Effect of replacing fish oil and meal in aquaculture diets on growth, feed utilisation and product quality.

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ABSTRACT: For optimal growth fish require not only a minimum level of protein, but also that the essential amino acids are balanced to meet the requirement of each single one. This can easily be done by using fishmeal as the main protein source; however, the amount of fish meal on a world wide basis is not high enough to cover the need for the constantly growing aquaculture industry. Protein requirement varies between species, but is generally high (>30%) even for the most omnivorous species. For catfish (omnivorous) around 32% protein is required (Wilson R.P. 2001, pers.com.), and for this species all the protein (98%) can come from a mixture of plant protein - in commercial diets mainly soy-bean. Using this almost "all-veggie" feed still results in satisfactory growth and feed utilisation. In a study with Nile tilapia (*Tilapia nilotica L.*) (also omnivorous) indications of even better digestibility and feed utilisation were found when anchovy meal was fully replaced by soybean concentrate, again showing no need for fish meal in diets for this species. For the more strictly carnivorous species, such as Atlantic salmon, there is still a challenge to optimise dietary proteins focussing alternatives to fishmeal, and only special qualities of plant proteins, or low levels of these, can be used without any negative effects on production results. In intensive aquaculture in Norway (and EU) most species are strictly carnivorous, showing protein requirements from 38% and higher (dm), and giving the best production results when using high quality fish meals such as LT-meal with minor additions of other protein sources. In addition to well-balanced dietary amino acids, the protein digestibility and absorption rate of each amino acid are of utmost importance. To increase protein retention from the diet, the quality and mixture of different proteins and the inclusion of partly pre-digested proteins have shown good results.

Even more critical for the fast-growing aquaculture industry is the need for alternatives to fish oils. Several studies have shown that lipid digestibility, feed utilisation and product quality are highly influenced by the dietary lipid level and by the fatty acid pattern in the diet. Fish health, as well as human (consumers) health, will be influenced by intake of some of these fatty acids. In focus are both mono-unsaturated and poly-unsaturated fatty acids. There is a large EU-project going on where fish oils with high contents of PUFA are partly substituted by plant oils with higher levels of monoenes and where the contents of n-3 fatty acids are shorter (not PUFAs) (i.e. linoleic acid). Some results from this study will be presented and discussed in relation to beta-oxidation vs. retention of different fatty acids.

I. INTRODUCTION

The growth in aquaculture production in the last decade, the prognosis for expected growth, and the need for cost-efficient feed resources in addition to traditional fish oil and meal, have resulted in increased demand for alternative feed resources of similar qualities to fully or partly replace the traditional marine ingredients. Such alternative resources must ensure the same production results, in terms of fish growth, health and product quality as obtained when using high quality fish meal and oil as feed ingredients.

By changing to alternative ingredients the aim is economical and environmental friendly usage of feed resources, and to secure production of safe and healthy seafood.

2. ANALYSIS OF FEED COSTS

Feed costs account for around 50% of total production costs and are the single factor with greatest impact on cost-efficiency in aquaculture production. Both because of costs and limited availability of fish oil and fish meal, the industry stands to gain by having alternative resources giving the same growth, digestibility and impact on fish health and fillet quality, as when the traditional ingredients dominate feed composition. The availability of fish oil and meal is expected to be a limiting factor for cost-efficient production well within the next decade. According to IFOMA (International Fishmeal and Oil Manufacturers Association), 1.2 - 1.4 million tons of fish oil and 6 - 7 million tons of fish meal are produced in a "normal" year, with two thirds of these quantities being produced in Chile and Peru. This means a dramatic reduction in years when "El Nino" occurs, as in 1998 when fish oil and meal prices increased by 50% and 20% respectively. FAO (Food and Agriculture Organization of the United Nations) and IFOMA 2000-statistics show a yearly aquaculture production of 19.2 million tons, requiring 2.1 million tons of fish meal. From 1988 to 1998 utilisation of fish meal for aquaculture production increased from 10 to 30% of total fish meal production. Currently somewhat more than one half of world fish oil production is used in aquaculture feeds with salmonid feeds alone consuming more than one half of the total oil used for aqua feeds. IFOMA currently estimates that, given continuation of the current rate of expansion of aquaculture, global demand for fish oils for aqua feeds will equal the total global supply of fish oils by circa 2009.

