Probiotics in Fish Nutrition

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Probiotics are live microbial additives that have a beneficial effect on the host by (1) modifying the host-associated microbial community, (2) ensuring improved use of the feed or enhancing its nutritional value, (3) enhancing the host response towards disease, and/or (4) improving the quality of its ambient environment.

probiotics aquaculture microbiome living gut species-specific bacteria mode-of-action

1. Overview

Over the last decades, aquaculture production increased rapidly. The future development of the industry highly relies on the sustainable utilization of natural resources. The need for improving disease resistance, growth performance, food conversion, and product safety for human consumption has stimulated the application of probiotics in aquaculture. Probiotics increase growth and feed conversion, improve health status, raise disease resistance, decrease stress susceptibility, and improve general vigor. Currently, most probiotics still originate from terrestrial sources rather than fish. However, host-associated (autochthonous) probiotics are likely more persistent in the gastrointestinal tract of fish and may, therefore, exhibit longer-lasting effects on the host. Probiotic candidates are commonly screened in in vitro assays, but the transfer to in vivo assessment is often problematic. In conclusion, modulation of the host-associated microbiome by the use of complex probiotics is promising, but a solid understanding of the interactions involved is only in its infancy and requires further research. Probiotics could be used to explore novel ingredients such as chitin-rich insect meal, which cannot be digested by the fish host alone. Most importantly, probiotics offer the opportunity to improve stress and disease resistance, which is among the most pressing problems in aquaculture.

2. Background

In view of stagnating fishery landings reported over the past 50 years, only the rapidly developing aquaculture industry can meet the increasing per capita demand for fish worldwide. Over the past decades, global aquaculture production has nearly doubled every ten years, which reflects the fastest growth in the food-producing sector [1]. Undoubtedly, the sustainable utilization of scarce natural resources is a challenge for the future development of the industry. Among the obstacles for future expansion, fish nutrition and the management of fish diseases and health are among the most critical. Sustainable development of the industry requires advanced disease and health management because the aquatic environment renders fish particularly susceptible to ubiquitous pathogens [2].

However, the administration of drugs such as antibiotics is associated with human health concerns, and prophylactic alternatives are highly desirable.

Feeding costs represent 40–70% of expenditure in intensive fish farming [3], mainly attributed to the protein-rich ingredients. In the past, fishmeal was the main protein source in fish nutrition, but, nowadays, it has become a scarce, costly ingredient. As a consequence, but also with regard to the vulnerable status of several industrial species, such as the Peruvian anchoveta, alternative plant ingredients are used in the diets [4][5][6]. Unfortunately, plant-based ingredients can have several negative effects on fish nutrition that involve the antinutritional effects of secondary plant metabolites, suboptimal amino acid composition, as well as mineral imbalances, which, in turn, may impact health and immune status [7][8][9]. Such restraints can be remedied, at least partly, by improving the digestion of these feedstuffs by making use of probiotic supplements and adjusting the gut microbiota.

In 1907, Metchnikoff was the first to point out the positive role of bacteria in milk and yogurt products. He assumed that these beneficial bacteria replace harmful microbes and are, therefore, responsible for the prolonged life of Balkan farmers who consumed high quantities of these products. In 1953, Kollath introduced the term probiotics, originating from the Latin word pro and the Greek word bios “for life” [10]. Traditionally, probiotics have thus been regarded as bioactive food additives, especially living bacteria, which have a positive influence on digestion and, moreover, the microbiome of the gastrointestinal tract (GIT) in general [11]. Verschuere et al. [12] expanded this definition, stating that probiotics are live microbial additives that have a beneficial effect on the host by (1) modifying the host-associated microbial community, (2) ensuring improved use of the feed or enhancing its nutritional value, (3) enhancing the host response towards disease, and/or (4) improving the quality of its ambient environment. Merrifield et al. proposed a slightly modified definition for probiotics in aquaculture [13]. They defined that “a probiotic organism can be regarded as a live or dead component of a microbial cell, which is administered via the feed or to the rearing water, benefiting the host by improving disease resistance, health status, growth performance, feed utilization, stress response, or general vigor. This is achieved, at least in part, by improving the host’s microbial balance or the microbial balance of the ambient environment”.

Intensification of aquaculture production exacerbates health threats of infectious diseases, including those arising from immunosuppression by plant ingredients. Over the last two decades, disease management has addressed new vaccines, immunostimulants, and disinfection strategies; in particular, probiotics have a huge potential in today’s disease management strategies. Administered probiotic strains can counteract the colonization of pathogens by competitive exclusion. This may involve either competition for binding sites, synthesis of antibacterial compounds, immune stimulation, or competition for nutrients [14]. Detailed reviews on the probiotic species and the respective fish host species have been provided elsewhere [14][15][16][17][18][19]

In this review, we summarize the current knowledge and recent findings in probiotic research. In particular, we address the concept of the core microbiome of the digestive system, discuss the utilization of host-associated, native (autochthonous) bacteria, and present modes of action that focus on the main site of host–microbe interaction, the gastrointestinal tract (GIT).

3. Conclusion

Undoubtedly, in the context of rapidly increasing global aquaculture production, alternative ecofriendly methods for the prevention and therapy of diseases as well as the improvement of growth performance are pressing issues. Here, probiotics offer the tempting opportunity to modulate the GIT microbiome persistently, exerting beneficial effects such as increased growth, feed conversion, health, disease, and stress resistance. Interestingly, probiotics may be capable of degrading compounds that the fish host cannot digest alone. Carbohydrate digestion and detoxification of antinutrients are the focus of aquaculture research. Probiotic-derived chitinase, for example, may allow the use of novel feedstuff such as insect meal or krill. Similarly, the probiotic digestion of secondary plant metabolites with antinutritional effects may improve the rate of fishmeal replacement with a respective plant feed ingredient. Multispecies probiotics exhibit better probiotic effects than single-species applications. The modulation of the gastrointestinal microbiome through dietary administration of probiotics represents a potential strategy to improve microbial metabolite production, stimulate immune signaling, and increase defense mechanisms against pathogens. However, modulation of the microbiome may induce adverse effects and may even bear the risk of paving the road for pathogens. Therefore, we need to deepen our knowledge of microbiome regulation. Additionally, species-specific studies are required before a given probiotic is applied in a novel species. Moreover, the antiviral activity of several *Lactobacillus* strains towards murine norovirus (MNV) has been reported, and it will be interesting to see if microbes can also alter fish-specific viral infectivity [20].

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