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Review

Recent advances in the role of probiotics and prebiotics in carp aquaculture: A review

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ABSTRACT

The demand for cultured carp species has grown tremendously during the last decade due to their high market value. Recently, intensive aquaculture system has been expanding and is emerging as one of the most practical and promising tools to meet the requirements of carp. However, in intensive fish farming, animals are subjected to stress conditions that weaken fish immune systems, leading to increased susceptibility to diseases. These diseases have resulted in production losses and remain as one of the major causes of concern for carp farmers. Recently, one of the major limiting factors in intensive fish culture is the use of dietary supplements probiotics and prebiotics. These natural ingredients enhance the immune response of fish, confer tolerance against different stressors and minimize the risk associated with the use of chemical products such as: vaccines, antibiotics and chemotherapeutics. The present review summarizes and discusses the results of probiotic and prebiotic administration on growth performance, gut physiology, intestinal microbiota, immune response and health status of different carp species. Furthermore, this study tries to cover the gaps in existing knowledge and suggest issues that merit further investigations.

Contents

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1. Introduction

Aquaculture has emerged as one of the most promising and fastest-growing industries, and provides high-quality animal protein with total global production increasing to 66.63 million tonnes in 2012 from 63.6 million tonnes in 2011 (FAO, 2014). Globally, carp production is still the most important group of aquaculture species, contributing over 72% of freshwater production (Kühlwein et al., 2014). Along with the increasing demand for this species, the challenges faced by farmers are to obtain an increase in growth rate while minimizing disease outbreaks. There has been a shift in aquaculture practices, moving from extensive systems towards the semi-intensive and intensive systems. As intensive aquaculture expanded, diseases occurred more frequently (Chen et al., 2014). The application of antibiotics and chemotherapeutics to control these diseases caused many other problems such as the spread of drug resistant pathogens, suppression of the aquatic animal's immune system and environmental hazards (Allameh et al., 2015; Brogden et al., 2014). Besides therapeutics and vaccines, an alternate approach to enhance disease resistance, immune responses and other health benefits is the administration of probiotics, prebiotics and other feed additives which have various health promoting properties for carp species are encouraged (Bandyopadhyay et al., 2015; Wu et al., 2015).

Fuller (1989) defined probiotics as a live microbial feed supplement which beneficially affects the host animal by improving its microbial balance. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) redefined Fuller's explanation, and considered probiotics to be "live microorganisms which when administered in adequate amounts confer a health benefit on the host" (FAO/WHO Report, 2001). Although probiotics offer a promising alternative to the use of chemicals and antibiotics in aquatic animals (Bandyopadhyay et al., 2015), and to assist in the protection of cultured species from diseases, the benefits to the hosts by the use of probiotics in aquaculture need to be considered. Various factors like source, dose and duration of supplementation of probiotics can affect the immunomodulatory activity of probiotics (Dawood et al., 2015a; Hai, 2015). Therefore, appropriate administration methods help to provide favorable conditions for probiotics to perform well. Furthermore, understanding the modes of action along with appropriate application methods may be the key for the use of probiotics in aquatic systems. Although the exact mode of action of probiotics is yet to be established in several fish species, probiotics often exert host specific and strain specific differences in their activities. Indeed, although the use of probiotics in fish farming is gaining increasing scientific and commercial interest in fish and shellfish aquaculture world-wide (Carnevali et al., 2014; Hoseinifar et al., 2014a; Kiron, 2012; Lauzon et al., 2014), there are fewer publications on probiotics in carp.

