survival of larvae has been one of the most problematic situations in the production cycle. Many diseases like BNP, columnar and red spots are prominent in nursery farms. Several benefits of the probiotics can be observed in host fish, fish producers, and consumers. Various research has proved that probiotics can be used in water and feed additives to obtain the benefits of probiotics in many fish species. *L. plantarum* is one of the most studied probiotics in aquaculture and has proved as a potential probiotic for improving growth, survival, and immune response in numerous fish species. Therefore, probiotics should be encouraged in small to large commercial aquaculture farms to have the corresponding benefits. Probiotics are more effective during the early life stage of many fishes, and more research for its use in various sizes of striped catfish should be done for more advancements.

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