European Journal of Nutrition & Food Safety



8(4): 240-242, 2018; Article no.EJNFS.2018.045 ISSN: 2347-5641

Criteria for Safe Use of Plant Ingredients in Diets for Aquacultured Fish

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Authors' contributions

This work was carried out in collaboration between all authors. The opinion has been assessed and approved by the Panel on Animal Feed of VKM. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2018/43861

Grey Literature

Received 11th August 2018 Accepted 11th September 2018 Published 15th September 2018

ABSTRACT

The Norwegian Food Safety Authority (Mattilsynet) asked the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet) to assess if the criteria for safe use of plant ingredients in diets for aquacultured fish fulfil the Feed regulative §7 to "not induce negative health effects in the animal", and in this context aquacultured fish. The use of feed ingredients of both plant and animal origin is set by the regulation "Forskrift 7. November 2002 nr 1290", and amendments. The objective of the regulation is to protect animals, consumers and the environment. For animals, the feed shall not pose a risk, or danger, to their health.

Aspects to be assessed were whether the changes in fish diet ingredient composition seen in recent years with high levels of plant ingredients, plus additions of immunostimulants, would in any

manner challenge fish health and if any ingredient should be limited due to its negative effect, or induce any long-term negative effect. "Long-term" here extends beyond normal production time for consumption, e.g. when substances that might affect fish health are included in broodstock diets. Atlantic salmon (*Salmo salar*), rainbow trout (*Onchorhyncus mykiss*), Atlantic halibut (*Hippoglossus hippoglossus*) and Atlantic cod (*Gadus morhua*) should especially be addressed. However, since all life stages should be included, especially broodstock, and also possible long-term effects, and literature on these for the requested species is scarce, the assessment mentions studies on other species when relevant.

With the exception of full-fat and extracted soybean meal for salmonids, substituting at least part of the fishmeal fraction of aquafeeds with individual plant ingredients is promising, at least in the short to medium term. Indeed in some cases, diets containing up to 20% inclusion level of high-quality plant protein sources have resulted in better nutrient digestibility and growth parameters than the fishmeal-based control diets. When substituting fishmeal with plant ingredients, however, it is necessary to balance the diets regarding limiting amino acids and minerals. Adding plant proteins to fish diets result in the introduction of anti-nutritional factors. There is an urgent need to investigate consequences of various anti-nutritional factors, individually and in combinations, to nutrient digestibility, utilization and metabolism as well as to intestinal function, structure, defence mechanisms and microbiota. Long-term effects also merit investigation. This will aid in the ability to predict how a newly introduced plant ingredient as well as combinations of plant ingredients may affect the fish and identify steps needed to avoid adverse health effects.

As many of the potential disadvantages of using plant oils in salmonid diets are related to either very high levels of n-6 PUFA (most available oils) or very high levels of linseed oil, it would be recommended that mixtures of plant oils should be used as feed inclusions. By adjusting the ratio of n-6 and n-3 the level of eicosanoids can be controlled. By including palm oil, potential problems in lipid digestibility and transport can be controlled. A standard inclusion of soybean lecithin may also be advisory. These and other variants of mixtures of oil sources have been explored in recent years with some success in salmonid fish. Such mixtures do not seem to be necessary for marine fish.

Modern finfish aquaculture faces problems such as bone and skeletal deformities, cataracts, heart disorders, unspecific ulceration and various digestive disorders including intestinal colic in Atlantic cod, gastric dilatation (bloat) in rainbow trout, and intestinal tumours, at low incidence, in Atlantic salmon broodstock. Most of the mentioned problems have been related to malnutrition, feed, intensive growth and/or unfavourable environmental conditions. The disorders are often not lethal, but may imply a fish welfare problem and increase the susceptibility to secondary disorders and infectious diseases. Major changes in feed composition and feed ingredients may increase the risk for such production-related disorders in intensive fish farming. Care should be taken when choosing plant alternatives, both types and qualities, to prevent nutrition-related diseases such as skeletal deformities, cataracts, heart conditions, and other, unspecific symptoms.

The change from marine- to plant-based diet ingredients, results in changed profile and content of undesirable substances. The list of undesirable substances included in the feed legislation is, in general, sufficient, but it should be considered to include pesticides in use today and more of the mycotoxins. Currently only aflatoxin B1 is included, while only recommendations exist for other mycotoxins. Studies of dietary exposure to undesirable substances, e.g. pesticides and mycotoxins, and their toxic effects and toxicokinetics in fish are scarce.

To date, the application of pre- and probiotics for the improvement of aquatic environmental quality and for disease control in aquaculture seems promising; however, the information is limited and sometimes contradictory. Currently there are numerous gaps in existing knowledge about exogenous nucleotide application to fish including various aspects of digestion, absorption, metabolism, and influences on various physiological responses, especially expression of immunogenes and modulation of immunoglobulin production. As limited information is available about the effect of immunostimulants, prebiotics and nucleotides on gut morphology, this topic should be given high priority in future studies. Heat processing of raw materials and of the complete fish diets may potentially alter nutritional properties of plant materials. However, the negative effects appear to be modest under practical conditions.

Keywords: Plant ingredients; fish feed; plant proteins; fibres; anti-nutritional factors; plant oils; immunostimulatory agents; undesirable substances; genetically modified plants; processing methods; fish growth; health; intestinal function; feed utilization; salmon; rainbow trout; cod; halibut.

Available: https://vkm.no/download/18.2994e95b15cc54507163564a/1501250466381/aef85c6079.pdf

ISBN: 978-82-8082-299-4

NOTE:

This work was carried out in collaboration between all authors. The opinion has been assessed and approved by the Opinion of the Panel on Animal Feed of the Norwegian Scientific Committee for Food Safety (VKM). All authors read and approved the final manuscript.

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Suggested citation: VKM (2009), Assessment of glucosamine and chondroitin in feed. Opinion of the Panel on Animal Feed of the Norwegian Scientific Committee for Food Safety, VKM Report 2009:03, ISBN 978-82-8082-299-4, Oslo, Norway.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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