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Review Article

ROLE OF PROBIOTICS IN GROWTH PROMOTION, IMMUNITY AND DISEASE PREVENTION IN SHRIMP

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ABSTRACT

In contemporary aquaculture, probiotics have become a viable and efficient substitute for antibiotics. They decrease the incidence of bacterial illnesses and antibiotic resistance while enhancing growth performance, feed consumption, immunological responses, disease resistance, and water quality. Shrimp's innate immune system is strengthened, gut microbial balance is improved, and digestive enzyme activity is stimulated by common probiotic genera such Bacillus, Lactobacillus, Pediococcus, and Enterococcus. Additionally, probiotics prevent harmful microbes, especially Vibrio species, by inhibiting quorum sensing, producing antimicrobial compounds, and competitively excluding them. Additionally, by lowering hazardous nitrogenous chemicals and organic trash, they help to improve the quality of pond water. Probiotics paired with prebiotics (synbiotics) and new technologies like precision aquaculture and microbiome engineering have exciting prospects for sustainable shrimp farming. All things considered, probiotic supplementation is a secure, sustainable, and effective way to enhance shrimp productivity, health, and environmental sustainability.

Keywords: Probiotics, Shrimp aquaculture, *Penaeus vannamei,* Gut microbiota, Growth performance.

INTRODUCTION

Enhancing the growth performance of farmed aquatic animals is one of the main benefits of probiotic supplementation in aquaculture. By preserving a healthy gut microbiota, boosting the release of digestive enzymes, and improving nutrient absorption and digestion, probiotic bacteria promote intestinal health (Gatesoupe, 1999; Merrifield *et al*., 2010). Better feed conversion efficiency (FCR), more weight gain, a higher specific growth rate (SGR), and lower feed costs are all outcomes of improved nutrient use (Hai, 2015). Probiotic addition greatly increases body weight, survival rate, and overall production performance in shrimp diets, according to several studies (Ringø *et al*., 2020; Hoseinifar *et al*., 2018). Species belonging to the genera *Bacillus*, *Lactobacillus*, *Pediococcus*, and *Enterococcus* have demonstrated beneficial effects on the growth of *Litopenaeus vannamei* and *Penaeus monodon* (Balcázar *et al*., 2006; Soltani *et al*., 2019). The synthesis of digestive enzymes such as protease, amylase, cellulase, and lipase is believed to be responsible for these positive effects (Ringø *et al*., 2020). By preserving the integrity of the intestinal epithelium and expanding the surface area available for nutrient absorption, probiotics also improve intestinal morphology (Merrifield *et al*., 2010). A healthy gut environment promotes efficient digestion and minimizes nutrient loss, enabling *L. vannamei* and *P. monodon* to convert feed into biomass more effectively. Consequently, probiotic-supplemented shrimp generally exhibit improved body condition, faster growth, and higher production performance than untreated groups (Hai, 2015).

Probiotics also synthesize essential nutrients including vitamins, amino acids, fatty acids, and growth-promoting metabolites that support normal physiological functions (Gatesoupe, 1999). Furthermore, these beneficial microorganisms suppress pathogenic bacteria through competitive exclusion and the production of antimicrobial compounds, thereby improving digestive efficiency (Balcázar *et al*., 2006). Numerous probiotic strains, particularly *Bacillus subtilis*, *Bacillus licheniformis*, *Lactobacillus plantarum*, *Enterococcus faecium*, and *Pediococcus acidilactici*, have been reported to

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significantly improve shrimp growth (Soltani *et al*., 2019; Ringø *et al*., 2020). Combined probiotic supplementation often produces synergistic effects, resulting in superior growth and survival compared with single-strain supplementation (Hai, 2015).

