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Opinion Article

Bacillus Probiotics for Sustainable Aquaculture Growth and Health

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DESCRIPTION

The sustainable development of aquaculture is increasingly reliant on innovative strategies to enhance productivity while minimizing environmental impacts. In recent years, the application of probiotics, particularly *Bacillus* species, has emerged as a promising approach to improve aquaculture health and efficiency. The probiotic potential of *Bacillus* lies in its ability to promote growth, enhance immunity and protect against pathogens, making it a valuable candidate for sustainable aquaculture practices. This commentary explores recent advances in the probiotic application of *Bacillus* in aquaculture, highlighting its multifaceted benefits and future potential.

One of the key advantages of using *Bacillus* probiotics in aquaculture is their strong ability to produce spores, which makes them highly resilient to extreme environmental conditions. Unlike many lactic acid bacteria, *Bacillus* strains can withstand high temperatures, variable pH levels and salinity fluctuations, making them particularly suited for aquaculture applications. This stability ensures that the probiotics remain viable and effective throughout feed processing, storage and administration. Moreover, the spore-forming nature of *Bacillus* extends its shelf life, enhancing its practicality for large-scale aquaculture operations.

Recent studies have demonstrated the growth-promoting effects of *Bacillus* probiotics in various aquaculture species. For example, dietary supplementation with *Bacillus subtilis* and *Bacillus licheniformis* has been shown to significantly enhance growth performance, feed conversion efficiency and survival rates in fish and shrimp. These effects are attributed to the probiotics' ability to improve gut health by modulating the intestinal microbiota, promoting beneficial bacteria and reducing the colonization of harmful pathogens. Furthermore, *Bacillus* probiotics enhance digestive enzyme activity, such as protease and amylase, which boosts nutrient absorption and improves overall growth efficiency.

Beyond growth promotion, *Bacillus* probiotics play an important role in enhancing the immune system of aquaculture species. They stimulate both innate and adaptive immunity by increasing the production of immune-related molecules, such as lysozymes, complement proteins and immunoglobulins. Recent research has highlighted the immunomodulatory effects of *Bacillus coagulans* and *Bacillus* amyloliquefaciens in fish, demonstrating increased resistance to bacterial and viral infections. By strengthening the immune response, *Bacillus* probiotics reduce the reliance on antibiotics and other chemical treatments, promoting a more sustainable and eco-friendly aquaculture industry.

Another major benefit of *Bacillus* probiotics is their biocontrol potential against aquaculture pathogens. Numerous studies have shown that *Bacillus* strains produce antimicrobial compounds, including lipopeptides, bacteriocins and enzymes, which effectively inhibit the growth of pathogenic bacteria such as *Vibrio*, *Aeromonas* and *Pseudomonas* species. Additionally, *Bacillus* probiotics compete with pathogens for adhesion sites in the gut, preventing their colonization and reducing disease incidence. This antagonistic activity makes *Bacillus* an eco-friendly alternative to conventional antibiotics, helping combat antimicrobial resistance while improving aquaculture health.

Water quality management is another area where *Bacillus* probiotics demonstrate significant benefits. In aquaculture systems, waste accumulation and nitrogenous compounds, such as ammonia and nitrite, can degrade water quality and stress aquatic species. *Bacillus* strains, particularly *Bacillus subtilis* and *Bacillus megaterium*, are known for their bioremediation capabilities. These strains efficiently degrade organic matter, reducing sludge formation and improving water clarity. Additionally, they promote the nitrification and denitrification processes, helping maintain optimal water quality parameters. This bioremediation potential contributes to more stable aquaculture environments, supporting healthier stocks and reducing mortality rates.

The sustainability of aquaculture is also closely linked to environmental stewardship and *Bacillus* probiotics align with this objective. By enhancing nutrient utilization and feed efficiency, these probiotics reduce feed waste and nutrient discharge into

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the environment. Lower waste output reduces the risk of eutrophication and the accumulation of harmful organic matter in aquaculture systems. Moreover, the reduced need for antibiotics and chemical treatments mitigates the environmental footprint of aquaculture operations, supporting sustainable production practices.

In conclusion, the use of *Bacillus* probiotics in aquaculture represents a significant advancement toward sustainable and eco-friendly farming practices. Their growth-promoting effects, immune-enhancing properties, pathogen control capabilities and water quality benefits make them valuable allies in aquaculture production. As research and innovation continue to expand, the integration of *Bacillus* probiotics into aquaculture systems holds great potential to improve productivity, reduce environmental impact and support the long-term sustainability of the industry.