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Short Communication

A Review of Probiotics in Aquaculture, Focusing on Biological Control, Efficacy, Safety and Genomics

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DESCRIPTION

Probiotics, defined as live microorganisms that, when consumed in adequate amounts, confer health benefits to the host, are gaining significant attention in the field of aquaculture [1]. These beneficial microbes exert positive effects on aquatic organisms through various mechanisms, such as enhancing immune responses, improving resistance to infectious diseases and increasing tolerance to environmental stressors. Given the growing demand for sustainable practices in aquaculture, the use of probiotics as a natural alternative to chemical treatments and antibiotics is becoming an important area of study [2]. This review provides an in-depth analysis of the methods used to identify and evaluate probiotics for aquaculture, focusing on their biological control, efficacy, safety and the latest advancements in genomics and experimental methodologies.

Probiotics in aquaculture: Mechanisms of action

In aquaculture, probiotics are primarily introduced to the host (usually fish or shrimp) through their diet. These microorganisms can enhance the health of aquatic organisms by supporting the gut microbiome, improving digestion and preventing pathogen colonization. Some key mechanisms through which probiotics exert their effects include:

Immune system modulation: Probiotics can stimulate the host's immune system, enhancing its ability to resist infections. This includes the activation of innate and adaptive immune responses, as well as the production of antimicrobial substances that protect the host from pathogens [3].

Disease resistance: Probiotics are known to enhance the resistance of aquaculture species to a range of infectious diseases, particularly those caused by bacterial pathogens. By competing for nutrients and space on the host's epithelial surfaces, probiotics inhibit the growth of harmful microbes [4].

Stress tolerance: Environmental stressors, such as fluctuations in water quality, temperature changes and handling, can severely affect the health of aquaculture species. Probiotics help mitigate the impact of these stressors by maintaining gut health and reducing oxidative stress in the host.

Genomic approaches: *In silico* analysis

One of the most prominent tools in the identification of probiotics is genomic analysis. *In silico* methods involve the use of computational tools to analyze the genetic makeup of microorganisms and predict their potential benefits or risks to the host.

Two main categories of genetic traits are examined using bioinformatics tools.

Safety-related traits: Safety is a primary concern when selecting probiotics for aquaculture. Probiotics should not possess genetic traits that could harm the host or human consumers. These traits include the ability to produce toxins, antibiotic resistance genes or other harmful metabolites. Advanced genomic tools can identify such traits and allow researchers to rule out microorganisms that pose a safety risk [5].

Beneficial traits: Conversely, beneficial traits include the ability of probiotics to produce helpful compounds, such as antimicrobial peptides, enzymes that aid in digestion or compounds that promote immune system health. Genomic tools can identify genes responsible for these beneficial traits, enabling researchers to prioritize microorganisms with the greatest potential for promoting health and growth in the host [6].

Experimental approaches

While genomic analysis provides valuable insights into the potential of a probiotic, it is essential to complement these findings with experimental methods. *In vitro* and *in vivo* experiments are used to evaluate both the safety and efficacy of probiotics in aquaculture species.

Adhesion to epithelia: Probiotics must adhere to the host's gastrointestinal tract to exert their beneficial effects. *In vitro* adhesion assays help identify probiotics that can colonize the host's gut and persist long enough to provide health benefits [7].

Antagonistic activity against pathogens: Probiotics should demonstrate the ability to inhibit the growth of harmful bacteria through competitive exclusion, the production of antimicrobial

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substances or other mechanisms [8]. *In vitro* assays can evaluate the antimicrobial activity of probiotics against a range of pathogens.

Toxicity testing: Probiotics must not produce harmful substances or exert toxic effects on the host. *In vitro* testing helps identify potential safety concerns by assessing the ability of probiotics to cause cell damage or immune dysregulation.

Evaluating host health and performance

Growth performance: Probiotics are expected to improve the growth rate and feed conversion ratio of aquaculture species. *In vivo* studies help determine the effects of probiotics on these important parameters [9].

Health and disease resistance: The ability of probiotics to improve disease resistance is a importance factor in their selection. *In vivo* studies can assess the impact of probiotics on the host's immune response, its ability to fight infections and the overall health of the organism [10].

Microbiome modulation: Probiotics can alter the microbial composition of the host's gut, leading to a more balanced and beneficial microbiome. *In vivo* studies help assess how probiotics affect the gut microbiota and whether these changes translate into improved host health.

CONCLUSION

The use of probiotics in aquaculture holds tremendous for improving the health, growth and sustainability of aquaculture systems. However, the identification of effective probiotics requires a careful and integrated approach, combining genomic analysis, *in vitro* testing and *in vivo* studies. By leveraging these advanced methodologies, researchers can identify safe and beneficial probiotics that enhance the performance of aquaculture species while minimizing the risks associated with antibiotic use. As study in this area continues to advance, probiotics are likely to become a cornerstone of sustainable aquaculture practices worldwide.

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