Prebiotics, on the other hand, are indigestible substances that allow specific changes in the composition and/or activity of gastrointestinal microbiota, which has a positive effect on the nutrition and health status of the host (Ringø et al., 2014). It has been well established that the byproducts produced when beneficial commensal bacteria ferment prebiotics play a major role in improving host health (Choque-Delgado et al., 2011; Song et al., 2014). In this respect, prebiotics are used as energy sources for the gut bacteria and can be referred to as functional saccharides (Roberfroid, 1993; Song et al., 2014). Numerous studies have investigated the different aspects of prebiotic application (e.g. inulin, oligofructose, xylooligosaccharide, fructooligosaccharide, mannanoligosaccharide, galactooligosaccharide, β-glucan) in cultured finfish and shellfish, and the results revealed that prebiotics are promising and have beneficial effects on growth performance, gut microbiota, immunity and disease resistance (Daniels and Hoseinifar, 2014; Dawood et al., 2015a, 2015b; Ganguly et al., 2013; Ringø et al., 2010, 2014; Song et al., 2014; Torrecillas et al., 2014).

Recently, there have been numerous reviews about probiotics and/or prebiotics for cultured fish species. However, the novelty here is that the current study is the first one to review the use of probiotics and prebiotics only for the culture of carp species, in which a critical evaluation of their effectiveness on carp species has been presented. Moreover, some ideas from the research findings are identified for further investigation and development as the use of pro- and/or pre- can be a sustainable and viable strategy for successful aquaculture.

2. The role of probiotic and/or prebiotic supplementation on carp immunity

2.1. General concepts

The fish immune response is used to designate immune reaction against foreign agents, including microorganisms (viruses, bacteria, fungi, protozoa and multicellular parasites), macromolecules (proteins and polysaccharides) and different stressors (handling, crowding and water low salinity) without pathological consequences. The fish immune innate response begins initially with the humoral (complement system, lysozyme, acute phase proteins, antimicrobial peptides, interferon, lectins, proteases, protease inhibitors or eicosanoids) and cellular (monocyte-macrophages, granulocytes, natural killer and nonspecific cytotoxic cells) components of the innate immune system after coming into contact with structures of the pathogen known as pathogen-associated molecular patterns, which are common molecules not typically found in eukaryotic cells, such as viral double-stranded RNA, bacterial lipopolysaccharide and certain sugars (Hoseinifar et al., 2015a; Manning, 1998).

The fish immune response is modulated by many intrinsic and extrinsic factors, including environmental factors (temperature, salinity, photoperiod, etc.) and physiological status (nutrition, age, reproductive cycle, hormonal balance, stress, etc.). Among them, the use of immunostimulants, mainly from natural sources, is a very practical approach to improve the success of the aquaculture because they increase the fish health reducing the impact of diseases and stress (Bricknell and Dalmo, 2005; Kiron, 2012; Sakai, 1999). Many authors have confirmed the beneficial effects of immunostimulants on humoral and cellular immunity in blood, head-kidney or spleen tissues, gene expression or disease resistance after oral administration as dietary supplements (Bricknell and Dalmo, 2005; Kiron, 2012; Sakai, 1999). Among the most well-known natural immunostimulants are probiotic, prebiotic and synbiotic. The physiological responses, including immunity, after oral administration of immunostimulants in the target tissue, the gastrointestinal tract, have been not widely analyzed until the last decade.

2.2. The effect of probiotics on the immune system of carp

As with similar effects of other immunostimulants in aquaculture, researchers have demonstrated the use of probiotics to elevate immune response, disease resistance and reduce malformations in carp species (Wu et al., 2015). Humoral, cellular immune responses and expression analyses of IL-1b, TNFα and lysozyme-C were improved when fish were fed *Aeromonas veronii*, *Vibrio lentus* and *Flavobacterium sasangense* enriched diet (Xu et al., 2014). Superoxide anion production and nitric oxide production, myeloperoxidase content, lysozyme, complement C3, total serum protein, albumin and globulin levels, respiratory burst activity, phagocytic activity by blood leucocytes and the expression of IL-1b, lysozyme-C and TNF-α were improved in several carp species (Chi et al., 2014; Das et al., 2013; Giri et al., 2013).

2.3. The effect of prebiotics on the immune system of carp

Innate immune cells such as neutrophils are an important component of the carp's, *Cyprinus carpio* innate immune defense against a range of invading pathogens (Brogden et al., 2012, 2014; Scharsack et al., 2003).