Enhancement of Immune Responses

Probiotics play a vital role in enhancing the immune responses of aquatic animals by stimulating both innate and adaptive defense mechanisms (Balcázar *et al*., 2006; Hoseinifar *et al*., 2018). Since shrimp such as *Litopenaeus vannamei* and *Penaeus monodon* lack an adaptive immune system, they rely primarily on innate immune responses (Söderhäll & Cerenius, 1992). Probiotic microorganisms activate hemocytes and stimulate the production of antimicrobial peptides, lysozyme, prophenoloxidase, respiratory burst activity, and antioxidant enzymes including superoxide dismutase (SOD), catalase, and glutathione peroxidase (Ringø *et al*., 2020; Hai, 2015). These immune responses enhance the ability of *L. vannamei* and *P. monodon* to recognize and eliminate invading pathogens (Hoseinifar *et al*., 2018).

Additionally, probiotics increase hemocyte counts, improve phagocytic activity, and stimulate the expression of immune-related genes involved in pathogen recognition and antimicrobial defense (Nayak, 2010; Ringø *et al*., 2020). Probiotics also strengthen antioxidant defenses by enhancing SOD and catalase activities, thereby reducing oxidative stress caused by reactive oxygen species (ROS). This protection maintains cellular integrity and promotes overall health in *L. vannamei* and *P. monodon* (Hai, 2015). Furthermore, a balanced gut microbiota contributes to sustained immune surveillance and resistance against opportunistic pathogens (Merrifield *et al*., 2010). Consequently, probiotic-fed shrimp exhibit improved disease resistance, higher survival, and enhanced productivity (Ringø *et al*., 2020; Hoseinifar *et al*., 2018).

Disease Prevention

The use of probiotics represents one of the most promising biological strategies for preventing bacterial diseases in shrimp aquaculture (Ringø *et al*., 2018; Hoseinifar *et al*., 2018). Unlike antibiotics, probiotics suppress pathogen colonization by creating a favorable microbial environment (Verschuere *et al*., 2000; Kesarcodi-Watson *et al*., 2008). Beneficial microorganisms inhibit pathogens through competitive exclusion, antimicrobial metabolite production, nutrient competition, and immune modulation (Verschuere *et al*., 2000; Gatesoupe, 1999). By colonizing the intestinal tract of *Litopenaeus vannamei* and *Penaeus monodon*, probiotics occupy ecological niches that would otherwise be available to pathogenic bacteria (Nayak, 2010).

Numerous probiotic strains produce bacteriocins, hydrogen peroxide, organic acids, and extracellular enzymes that inhibit pathogenic bacteria (Ringø & Gatesoupe, 1998; Balcázar *et al*., 2006). They also interfere with quorum sensing, thereby reducing toxin production and biofilm formation (Defoirdt *et al*., 2004; Defoirdt *et al*., 2011). Several studies have reported antagonistic activity against *Vibrio harveyi*, *Vibrio parahaemolyticus*, *Vibrio alginolyticus*, *Vibrio vulnificus*, and *Vibrio campbellii* (Zheng & Wang, 2017; Gao *et al*., 2018; Du *et al*., 2019; Zuo *et al*., 2019). Experimental challenge studies in *Litopenaeus vannamei* consistently demonstrate lower bacterial loads, improved survival, and greater disease resistance following probiotic supplementation (Chomwong *et al*., 2018; Wang *et al*., 2019).

Improvement of Water Quality

Probiotics contribute significantly to maintaining pond water quality in shrimp aquaculture (Verschuere *et al*., 2000; Wang *et al*., 2008). Beneficial bacteria degrade uneaten feed, feces, and organic waste, thereby reducing ammonia, nitrite, and hydrogen sulfide accumulation (Moriarty, 1998; Gatesoupe, 1999). Certain nitrifying bacteria convert toxic ammonia into less harmful nitrate, improving water quality (Boyd & Tucker, 1998; Hai, 2015). These improvements reduce physiological stress in cultured *Litopenaeus vannamei* and *Penaeus monodon*, leading to better growth, survival, and production performance (Verschuere *et al*., 2000; Ringø *et al*., 2020).