3. ALTERNATIVE SOURCES/REPLACEMENTS FOR FISH OILS

3.1. Plant proteins and oils

Plant proteins and plant oils have been tested industrially as partial replacements for fish meal and fish oil in fish feeds ingredients for several years now, with considerable success. However, results on different inclusion levels and qualities of soya-beans, gluten from corn and wheat, and various plant oils have shown that changes can occur in gut morphology, digestion, protein and fat retention, fillet composition and fish health. This is especially the case when replacement is extensive, or if it generates imbalances in fatty acids or amino acids, or if the replacing materials are insufficiently refined. However, neither the amino acid patterns of plant proteins, nor the fatty acid patterns of plant oils, nor the protein or lipid classes in plants, match the composition of the marine ingredients. Therefore, more knowledge on sophisticated mixing of various quantities and qualities of these new ingredients is urgently required.

3.2. By-catch, by-product and untargeted fish species

As an alternative to fish meal, at least in Norway, is the direct (on-line) utilisation of either unexploited pelagic organisms, or utilisation of by-catches / by-products. Figure 1 shows growth performance of Atlantic salmon given either a control diet based on fish meal and oil, or two experimental diets, season and by-catch, both based on by-products of different mixtures. The results show the possibility to obtain the same growth performance using a by-product based feed and a tradition fish meal + oil diet.

