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Probiotics in Aquatic Ecosystem – A Review

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ABSTRACT

Aquaculture suffers from bad soil conditions which lead to higher mortality, disease incidence, and a decrease in yield. Soil deterioration in aquaculture ponds is mainly due to the excess feed, fecal matter of the cultured organism such as shrimp and fish, and dead animals. Two major gases cause problems namely hydrogen sulfide and ammonia. Unless we understand the nitrogen cycle and sulfur cycle in the pond ecosystem, the solution is impossible. Nitrogen from amino acids, proteins, nucleic acid, minerals from feed supplements, etc., from organic matter accumulated as mentioned from the sources above, is converted to ammonia by a group of bacteria called nitrogen reducers. Sulfur from sulfur-containing amino acids, proteins, and a mineral is converted to hydrogen sulfide by sulfur-reducing bacteria. Nature has both oxidizing and reducing bacteria in perfect harmony. In a man-made system, one overtakes the other. In recent years, there has been growing interest in the biocontrol of microbial pathogens in aquaculture using antagonistic micro-organisms. Remediation of these unpleasant and unwanted problems in aquaculture there is a need for probiotics in shrimp culture through feed and/or water to prevent the aquaculture ponds from undergoing eutrophication and to control the microbial diseases in shrimps and enhance their growth rate and survival in an eco-friendly ambience without the use of antibiotics thus, resulting in quality assurance, quality control and above all environmental safety.

1. Introduction

Aquaculture has grown tremendously during the last few years becoming an economically important industry. With the increasing intensification and commercialization of aquaculture production, the disease is a major problem in the fish farming industry. The marine fisheries stocks have declined worldwide in general and provided an impetus for rapid development in fish and shellfish farming. The production process in shrimp aquaculture is determined by biological, technological, economic, and environmental factors [1]. However, the utility of antimicrobial agents as a preventive measure has been questioned, given extensive documentation of the evaluation of antimicrobial resistance among pathogenic bacteria. On the other hand, antibiotics inhibit or kill beneficial microbiota in the gastrointestinal (GI) ecosystem but they also made antibiotic residue accumulated in fish products to be harmful for human consumption. Another important problem faced by our Indian shrimp culture farmer is excess ammonia in pond water and sediment which is caused by excess feed, fecal matter, and dead algae deposited in the bottom of the pond. Due to this, shrimps are exposed to toxic gases like NH₃, NO₂, and H₂S further leading to eutrophication in the culture system and causing stress to the animal, and ultimately ends with microbial diseases and high mortality occurs [2].

One of the most significant technologies that evolved in response to disease control problems is the use of probiotics. The term probiotic means life; it was derived from two Greek words 'pro' and 'bios'. Probiotics are live microbes that can be used to improve the host intestinal microbial balance and growth performance. The development of probiotics in aquaculture management will reduce the use of antimicrobial drugs which were prophylactic alone and over-dependence in recent times poses potential hazards to the man who consumes them. This chapter summarizes the probiotic strains with relevance to algae and bioremediation processes and their significance in aquaculture. The alternative to antibiotics has prompted scientists to search for probiotics in controlling diseases in shrimp farms [3, 4].

2. Aquatic Ecosystem and Probiotics

Nowadays, probiotics are used in aquaculture to regulate micro dysbiosis, maintain microeubiosis, raise the health level of hosts, and promote proliferation enhancing their metabolic products in microecology. The other is to decompose organic matter (feces, wastes, remnants, or leftovers of feed), to maintain dynamic ecological balance among organisms from the five kingdoms in nature and microbial ecological equilibrium in water and sediments, and to create a friendly environment for fish and shrimp growth. Microorganisms are broadly classified into microalgae, bacteria, fungi, and viruses. Photosynthesis by absorbing CO₂ therefore, supplying oxygen to aquatic animals is done by microalgae. The decomposition of organic matter is done by bacteria and fungi in sediments to maintain good water quality. However, due to the lack of oxygen, there might be anaerobic decomposition or fermentation in sediments, producing harmful gases such as hydrogen sulfide and methane. There are two food chains in the aquatic ecosystem: the detritus food chain and prey-predatory food chain.

