Use of Probiotics in Aquaculture: A Safer Alternative to Antibiotics

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ABSTRACT

Aquaculture has emerged as one of the fastest-growing food-producing sectors in the world, contributing significantly to global food security and nutritional demand. However, the rapid intensification of aquaculture practices has increased the occurrence of infectious diseases, leading to the extensive use of antibiotics for disease prevention and treatment. Continuous and indiscriminate application of antibiotics has resulted in the development of antimicrobial resistance, environmental contamination, and accumulation of antibiotic residues in aquatic products, posing serious risks to aquatic organisms, human health, and ecosystem sustainability. In recent years, probiotics have gained considerable attention as a sustainable and eco-friendly alternative to antibiotics in aquaculture. Probiotics are beneficial microorganisms that improve the microbial balance of the host, enhance digestion and nutrient utilization, stimulate immune responses, and inhibit the growth of pathogenic microorganisms through competitive exclusion and production of antimicrobial substances. Various probiotic strains, including species of Bacillus, Lactobacillus, Pseudomonas, and Saccharomyces, have demonstrated positive effects on fish and shrimp health, growth performance, survival rate, water quality management, and disease resistance. The use of probiotics not only reduces dependency on antibiotics but also promotes environmentally sustainable aquaculture practices. This article highlights the importance, mechanisms, benefits, and future prospects of probiotics in aquaculture as a safer and more effective alternative to antibiotics for achieving healthy and sustainable aquatic production systems.

INTRODUCTION

Aquaculture is one of the fastest-growing food-producing sectors in the world, contributing significantly to global food security and nutrition (FAO, 2022). The increasing demand for fish and shellfish has led to the intensification of aquaculture practices, which often results in higher disease outbreaks due to stress and poor water quality (Bondad-Reantaso *et al*., 2005). Traditionally, antibiotics have been widely used to control bacterial infections in fish farming systems (Cabello, 2006). However, the excessive and unregulated use of antibiotics has raised serious concerns regarding antibiotic resistance, environmental contamination, and food safety (Defoirdt *et al*., 2011). In recent years, probiotics have emerged as a promising and eco-friendly alternative to antibiotics in aquaculture (Nayak, 2010). Probiotics are live microorganisms that, when administered in adequate amounts, confer health benefits to the host organism (FAO/WHO, 2002). Their use in aquaculture is gaining popularity due to their ability to improve growth, enhance immunity, and maintain water quality without harmful side effects (Merrifield *et al*., 2010).

The requirements that a probiotic organism must meet are:

- Resistance to the acid stomach environment, bile and pancreatic enzymes;
- Accession to the cells of the intestinal mucosa;
- Capacity for colonization;
- Staying alive for a long period of time, during the transport, storage, so that they can colonize the host efficiently;
- Production of antimicrobial substances against the pathogenic bacteria; and
- Absence of translocation.
- Should be able to withstand the feed processing.

Mechanism of action

- **Competition for binding sites**: also known as "competitive exclusion", where probiotics bacteria bind with the binding sites in the intestinal mucosa, forming a physical barrier, preventing the connection by pathogenic bacteria;
- **Production of antibacterial substances**: probiotic bacteria synthesize compounds like hydrogen peroxide and bacteriocins, which have antibacterial action, mainly in relation to pathogenic bacteria. They also produce organic acids that lower **the environment's pH of the gastrointestinal tract**, preventing the growth of various pathogens and development of certain species of *Lactobacillus*;
- **Competition for nutrients**: the lack of nutrients available that may be used by pathogenic bacteria is a limiting factor for their maintenance;
- **Stimulation of immune system**: some probiotics bacteria are directly linked to the stimulation of the immune response, by increasing the production of antibodies,

activation of macrophages, T-cell proliferation and production of interferon.

Types of probiotics used in aquaculture

Feed probiotics:

Bacillus strains that are lactic-acid-producing and spore-forming are used as feed probiotics. On-lactic acid producing Bacillus sporogenes don't work as feed probiotics because of thermal sensitivity. Examples of feed probiotics: -Bacillus acidophilus, B. subtilis, B. megaterium, B. lechiniformis, Lactobacillus delbruckii, L. bulgaricus, Acetobacter xylinum, Saccharomyces cerevisiae [fungus, yeast] Saccharomyces bouvardia [fungus, yeast].

Water probiotics

Probiotic products like Super-biotic, Super Ps, Zymetin, Aquastar, and Mutagen play a vital role in postlarvae of *P.monodon* by maintaining good water quality parameters throughout the culture period. The most common genera of heterotrophic bacteria used in probiotic formulations are *Bacillus* and *Lactobacillus*, both of which are gram-positive. It is not necessary, however, to inoculate a pond with commercial probiotics in order to manage a heterotrophic production system. This can be accomplished simply by maintaining a C:N ratio greater than 12:1, and supplying adequate aeration. Shrimp feeds used in intensive shrimp ponds typically have at least 35% protein with C:N ratios in these feeds typically run around 9:1. The bacteria require about 20 units of carbon per unit of nitrogen assimilated. The accumulation of waste compounds favors the growth of potentially harmful microorganisms while impacting the performance of farmed species. As water quality plays an important role, it is of great value to understand the various interactions taking place within the ponds. Probiotic bacterial cultures added to shrimp ponds typically are composed primarily of heterotrophic bacteria, or a mixture of heterotrophic bacteria and autotrophic nitrifiers. The protein in the organic detritus supplies most of the nitrogen requirement for the heterotrophic bacteria. This is solved by adding a carbohydrate source such as molasses in addition to the regular feed, the increased availability of carbon allows the heterotrophic bacterial proliferation. The oxygen required to support this additional bacterial biomass will increase proportionally with the increase in bacterial population. Likewise, CO_2 production will increase, driving pH down. Thereby pond should be well-aerated and circulated to keep the organic detritus suspended in the water column where there is sufficient oxygen for the heterotrophs. Also, sudden discontinue of the carbohydrate supplementation will starve the bacteria of carbon, a die-off will occur and consequence will be ammonia spike.

