Food Chemistry 127 (2011) 1409–1426

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Review

Non-starch polysaccharides and their role in fish nutrition – A review

Amit K. Sinha [a,1], Vikas Kumar [b,1], Harinder P.S. Makkar [b,*], Gudrun De Boeck [a], Klaus Becker [b]

[a] Laboratory for Ecophysiology, Biochemistry and Toxicology, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp, Belgium
[b] Institute for Animal Production in the Tropics and Subtropics, University of Hohenheim, 70599 Stuttgart, Germany

ARTICLE INFO

Article history:
Received 22 November 2010
Received in revised form 28 January 2011
Accepted 8 February 2011
Available online 12 February 2011

Keywords:
Fish feed
Non-starch polysaaccharide
Anti-nutritive effects
Nutrient metabolism
Immunostimulants

ABSTRACT

The success and sustainability of aquaculture depends on minimising the operational cost of feed that in general comprises 50–60% of the total cost in intensive farming. The major feed ingredient, fish meal, is expensive and there is increasing competition with other livestock industries for the available static supply of fish meal. Hence, the incorporation of plant-derived materials in fish feeds is receiving increasing attention. One of the main constraints in the utilisation of plant ingredients in aquaculture is the presence of indigestible carbohydrates, which consist primarily of non-starch polysaccharides (NSPs). These form a part of the cell wall structure of cereals and legumes. The presence of NSPs in the diet interferes with feed utilisation and adversely affects performance of the animal. Supplementation of NSP-degrading enzymes in feed mitigates the adverse effects of NSPs. The effects of NSPs in pigs and poultry have been widely studied; however little information exists for fish. This review synthesizes the available information on fish and highlights the knowledge gaps. It is hoped that this review will provide a momentum to the research on the roles of NSPs in fish nutrition and physiology and on the efficient use of NSP-degrading enzymes.

Contents

* Corresponding author. Tel.: +49 711 45923640; fax: +49 711 45923702.
E-mail address: makkar@uni-hohenheim.de (H.P.S. Makkar).
[1] These authors contributed equally to this review.

0308-8146/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2011.02.042

1. Introduction

The growing demand for fish and limited supply from wild capture are giving momentum to the development of aquaculture. The progress of culture-based fisheries is determined mainly by the quality of feed delivered. Fish meal (FM) having high protein content and favourable amino acid profile is highly preferred by fish culturists. The total world FM production is about 5–6 million tonnes per annum, which accounts for 4–5% of total fish production of 144 million metric tonnes (Food, 2008). In spite of being the most important protein source in commercial feeds, production of FM is restricted to certain parts of the world only; as a result it is becoming too expensive for many aquaculture practising countries. Furthermore, the abundance of FM appears to be ending, since the level of FM production is expected to remain stable over the next 10 years (Mazurkiewicz, 2009). As a consequence, the fisheries sector may have to undergo a recessionary phase over the coming years. In order to provide sustainability, therefore, it is of utmost importance to reduce the presence of FM in aquafeeds and replace it with plant-based sources. The higher availability and low cost of plant-based feeds give them advantages over FM. Although the carbohydrate component of grains and legumes may provide a cheap source of dietary energy for fish, it is poorly utilised, compared to protein and lipid, by most fish species (Allan et al., 2000). In addition, the quality and level of protein in, and palatability of, plant-based protein sources are generally inferior to FM. However, the main limitation with plant-derived materials, such as legume seeds, soybean meal, different types of oilseed cake, canola (rapeseed) meal, sunflower oil cake, root tuber meal, is the presence of a wide range of anti-nutritional factors, such as protease inhibitors, non-digestible carbohydrates, lectins, saponins, phytates and possibly allergenic storage proteins (Francis, Makkar, & Becker, 2001). In addition to these factors that hamper digestion in fish (Refstie, Svihus, Shearer, & Storebakken, 1999; Storebakken, Shearer, & Roem, 1998), non-starch polysaccharides (NSPs) play an important role. In general, NSPs are a complex group, composed predominantly of linked monomers of hexoses and pentoses, e.g., galactose, glucose, arabinose, xylose and mannose (van Barneveld, 1999). The NSP content in wheat and lupin may account for 25% and 50% of the total grain and seed respectively and acts as the primary energy storage carbohydrate in lupin (van Barneveld, 1999). However, in fish and other monogastric animals enzymes such as β-glucanases or β-xylanases that digest NSPs are scarce or non-existent (Kuz'mina, 1996). Consequently, the dietary NSPs remain indigestible and cannot be used as an energy source. The addition of NSP-containing feedstuffs to the diets of monogastric animals, for example, broiler and swine, reduces the apparent digestibility of the diet and has negative impacts on growth. However, only a limited number of such studies have been conducted in fish. Refstie et al. (1999) have demonstrated negative effects of NSPs on digestion and absorption of lipid in Atlantic salmon. Non-starch polysaccharides are also thought to be responsible for a slower rate of gastro-intestinal passage of NSP-containing diets in fish (Storebakken, Kvien, Shearer, Grisdale-Helland, & Helland, 1999). Feeding of salmonids with diets incorporating NSP has been shown to reduce the availability of nutrients (Storebakken & Austreng, 1987).

At present approximately 2.0 billion tonnes of cereal grains and 140 million metric tonnes of legumes and oil seeds are produced worldwide per year and approximately 230 million metric tonnes of fibrous materials are produced as a by-product. This wide availability of plant resources can very well be utilised as cheaper fish feed ingredients, through proper management of the NSPs in these plant materials. Feed processing and utilisation of exogenous enzymes (β-glucanase and β-xylanases) have been used to decrease the negative effects of NSP and thus to improve the nutritive value of feed. Moreover, there is a contemporary trend to seek feed ingredients which may contribute to better health by interfering with colonisation and microbial growth in the gut. In this regards NSPs such as β-glucans and mannose have been shown to have immunostimulating activities (Kumar, Saurabh, Sahu, & Pal, 2005).

2. Classification of non-starch polysaccharide

The term NSP covers a large variety of polysaccharide molecules, excluding α-glucans (starch). NSPs have been classified based on different criteria. Historically, the classification was based originally on the methodology used for extraction and isolation of polysaccharides. The residue remaining after a series of alkaline extractions of cell wall materials was called cellulose, and the fraction of this residue solubilised by alkali was named hemicellulose (Neukom, 1976). Another classification was based on the differences in solubility. This classification includes three categories of NSP, namely crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF). CF refers to the remnants of plant material after extraction with acid and alkali, and includes variable portions of insoluble NSP. NDF comprises the insoluble portion of NSP plus lignin, while ADF refers to a portion of insoluble NSP comprised largely, but not solely, of cellulose and lignin. However, this basis of categorisation lacked precision with respect to both chemical structures and biological functions and, moreover, the nutritional significance of values obtained using this method in monogastric nutrition is doubtful.

Bailey (1973) proposed a clearer classification of NSP into three main groups, namely cellulose, non-cellulosic polymers and pectic polysaccharides. Arabinoxylans, mixed-linked β-glucans, mannans, and xyloglucan come under the category of non-cellulosic polymers while polygalacturonic acids substituted with arabinan, galactan and arabinogalactan are included in the group of pectic polysaccharides (Table 1).