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Novel marine ingredients for aquaculture

Fish nutrition, physiology, and intestinal health

Niklas Warwas
Institutionen för biologi och miljövetenskap
Naturvetenskapliga fakulteten

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Dissertation abstract

Aquaculture is among the fastest growing food production sectors globally and supplies more fish to the growing human population than capture fisheries. One of the major challenges in salmonid aquaculture is to find renewable and sustainable feed ingredients which also satisfy the nutritional requirements of the fish. Feed production accounts for the majority of both the environmental and economic footprints of modern aquaculture operations. It is therefore clear that sustainable aquaculture can only be achieved using sustainable feed. The overarching aim of this thesis is to expand the pool of alternative feed ingredients by developing and evaluating novel marine ingredients using both a nutritional and a physiological approach. The aspiration is further to carry out this work in the framework of a circular economy approach where side streams and their nutrients are reintroduced into the food production system rather than discarded.

Paper I demonstrates that marine yeast (*C. sake)* can be cultivated on processing water of the fish processing industry. Marine yeast could therefore be used transform side streams into a promising feed ingredient for salmonid fish. *C. sake* contained 55% protein and significant levels of omega-3 fatty acids. Additionally, *C.sake* was highly digestible by rainbow trout and therefore can be used in diet formulations at up to 20% of the overall content without negative effects on animal health and growth. Furthermore, there is potential to use *C. sake* as an immunostimulant due to its complex polysaccharide and nucleotide content.

Paper II assesses the potential of using a marine insect in fish feed. Marine insects contain higher levels of essential nutrients, such as unsaturated fatty acids and amino acids, compared to terrestrial insects. However, they have not been evaluated as feed ingredients for salmonid fish. This thesis shows that the seaweed fly (*Coelopa frigida*) can be cultivated on side streams from an algae farm producing brown seaweed. Furthermore, seaweed fly larvae could substitute 40% of fish meal content without negative effects on growth and intestinal health. Compared to black soldier fly larvae, *C. frigida* inclusion resulted in higher feed intake and growth for rainbow trout.

Papers III & **IV** address the possibility to use fish processing side streams in feed formulations without additional processing. Fish processing side streams are highly nutritious and currently contribute to about 30% of the global fishmeal and fish oil production. However, due to the additional processing costs and the lower price of fishmeal and oil produced from sides streams compared to whole fish fishmeal, large amounts of such side streams remain unused or are converted to lower value commodities. In **paper III**, three different fish processing side streams (fillets and trimming) were included in diets for rainbow trout without separating oil and protein fractions. The results show that whether side streams can be used directly as ingredients, depends on storage condition and handling. The inclusion of 50% fresh sprat trimmings, resulting in high growth rates, high feed intake and good intestinal health, while the inclusion of suboptimal stored marinated herring fillets impaired growth, intestinal health, and appetite. To evaluate if these results are transferable to an industry setting, 500 kg of feed containing moist sprat trimmings (**paper IV**) were extruded using industrial scale equipment. The pellet quality was generally comparable to commercial feed except for a slightly lower boyancy. Compared to a state of the art commercial diet, fish fed the experimental diet displayed slightly lower feed intake and growth. However, the differences in growth and weight gain were largely due to lower lipid deposition in the muscle and intraperitoneal cavity, which would suggest higher product quality of fish fed the experimental diet. Overall, moist side streams can be incorporated in extruded diets which reduce costs and emission.

This thesis demonstrates for the first time, that marine yeast and marine insects are promising alternative marine ingredients for future aquaculture. Additionally, side streams with high nutritional value may be utilized as feed ingredients with no or minimal additional processing. Nonetheless, additional processing has clear benefits regarding storage, transport, and maximum inclusion levels in the feed. The results of this thesis can therefore by applied to both the development of local sustainable aquaculture in Sweden but also to the global aquafeed market, which currently lacks realistic marine alternatives, exhibits increasingly unstable supply chains, and high prices.

Keywords: Marine ingredients, Intestinal health, Sustainable feed, Circular economy