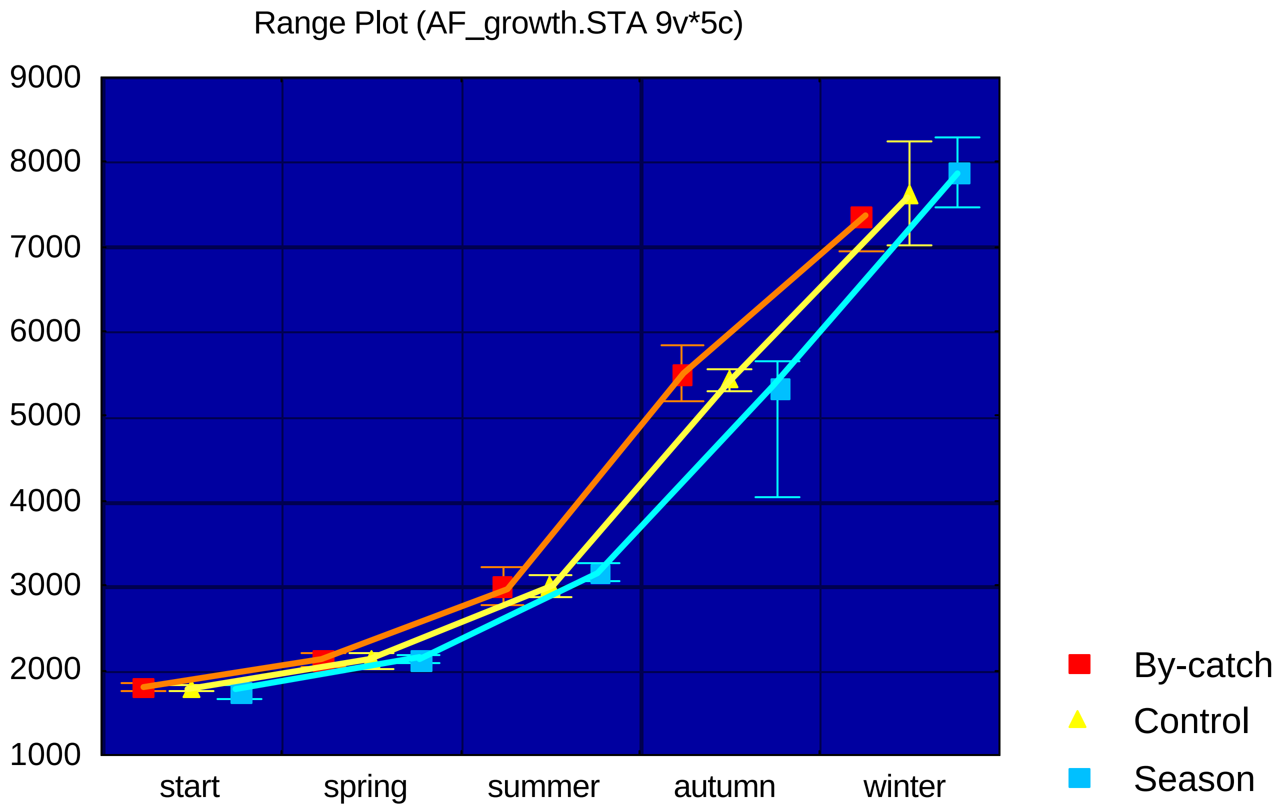

Figure 1. y-axis gram live weight, x-axis shows season, start is beginning of March (every season lasts for 3 months), the groups By-catch and Season are given by-product based diets, the control is given a fish meal and oil based diet. The salmon were fed in triplicate throughout one year.

Condrico AB and Ewos Innovation have tested suprex pea (special Condrico AB treatment of the plant protein) with good results (shown in Figure 2). Their results shows that it is possible to obtain the same growth and feed utilisation when pea-protein replaces more than half of the protein. These data were kindly given by Karl-Erik Slinning and Mattew Kouzeh - and are preliminary.

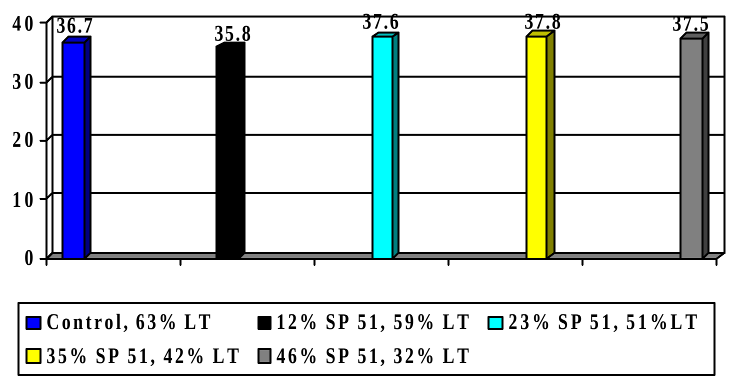

Figure 2. Growth of Atlantic salmon fingerlings, y-axis shows live weight gain (8 weeks). No difference were found between fish fed only LT-fish meal and fish fed a mixture of fish meal and suprex pea - up to 46% pea + 32% LT-fish meal.

3.3. Protein addition

There is also a possibility to further increase pure protein growth by clever additions of special protein qualities, thereby giving the opportunity to decrease dietary protein concentration still obtaining the same protein growth. Some results from dr. M.Espe's research where partly pre-digested protein is added in addition to the fish meal is shown in figure 3a (growth) and 3b (protein retention, PPV).

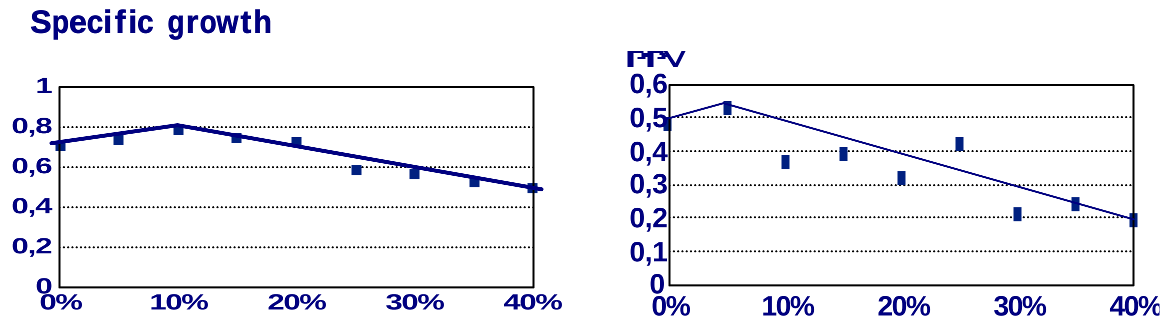

Figure 3. A (upper) shows specific growth rate of Atlantic salmon given diets with increasing additions of fish protein concentrate (FPC; partly digested), and B (lower) shows protein productive value (PPV) given the same diets. All diets held a protein level of 40% of feed dry matter.

