

Research into novel plant-based meals and oils to replace fishmeal and fish oil in more sustainable feeds for Atlantic salmon (*Salmo salar*) J. Gordon Bell and Douglas R. Tocher

In aquaculture, feeds for the carnivorous and marine fish species cultured in the UK and Europe have traditionally relied on fishmeal and fish oil. These marine resources are derived from reduction fisheries that are at their sustainable limits. Thus, fishmeal and fish oil are finite and limited resources and global supply is not able to support sustainable aquaculture development. The challenge for aquaculture is to farm fish in a sustainable and environmentally friendly manner and yet maintain their nutritional quality and status as beneficial and healthy components of human diets. Omega-3 long-chain polyunsaturated fatty acids (LC-PUFA), which have well-established beneficial effects in human health, have been a particular focus in the Nutrition Group at the Institute of Aquaculture. The primary source of these fatty acids in our diet is fish and seafood and, with declining fisheries worldwide, an increasing proportion is now being supplied by aquaculture. However, high levels of omega-3 in farmed fish were only ensured by the use of fish oil and fishmeal as feed ingredients and so the replacement of these with more sustainable alternatives can have a major impact on nutritional quality.

The Institute's Aquaculture Nutrition Group has been at the heart of research into the replacement of fishmeal and fish oil in Europe, and have addressed these issues in a highly integrated manner in collaboration with industrial and academic partners spanning the food production sector. Three large projects currently in progress in the Nutrition Group are building on the considerable advances in the development of sustainable aquaculture feeds resulting from several previous large EU and RCUK projects and initiatives, and highlight the current research in Stirling into the development of more sustainable feeds for

Atlantic salmon and other farmed fish species.

A £1.1 million Biotechnology and Biological Sciences Research Council (BBSRC) - funded project is taking a radical approach to fish oil replacement and has considerable potential to enhance sustainability of aquaculture. "Evaluating novel plant oilseeds enriched in omega-3 LC-PUFA to support sustainable development of aquaculture" addresses the fundamental problem of the global lack of omega-3 LC-PUFA. The aim is to produce novel vegetable oils containing high levels of omega-3 LC-PUFA through a synthetic biology approach utilising metabolic engineering to produce GM oilseed crops. The resultant vegetable oils represent entirely *de novo* omega-3 LC-PUFA that can very effectively replace fish oil in aquafeeds. The



interdisciplinary collaboration between the Nutrition Group at the Institute of Aquaculture, plant scientists at Rothamsted Research, and the major international fish-feed company, BioMar Ltd., represents an integrated approach to the supply chain underpinning the aquaculture industry. Although GM technology has a currently limited role in Europe, the opportunities and markets for aquaculture are global and, in these terms, GM products already have wide application in animal feeds in many parts of the world.

The major objective of the €11 million EU FP7 project, ARRANA, is to determine the

long-term, full life-cycle effects of feeds formulated with alternative, largely plant-based, ingredients on fish metabolism, performance and quality, including threshold effects of dietary components, carry-over from maternal diets to larvae, the use of feed additives to supply essential micronutrients, antagonistic interactions between nutrients, and effects of undesirable components linked to novel feed ingredients. In addition, ARRANA is developing novel methods to estimate nutritional requirements, focusing on the establishment of the quantitative requirements for micronutrients and vitamins.

A third project aims to develop novel replacements for fishmeal rather than the current over-reliance on imported soy products, which are subject to price variations that limit their use and can have negative effects due to anti-nutritional factors. "Development of protein-rich and starch-rich fractions from faba beans for salmon and terrestrial animal production respectively", will process broad/field beans to produce a protein concentrate for use in salmon feeds, and a starch concentrate for use in pig and poultry feeds. The £2.1 million Technology Strategy Board (TSB)-funded project involves industrial partners including feed companies (EWOS, BioMar, Harbro), a fish producer (Marine Harvest Scotland) and plant breeder/seed company (Limagrains UK), and five academic partners including Marine Alliance for Science and Technology for Scotland (MASTS) institutions Stirling, Aberdeen and St. Andrews Universities, the James Hutton Institute (JHI) and Scotland's Rural College (SRUC). The project represents a unique, holistic approach involving all key players in the animal feed supply chain, combining critical commercial drivers with sustainability and food security.