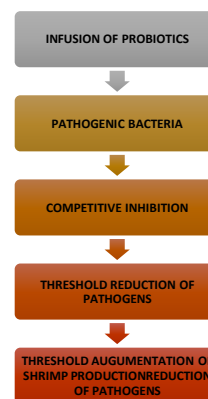


Fig. 1 Mechanism of probiotics in grow outs

Microbes are the predominant photosynthetic organisms in most aquatic environments. Algae, diatoms, and cyanobacteria predominate in aerobic conditions (e.g., shallow water), whereas other photosynthetic

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bacteria are dominant in anaerobic conditions (polluted or eutrophic waters), There is a big difference between natural aquatic ecosystems and man-made aquatic ecosystems, especially in intensive culture with high-stocking density and high input. The water body in a high-stocking density fishpond often in a small area has a limited self-purification capability. The need to add probiotics in various stages is required for good water quality to reduce the prevalence of diseases. The infusion of probiotics in the water body primarily helps in the multiplication of beneficial bacteria and competitive inhibition of pathogens takes place which encounter the water system via various sources such as air, feed, fecal matter, etc. (Fig. 1) [5-8].

3. Beneficial Bacteria

The luminous bacteria *Vibrio harveyi* has been considered a devastating disease in aquaculture practices and is the largest economic loss in shrimp aquaculture due to mass mortalities [9]. The role of probiotics emerges as prophylaxis to control the pathogens in the aquaculture system for its environment and eco-friendly nature [10]. The growth rate and survival of shrimp are currently enhanced by using beneficial microbes which cater to a wide range of benefits. In general, the gastrointestinal tract (GIT) of aquatic animals is mainly composed of gram-negative bacteria [11]. Researchers also have demonstrated the use of beneficial bacteria in aquaculture to improve the water quality and immune system by balancing bacterial flora in water and reducing the pathogenic bacteria load [12].

The attempt to isolate beneficial bacteria from various sources like soil, water, and animal gut to control disease-causing pathogens in aquaculture systems has been practiced [13-18]. The wide range of beneficial bacteria used in the aquaculture system belongs to the taxa *Lactobacillus*, *Bifidobacterium*, *Pediococcus*, *Lake Streptococcus* sp, and *Carnobacterium* sp. *Bacillus*, *Flavobacterium*, *Cytophaga*, *Pseudomonas*, *Alteromonas*, *Aeromonas*, *Enterococcus*, *Nitrosomonas*, *Nitrobacter* and *Vibrio* spp., and yeast *Saccharomyces*, *Debaryomyces* [19-21]. While using some beneficial bacteria for fish, some might be highly pathogenic *Vibrio alginolyticus* and lead to destructive effects in the aquaculture systems. Therefore, it is necessary to take care of the choice of beneficial microbes before administration. The best-known beneficial bacteria such as *Bifidobacteria* species, *Lactobacillus* sp, and *Streptococcus thermophilus* are employed as dietary supplements with feed in the aquaculture industry and increased the efficiency and sustainability of aquaculture production [17]. Beneficial microbes thus fulfill the concept of sustainable growth and production of shrimps by minimizing or de-promoting the growth of the disease-causing harmful pathogens.

4. Beneficial Microalgae

The water quality of the pond environment is determined by the dominant presence of diatoms. The species such as *Pyrrophyta* sp., *Cyanophyta* sp., and *Cryptophyta* sp. dominate the pond water due to the increase in organic pollution compared to diatoms. The diatoms are considered the best nutritional requirement for the post-larvae of Penaeus shrimp and also possess antibacterial activity. The diatom *Thalassiosira* acts as a good nutritional source of food and the *Chaetoceros* sp can rapidly reduce ammonia nitrogen. To maintain good pond water quality infusion of diatoms before probiotic application yield good results. However, diatom inoculation is not recommended due to its specific growth requirements and requires specialized environmental conditions. The kind of ecological environment that is required to promote the growth of diatoms has not been reported so far [22]. Austin *et al.* [14] reported a kind of microalgae (*Tetraselmis suecica*), which can inhibit the pathogenic bacteria in fish. *Tetraselmis suecica* was observed to inhibit *Aeromonas hydrophila*, *A. salmonicida*, *Serratia liquefaciens*, *Vibrio anguillarum*, *V. salmonicida* and *Yersinia ruckeri* type I. When used as a food supplement, the algal cells inhibited laboratory-induced infection in Atlantic salmon. When used therapeutically, the algal cells and their extracts reduced mortalities caused by *A. salmonicida*, *Serratia liquefaciens*, *V. anguillarum*, *V. salmonicida*, and *Yersinia ruckeri* type I. They suggested that there may be some bioactive compounds in the algal cells, and there appears to be a significant role for *Tetraselmis* in the control of fish diseases [23, 24].