Table 1. Summary of pond interactions with and without the addition of beneficial bacteria.

Effect on	Without beneficial bacteria	With beneficial bacteria
Feed waste, faeces and organic matter	Accumulation	Reduction
Ammonia (NH_3), Nitrogen dioxide (NO_2), Hydrogen sulphide (H_2S)	▲ Increase	▼ Decrease
Oxygen (O_2)	▼ Decrease	▲ Increase
Eutrophication	▲ Increase Contaminated pond, water and bottom	▼ Decrease Improved pond, water and bottom
Pathogen and disease	▲ Increase	▼ Decrease
Shrimp growth and crop	▼ Decrease	▲ Increase

Role of Probiotics in Aquaculture

Probiotics play a crucial role in maintaining the balance of microbial communities in aquaculture systems (Verschuere *et al*., 2000). They work by competing with pathogenic bacteria for nutrients and space, thereby preventing disease outbreaks (Kesarcodi-Watson *et al*., 2008). Some probiotic strains also produce antimicrobial substances that inhibit harmful microorganisms (Balcázar *et al*., 2006). In addition to disease prevention, probiotics enhance digestion and nutrient absorption in fish by producing digestive enzymes such as proteases, amylases, and lipases (Balcázar *et al.*, 2006). This leads to improved growth performance and feed efficiency, which are essential for profitable aquaculture (Nayak, 2010). Moreover, probiotics stimulate the immune system of fish, making them more resistant to infections (Newaj-Fyzul *et al.*, 2014). Another important benefit of probiotics is their role in improving water quality. They help in breaking down organic waste, reducing ammonia and nitrite levels, and maintaining a healthy aquatic environment (De Schryver & Vadstein, 2014). This is particularly beneficial in intensive aquaculture systems where waste accumulation can be a major problem.

INDIGENOUS MICROBIOTA OF SHRIMP AND THEIR SIGNIFICANCE

Name of the organism	Significance
Aeromonas media A199	Decrease of mortality and suppression of the pathogen of Pacific oyster larvae when challenged with a pathogenic *Vibrio tubiashii*
Plesiomonas spps.	Show inhibitory activity against primary pathogens *Pseudomonas aeruginosa, P. fluorescens,* secondary pathogens Salmonella, Shigella, E. coli, Streptococcus
Pseudomonas spp.	Potential antagonistic bacterium against pathogenic vibrios in penaeid shrimp. Produces extracellular antivibrio component
Enterobacteriaceae	Indicators of hygienic quality of foods and water. Their presence in prawn may be attributed to the feed or animal manure commonly used to fertilize ponds
Vibrio P62, Vibrio P63	Immunostimulatory effect in *Penaeus vannamei*
Bacillus strain S11	Better yield and good control of disease and immunity enhancement in *Penaeus monodon*
Lactobacillus plantarum	Stimulate nonspecific immune response in Litopenaeus vannamei when challenged with *V. harveyi*

Advantages Over Antibiotics

Unlike antibiotics, probiotics do not contribute to the development of antimicrobial resistance, which is a major global health concern (Defoirdt *et al.*, 2011). They are environmentally friendly and do not leave harmful residues in fish tissues or aquatic ecosystems (Cabello, 2006).

Probiotics also promote sustainable aquaculture by reducing dependency on chemical treatments and enhancing natural biological processes (Merrifield *et al.*, 2010). Their continuous use can lead to long-term improvements in fish health and farm productivity without negative side effects (Nayak, 2010). Furthermore, probiotics are safe for consumers, as they do not pose risks associated with antibiotic residues in seafood (FAO/WHO, 2002). This makes probiotic-based aquaculture products more acceptable in international markets, where strict regulations on antibiotic use are enforced.

Challenges and Future Prospects

Despite their numerous benefits, the application of probiotics in aquaculture faces certain challenges (Newaj-Fyzul *et al.*, 2014). The selection of suitable probiotic strains for specific fish species and environmental conditions is still a complex task (Kesarcodi-Watson *et al.*, 2008). Additionally, maintaining the viability and effectiveness of probiotics during storage and application requires proper management practices (Balcázar *et al.*, 2006).Future research should focus on developing species-specific probiotics and understanding their mechanisms of action in different aquaculture systems (De

Schryver & Vadstein, 2014). The integration of probiotics with other sustainable practices, such as biofloc technology and recirculating aquaculture systems, can further enhance their effectiveness (Nayak, 2010).

CONCLUSION

The use of probiotics in aquaculture represents a safe, sustainable, and effective alternative to antibiotics. They not only help in disease prevention but also improve growth performance, immunity, and water quality. With increasing concerns over antibiotic resistance and environmental sustainability, probiotics are becoming an essential component of modern aquaculture practices. Although some challenges remain, continued research and proper application can unlock their full potential, paving the way for a healthier and more sustainable aquaculture industry.

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