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Editorial Open Access

Use of Plant Products as Candidate Fish Meal Substitutes: An Emerging Issue in Aquaculture Productions

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Editorial

Abstract

The search for new dietary ingredients for total or partial replacement of fish oil has assumed a growing importance and is currently the subject of advanced scientific research. Plants are recognized to be a good source of both peptides and oils for fish aquafeeds. The present paper reviews the effects played on fish growth and physiology by some plant products, highlighting also their possible detrimental effects related to the presence of anti-nutritional factors. Although complete replacement of fish meal in feeds for cultured species is still difficult, the results obtained by the current studies performed on plant products are promising and encourage further research on this issue.

Keywords: Fish nutrition; Fish meal replacement; Plant proteins; Physiological effects

The aquaculture field has recently experienced a significant increase and in future the amount of global productions is expected to provide an important supply of seafood to satisfy the growing consumers demand [1,2]. To improve the sustainability and profitability of current productive practices, however, many issues require a substantial revision, especially those related to fish nutrition. Fish meal and fish oil are one of the most important ingredients for aquafeeds, however both are a limited resource; in fact, in parallel the impact on ocean fisheries of increased aquaculture production is likely to expand further, since farming carnivorous species requires large inputs of wild fish for feed [3]. Consequently, a reduced use of fish meal and oil represents a challenge for fast growing and sustainable aquaculture production.

The decrease in the availability and the increase in the prices of fish meal and fish oil have stimulated the search for sustainable alternatives for aquaculture feeds. To this regard, plant protein sources are increasingly used to satisfy the growing demands of the aqua-feed industry, since they represent good candidates for partial or total replacement of fish meal in fish diets [1]. The attention addressed to alternative protein sources for fish meal replacement is also shown by recent research funded by the European Community in this field (see for example the Project PEPPA-Perspectives of plant protein use in aquaculture: biological, environmental and socio-economic consequences, funded under the EC FP5-Life quality). Moreover, several studies have explored the possibility that plant proteins could be used for total or partial replacement of fish meal, with the aim not only of testing the nutritional value of fish products, but also of taking into consideration their eventual effects on fish health. Due to good performance and fish quality, the suitability of plant protein sources has been shown for many carnivorous fish [4]. However, it is well recognized that high dietary level of plant proteins (>40% of total protein) for partial replacement of fish meal reduces feed efficiency and growth performances [5,6]. Total replacement of fish meal is feasible when amino acid-supplemented diets are used [7-9].

Among plant protein sources, the most frequently used are legumes such as soybean, pea and lupin [7-11]; corn gluten meal [12] as well as cereal concentrates, including maize and wheat [13,14] that have already been tested for European sea bass, turbot, Atlantic salmon, and carp nutrition.

When plant proteins are used as alternative to replace fish meal, the presence of anti-nutritional factors (ANFs) represents one of the most important features that need to be addressed [15]. ANFs are mainly alkaloids that affect palatability and can be washed out using water or through feed extrusion. Other anti-nutritional factors are oligosaccharides, phytate, saponin and protease inhibitors [16]. ANFs play a limiting effect on fish growth; moreover they may cause patho-morphological changes in the intestinal epithelium of fish [17]. Intestinal inflammatory processes induced by ANFs have been documented for soybean meal-fed rainbow trout [18], Atlantic salmon [17], whereas no significant histological alterations have been reported for lupin kernel meal-fed rainbow trout [11].

Lupin (Lupinus albus) is a non-starch leguminous; its seeds have a good potential for aquaculture diets due to their its nutritional value (high protein content: 30-40 g/100 g), availability and low price. Lupin seeds have a crude protein (CP) content between 31 and 42%, which is higher than the content of most other grain legumes [16]. Lupin seed meal may be a good alternative vegetable protein of high nutritive quality when used at levels up to 30% or 40% in rainbow trout diets.

Another widely used plant protein source for aquafeeds is soybean [19]. Soybean meal (SBM) has been one of the most studied alternatives to fish meal, but it has several limitations, including the presence of anti-nutritional factors, low level of methionine and adverse effects on the intestinal integrity of some carnivorous species [20]. Another source of soybean is soy protein concentrate (SPC), produced using SBM fractionation, which is a highly refined ingredient, since most of the anti-nutritional factors present in SBM have been removed during processing [21]. SPC has been tested in several juvenile fish species, such as rainbow trout, Oncorhynchus mykiss [7], turbot, Scophthalmus maximus [22], Japanese flounder, Paralichthys olivaceus [23] or kingfish, Seriola lalandi [24], showing that adequate inclusion levels of SPC in diet are different depending on the studied species.

González-Rodríguez et al. [21] have studied the effects of total and partial replacement of fish meal with soy protein concentrate (SPC) in juvenile tench. Fish fed from 0% to 45% replacement diets have shown significantly lower feed conversion ratios and higher protein productive values than those fed diets with higher replacement levels. At higher replacement levels (from 55% to 100%), fish have shown significantly lower growth.

Rice protein concentrate (RPC) is a good raw material for fish nutrition due to its high protein (75% crude protein) and lipid content (11% ether extract). It is known to provide a source of easily available amino acids and nutrients, so that its inclusion as a dietary ingredient for fish has attracted attention [25,26]. In rainbow trout no adverse effects on growth performance traits (up to 20% inclusion) were observed [26].

In blackspot seabream (Pagellus bogaraveo) juveniles, experimental trials were carried out at the CNR-IAMC in order to investigate the effects induced on the digestive enzymes by the administration of two diets containing different levels (20% and 35%) of RPC as a protein source, in partial replacement of fish meal [27,28]. compared to a control group fed a diet without RPC.

