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Optimizing Aquaculture through Prebiotics: Enhancing Fish Health, Growth and Disease Resistance

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Abstract

Prebiotics represent a promising, eco-friendly alternative to antibiotics in aquaculture, fostering beneficial gut microbiota and enhancing overall fish health. These non-digestible food ingredients selectively stimulate the growth and/or activity of specific colonic bacteria, leading to improved nutrient absorption, immune function and disease resistance. Various prebiotics, such as fructooligosaccharides (FOS), inulin, xylooligosaccharides (XOS), mannan oligosaccharides (MOS) and galactooligosaccharides (GOS), have demonstrated positive effects on diverse aquaculture species, improving growth performance, feed utilization and disease resistance. However, prebiotic efficacy is influenced by factors like fish species, diet, environmental conditions and dosage. Future research should prioritize identifying fish health biomarkers, understanding species-specific responses, evaluating the environmental impact of prebiotics and investigating long-term effects to optimize their application in sustainable aquaculture. Addressing these gaps will unlock the full potential of prebiotics for improved fish health and production while reducing antibiotic dependence.

Key words: Prebiotic, fructooligosaccharides, xylooligosaccharides, galactooligosaccharides, mannanoligosaccharides, inulin

1.0 Introduction

Prebiotics are non-digestible food components that positively impact the host by selectively promoting the growth and activity of specific beneficial bacteria in the colon (Ringø et al., 2010). These compounds remain undigested in the host's digestive system due to their resistance to the acidic environment of the stomach but effectively support the proliferation of beneficial gut microbiota (Gibson and Roberfroid, 1995). While the host cannot break down prebiotics, gut microbiota ferment them externally, stimulating their growth and multiplication, which in turn enhances the host's overall health. Common prebiotics used in aquaculture include inulin, arabinoxylan oligosaccharide, beta-glucan, mannan oligosaccharide (MOS), fructooligosaccharides (FOS) and various oligosaccharides. Numerous scientific studies have demonstrated that prebiotics contribute to improved immune responses, enhanced growth performance, better feed utilization and increased disease resistance in aquaculture species (Wee et al., 2022).

2.0 Mode of action of Prebiotics

In aquaculture, prebiotics play a key role in selectively enhancing the growth of beneficial gut bacteria, triggering a series of positive effects. These indigestible compounds help maintain a balanced gut microbiota, improving nutrient absorption, immune response and resistance to diseases. By stimulating the production of short-chain fatty acids and reinforcing the gut barrier, prebiotics support overall fish health and well-being, ultimately leading to better growth rates and increased feed efficiency (Kiruthisha et al., 2024).

3.0 Prebiotic used in aquaculture

3.1 Fructooligosachharide

Fructooligosaccharides (FOS) are naturally occurring oligosaccharides present in various medicinal plants such as onions, chicory, garlic, asparagus, bananas and artichokes, among others (Sridevi et al., 2014). As a promising prebiotic, FOS offers a protective and environmentally friendly alternative to reduce antibiotic use in aquaculture. These compounds consist of short chains of βD-fructans and are widely found in different food sources (Fuller and Gibson, 1998). FOS can be produced through the hydrolytic action of β-fructofuranosidases. A specific type of FOS, known as short-chain FOS (scFOS), is derived from sources like barley and wheat (Kumar et al., 2018).

3.2 Inulin

Inulin is naturally present in a variety of vegetables, fruits and cereals, including leeks, onions, garlic, wheat, chicory, artichokes and bananas. Primarily extracted from chicory roots, inulin is widely used as a functional food ingredient due to its valuable nutritional properties and technological benefits. It has been shown to enhance weight gain, specific growth rate, protein efficiency ratio and food conversion ratio in fish. Additionally, inulin significantly boosts total serum immunoglobulin levels, bactericidal activity and anti-protease activity in fish fed a diet based on food waste (Mo et al., 2015). Beneficial gut bacteria, such as Bifidobacteria, Lactic Acid Bacteria (LAB) and Clostridia, are known to ferment inulin (Carbone & Faggio, 2016).