The gastrointestinal tract of *Litopenaeus vannamei* and *Penaeus monodon* contains a diverse microbial community that plays an essential role in digestion, nutrient absorption, metabolism, and immunity (Ringø *et al*., 2016; Hoseinifar *et al*., 2018). Dietary probiotics regulate the gut microbiota by promoting beneficial microorganisms and suppressing opportunistic pathogens (Verschuere *et al*., 2000; Nayak, 2010). A balanced intestinal microbiota enhances nutrient utilization, strengthens intestinal integrity, and improves overall health (Merrifield *et al*., 2010; Ringø *et al*., 2018). Advanced molecular techniques, including next-generation sequencing and metagenomics, have confirmed that probiotics increase microbial diversity and promote a stable intestinal ecosystem in cultured shrimp (Xiong *et al*., 2017; Ringø *et al*., 2020).

Modulation of Gut Microbiota

The gastrointestinal tract of *Litopenaeus vannamei* and *Penaeus monodon* contains a diverse microbial community that plays an essential role in digestion, nutrient absorption, metabolism, and immunity (Ringø *et al*., 2016; Hoseinifar *et al*., 2018). Dietary probiotics regulate the gut microbiota by promoting beneficial microorganisms and suppressing opportunistic pathogens (Verschuere *et al*., 2000; Nayak, 2010). A balanced intestinal microbiota enhances nutrient utilization, strengthens intestinal integrity, and improves overall health (Merrifield *et al*., 2010; Ringo *et al*., 2018). Advanced molecular techniques, including next-generation sequencing and metagenomics, have confirmed that probiotics increase microbial diversity and promote a stable intestinal ecosystem in cultured shrimp (Xiong *et al*., 2017; Ringo *et al*., 2020).

Role of Synbiotics

Synbiotics, a combination of probiotics and prebiotics, have emerged as an effective nutritional strategy for improving the health and productivity of cultured *Litopenaeus vannamei* and *Penaeus monodon* (Gibson & Roberfroid, 1995; Ringø *et al*., 2010). Prebiotics such as fructooligosaccharides (FOS), mannan oligosaccharides (MOS), galactooligosaccharides (GOS), and inulin selectively stimulate beneficial gut bacteria, thereby improving intestinal microbial balance (Merrifield *et al*., 2010; Hoseinifar *et al*., 2016). Compared with probiotics or prebiotics alone, synbiotics significantly enhance growth, feed utilization, digestive enzyme activity, immunity, and disease resistance (Hai, 2015; Hoseinifar *et al*., 2018). Therefore, synbiotics are increasingly recognized as important tools for sustainable shrimp aquaculture (Ringø *et al*., 2018; Dawood *et al*., 2018).

Future Prospects of Probiotics in Aquaculture

Recent advances in genomics, metagenomics, and microbiome research have facilitated the identification of host-specific probiotic strains for *Litopenaeus vannamei* and *Penaeus monodon*. Emerging technologies, including microbiome engineering, encapsulation techniques, precision feeding, and artificial intelligence-based health monitoring, are expected to improve probiotic efficacy and disease management. Future research is focusing on combining probiotics with bacteriophages, phytobiotics, immunostimulants, and biofloc technology to develop environmentally sustainable disease-control strategies for shrimp aquaculture.

CONCLUSION

Probiotics have become an essential component of sustainable shrimp aquaculture due to their ability to improve growth performance, feed utilization, immune responses, and disease resistance in *Litopenaeus vannamei* and *Penaeus monodon*. By enhancing digestive enzyme activity, maintaining a balanced gut microbiota, and improving water quality, probiotics promote better health and production efficiency. They also provide an eco-friendly alternative to antibiotics by suppressing pathogenic microorganisms and reducing the risk of antimicrobial resistance. The combined use of probiotics with prebiotics as synbiotics further enhances shrimp growth, survival, and resilience against infectious diseases. Recent advances in microbiome research, genomics, and precision aquaculture are expected to optimize probiotic applications and enable the development of host-specific microbial formulations. Overall, integrating probiotics into shrimp farming practices offers a promising and environmentally sustainable approach for improving productivity, animal welfare, and long-term aquaculture sustainability.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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