5. Biodegradation of Grow Outs

Bioremediation using beneficial microbes either by single strain or combinations of strains is helpful to reduce the effluents from water bodies in the aquaculture system and other industries (Fig. 2). Some of the advantages of bioremediation include,

- On-site process implementation
- Permanent excess waste elimination can be implemented
- Cost-effective due to its biological nature

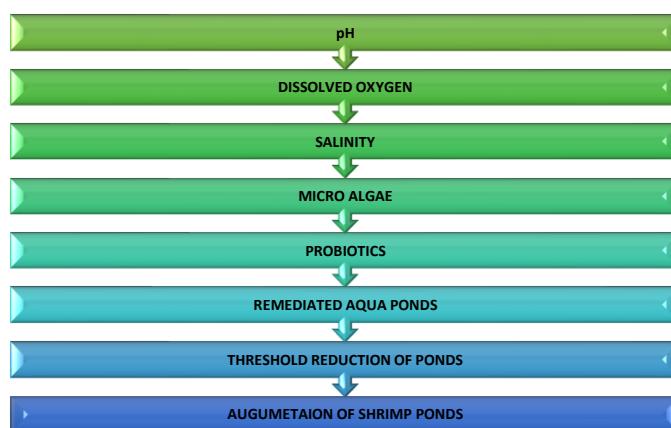


Fig. 2 Mechanism of non-specific commensals in grow outs

6. Aquaculture Grow Outs and Microbial Biodegradation

The water probiotics contain multiple strains of bacteria like *Bacillus acidophilus*, *B. subtilis*, *B. licheniformis*, *Nitrobacter* sp., and *Aerobacter* and *Saccharomyces cerevisiae*. These water probiotics in tanks and ponds will play a crucial role in fish health by improving the quality of water by modifying the bacterial composition of the water and sediments. The degradation of organic matter by microbes determines the water quality in aquaculture systems [25-27]. The carbon compounds in dissolved and suspended organic matter help the beneficial microbes to thrive and multiply by enzymatic cascade. The bacteria such as *Bacillus subtilis*, *B. licheniformis*, *B. cereus*, and *B. coagulans* were used as suitable for the bioremediation of organic detritus [28, 29]. *Lactobacillus* sp. is also used along with *Bacillus* to break down the organic detritus. These bacteria produce a variety of enzymes that break down proteins and starch into small molecules, which are then taken up as energy sources by other organisms. The removal of large organic compounds reduces water turbidity [30]. Many examples in which both singular bacterial strains and microbial systems have been successfully utilized to reduce and or transform selected pollutants into nontoxic molecules in laboratory conditions [31-34]. Nitrogen applications over pond assimilatory capacity can lead to the deterioration of water quality through the accumulation of nitrogenous compounds (e.g., ammonia and nitrite) with toxicity to fish and shrimp. Bacteriological nitrification is considered beneficial for the reduction of ammonia from closed aquaculture systems and it is commonly achieved by setting up sand and gravel bio-filter through which water is allowed to circulate. The ammonia-oxidizing bacteria are *Nitrosomonas*, *Nitrosovibrio*, *Nitrosococcus*, *Nitrolobus*, and *Nitrospira* and the nitrate oxidizing bacteria are *Nitrobacter*, *Nitrosococcus*, and *Nitrospira* are the commonly used bacteria in aquaculture systems. Sulfur is of some interest in aquaculture because of its importance in anoxic sediments. Sulfide oxidation is mediated by microorganisms in the sediment, though it can occur by purely chemical processes. The photosynthetic benthic bacteria that break H_2S at the pond bottom have been widely used in aquaculture to maintain a favorable environment. These bacteria contain bacterio-chlorophyll that absorb light (blue to the infrared spectrum, depending on the type of bacterio-chlorophyll) and perform photosynthesis under anaerobic conditions.

7. Conclusion

Increased use of antibiotics has led to a high proportion of antibiotic-resistant bacteria which provide a threat to fish and man through consumption of the infected fish. Inefficiencies in antibiotic treatment of fish illnesses lead to significant economic losses. But the use of probiotics in aquaculture has been shown to have a beneficial impact on fish health and thereby the economic performance of fish farming. Shrimp aquaculture is burdened with environmental problems that arise from the consumption of resources, such as land, water, seed, and feed, and their transformation into products valued by society. In addition, after the culture period, effluents from aquaculture ponds contain living and dead particulate organic matter, dissolved organic matter, ammonia, nitrite, nitrate, phosphate, suspended soil particles, and other substances that can be considered potential pollutants. Hence, the application of probiotics in

aquaculture systems has been rising over the years with increasing demand for more eco-friendly aquaculture practices. At the same time, the use of probiotics has also important environmental benefits. Therefore, the use of probiotics in fish and shrimp feed should also be seen as an important step in aquaculture sustainability.

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