3.3 Xylooligosaccharides

Xylooligosaccharides (XOS) are sugar oligomers composed of xylose units, known for their excellent prebiotic properties and nutritional benefits. They support the growth of

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probiotic bacteria in the intestinal tract. The selective stimulation of beneficial gut microflora through XOS consumption offers several advantages, including lowering glycemic indexes and blood cholesterol levels, reducing pro-carcinogenic enzyme activity in the gastrointestinal tract, enhancing mineral absorption in the large intestine and boosting the immune system. (De Freitas et al., 2019)

.3.4 Mannanoligosaccharides

In aquaculture, most mannanoligosaccharide (MOS) products are sourced from the outer cell wall of yeast (*Saccharomyces cerevisiae*), where they exist as complex molecules bound to proteins. The primary benefits of MOS include preventing pathogen colonization and enhancing immune system function. Additionally, its inclusion in the diet has been linked to improved growth performance and better feed conversion efficiency (Torrecillas et al., 2014).

3.5 Galactooligosaccharides

Galactooligosaccharides (GOS) are composed of 2–20 galactose and glucose molecules and are produced through the enzymatic conversion of lactose (Kiron, 2012). In aquaculture, GOS has gained significant attention for its positive effects on growth performance, antioxidant activity, immune response, gut microbiota and disease resistance in species such as Caspian roach (*Rutilus rutilus*) (Hoseinifar et al., 2013) and rainbow trout (*Oncorhynchus mykiss*) (Hoseinifar et al., 2017).

4.0 Effects of prebiotic growth, Immune System Boost and Disease Resistance:

Prebiotics play a crucial role in stimulating the growth of gut microbiota in the host (Dawood & Koshio, 2016). As functional components in fish nutrition, prebiotics have been associated with improvements in growth performance, feed efficiency, gut microbiota balance, digestive enzyme activity, intestinal structure, immune response, disease resistance, metabolic functions and stress adaptation (Guerreiro et al., 2018).

Fish/shrimp species	Prebiotics	Doses	Duration (days)	Effects
Labeo rohita	Potato powder	0, 5, 10 & 15%	63	Enhanced growth and feed utilization
Danio rerio	GOS	0.5, 1.0 & 2.0%	56	Increased immunity Increased expression of tnf-32α and lyz genes
Cyprinus carpio	Inulin	1%	45	Increased lysozyme activity, blood protein, Globulin

Sciaenops ocellatus	FOS, GOS MOS and GGM	10 g kg-1	56	Improved growth performance Enhanced immunity Increased microvilli heights
Oreochromis niloticus	MOS	0, 2, 4 & 6 g kg-1	21	Enhanced growth, Improved disease resistance

(Rohani et al., 2021)

5.0 Factors Affecting Prebiotic Efficiency

The effectiveness of probiotics, prebiotics and synbiotics in aquaculture depends on several factors, including fish species, diet, environmental conditions and dosage (Cerezuela et al., 2013). The activity of digestive enzymes such as amylase, protease and lipase in fish is influenced by species, age, dietary enzyme intake and feeding habits (Assan et al., 2022). Stocking density also plays an indirect role in enzyme activity, as higher densities lead to reduced levels of lipase, amylase and trypsin in fish and shrimp (Liu et al., 2017). Since different fish species have distinct physiological and immune characteristics, their responses to probiotics, prebiotics and synbiotics can vary accordingly (Ringø and Song, 2016).

6.0 Future Perspectives

Further research is required to identify reliable biomarkers that accurately assess fish health in response to probiotics, prebiotics and synbiotics. It is essential to investigate species-specific variations, as different fish species may exhibit distinct gut microbiota compositions and physiological reactions to these supplements. Additionally, future studies should examine the environmental impact of probiotics, prebiotics and synbiotics in aquaculture, considering sustainability and potential ecological effects. While current research highlights their benefits on digestive enzymes, oxidative stress and antioxidant defense in fish farming, more studies are needed to address species-specific differences and long-term implications for sustainable aquaculture. Addressing these knowledge gaps will help optimize the effective application of these supplements in fish farming (Amenyogbe et al., 2024).

7.0 Conclusion

Prebiotics play a crucial role in enhancing the sustainability and productivity of aquaculture. By selectively promoting the growth of beneficial gut microbiota, prebiotics improve the health, growth and immune response of cultured aquatic species. Their use reduces dependence on antibiotics, contributing to an eco-friendlier and health-conscious aquaculture industry. Additionally, prebiotics enhance feed efficiency and nutrient absorption, leading to better growth rates and improved water quality. As research continues to expand,

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the strategic application of prebiotics holds great promise for supporting sustainable aquaculture practices and meeting the growing global demand for safe and nutritious seafood.

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