3.5. Current trends in global demand for fish oil

Currently somewhat more than one half of world fish oil production is used in aquaculture feeds with salmonid feeds alone consuming more than one half of the total oil used for aqua feeds. IFOMA currently estimates that, given continuation of the current rate of expansion of aquaculture, global demand for fish oils for aqua feeds will equal the total global supply of fish oils by circa 2009. This means an urgent need for alternatives to fish oil.

Since dietary lipids are essential for energy and since, additionally, fish are not able to synthesise either the n-3 or the n-6 polyunsaturated fatty acids (PUFA) which are dietary essential fatty acids, these must be included in the diet. Preliminary results indicate however, that similar growth and feed utilisation can be obtained when substituting fish oil with mixtures of plant oils (Rafoa - EU report 2002). Nevertheless, substantial differences in relative fillet fatty acid compositions and the amount of fatty acids (mg fatty acid per mg fillet) are obtained. An example is given in Table 1.

	Capelin	Capelin +Sunflower	Sunflower	Palm oil
Diet EPA	25.2	17.2	7.2	5.4
Fillet	44.1	34.0	23.4	29.4
Liver	4.5	3.3	2.3	2.4
Diet DHA	19.1	14.6	8.2	6.5
Fillet	50.8	43.1	35.2	42.1
Liver	8.4	7.0	7.1	6.9
Diet sum n-3	61.0	42.2	17.9	13.7
Fillet	141.0	113.0	83.5	103.1
Liver	14.6	11.7	10.2	10.1
Diet n-3/n-6	8.6	2.8	0.8	0.6
Fillet	5.8	3.5	1.8	2
Liver	13.6	7.1	2.8	3.3

Table 1. Concentration of selected fatty acids in Atlantic salmon fed different oil mixtures, given above colum. The concentrations of EPA (20:5n-3), DHA (22_6n-3), sum n-3 and ratio n-3/n-6 in diets are reflected in both fillets and liver.

The different oil mixtures also resulted in different energy utilisation (b-oxidation), or different capacity to oxidise lipids, as shown in Figure 4 (from Torstensen et al. 2000).

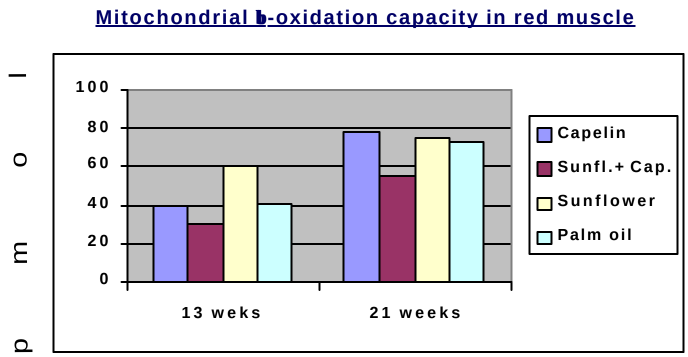

Figure 4. Atlantic salmon fed for 13 and 21 weeks with different oil mixtures, resulting in differential b-oxidation in red muscle.

4. CONCLUSIONS

- To summarise the very fine balance of essential amino acids in LT-fish meal, and that carnivorous fish have an obligatory need for protein also as energy, quite a large proportion of the marine protein may be substituted by various plant protein resources, but only if done cleverly.
- There is an urgent need for alternatives to fish oil.
- The final conclusion must therefore be that more knowledge is needed to meet the future demand for alternatives to fish meal and oil in aquaculture diets.