No significant differences in nutrient apparent digestibility values of crude protein, dry matter and gross energy were observed among the fish groups [29]. The histological analysis confirmed that RPC did not induce intestinal mucosa alterations in this fish species or changes in the histochemical enzyme activities of the different intestinal regions, except for the acid phosphatase in the distal portion. The diet containing the highest level of RPC (35%) caused a significant increase of pepsin in the stomach and of trypsin in the intestine. The same stimulating effect was also observed with the diet containing 20% of RPC. The contents of chymotrypsin, carboxypeptidase A and B values were significantly enhanced in the intestine of fish fed the diet containing 35% of RPC. Therefore, data obtained in blackspot seabream suggested the inclusion of this compound as a dietary ingredient for this species due to its positive effects on protein digestibility.

In nutritional research, another interesting issue concerns the replacement of fish oil with vegetable oil, regarded as important dietary ingredient. Concerning the use of plants or grain seeds as a source of polyunsaturated oils, some trials were carried out with blackspot seabream to test the use of linum and echium oils in replacement of fish oil. A first experiment was performed in blackspot juveniles, in order to investigate the effect on the digestive enzymes of blackspot seabream of linum and echium seed oils, included in the dietary composition, as a source of polyunsaturated fatty acids [27]. Three different groups were fed with different experimental diets, indicated as “fish”, “linum” and “echium”. Fish” diet consisted of a standard diet containing fish oil (fish flour 55%, corn flour 20%, oil 7.5%, crude starch 6.5% extruded soybean flour 5.5%, crude fibre 5.5%, mineral salts 3%); “linum” and “echium” diets had been obtained by replacing the fish oil contained in the “fish” diet with linum and echium oils. A control group was fed a commercial dry diet for carnivorous fish. Diets were administered as 1.2% of the total body biomass calculated weekly. Fish fed a diet supplemented with fish oil showed a significant reduction of pepsin content in the stomach, compared with fish fed echium oil. This depressive effect could induce alterations in the preliminary, gastric, breakdown of dietary components, resulting in the elongation of digestive times. In the same group (fish fed with fish oil), trypsin content in the intestine decreased, although not at a significant level, compared with the control group. Diet containing linum oil caused a decrease in chymotrypsin values in the pyloric caeca and in the intestine; in this organ, an increase in lipase content occurred, while the carboxypeptidase B levels were significantly reduced. Compared with the control, both linum and fish oils increased significantly amylase levels, particularly in the stomach at starvation. This result suggested that the vegetable nature of the linum oil was effective in stimulating the digestive capabilities of the carbohydrate component.

In conclusion, nutritional issues must be considered to achieve aquaculture sustainability. In this context, the search for new dietary ingredients for total or partial replacement of fish oil assumes a growing importance and is currently the subject of advanced scientific research [30-32]. At present, fish meal remains the primary protein source in aquafeeds for marine species at the fry or fingerling stages. Complete replacement of fish meal in feeds for marine species is still difficult and will require further research efforts to be obtained. Nevertheless, the results obtained by the current studies performed on plant products are promising and encourage further experimentation to meet seafood production and environmental sustainability.

References

1. Hardy RW (2010) Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal. Aquacult Res 41: 770-776.
2. Hixson SM (2014) Fish nutrition and current issues in aquaculture: the balance in providing safe and nutritious seafood, in an environmentally sustainable manner. J Aquacult Res Devel 5(3): 234 doi: 10.4172/2155-9546.1000234
3. Naylor RL, Goldburg RJ, Primavera JH, Kautsky N, Beveridge MCM, et al. (2000) Effect of aquaculture on world fish supplies. Nature 405: 1017-1024.
4. Palmegiano GB, Costanzo MT, Daprà F, Gai F, Galletta MG, et al. (2007) Rice protein concentrate meal as potential dietary ingredient in practical diets for blackspot sea bream (Pagellus bogaraveo). J Anim Physiol Anim Nutr 91: 235-239.
5. Robaina L, Izquierdo MS, Moyano FJ, Socorro J, Vergara JM, et al. (1995) Soybean and lupin seed meals as protein sources in diets for gilthead seabream (Sparus aurata): nutritional and histological implications. Aquaculture 130: 219-233.
6. Refstie S, Korsoen OJ, Storebakken T, Baeverfjord G, Lein I, et al. (2000) Differing nutritional responses to dietary soybean meal in rainbow trout (Oncorhynchus mykiss) and Atlantic salmon (Salmo salar). Aquaculture 190: 49-63.
7. Kaushik SJ, Cravedi JP, Lalles JP, Sumpter J, Fauconneau B, et al. (1995) Partial or total replacement of fish meal by soybean protein on growth, protein utilization, potential estrogenic or antigenic effects, cholesterolemia and flesh quality in rainbow trout, Oncorhynchus mykiss. Aquaculture133: 257-274.
8. Kaushik S, Coves D, Dutto G, Blanc D (2004) Almost total replacement of fish meal by plant protein sources in the diet of a marine teleost, the European seabass, Dicentrarchus labrax. Aquaculture 230: 391-404.
9. Dias J, Alvarez MJ, Diez A, Arzel J Corraze G, et al. (2005) Dietary protein source affects lipid the metabolism in the European seabass (Dicentrarchus labrax). Comp Biochem Physiol A 142: 19-31
10. Pereira TG, Oliva-Teles A (2002) Preliminary evaluation of pea seed meal in diets for gilthead sea bream (Sparus aurata) juveniles. Aquacult Res 33: 183-189.
11. Glencross B, Evans D, Hawkins W, Jones B (2004) Evaluation of dietary inclusion of yellow lupin (Lupinus luteus) kernel meal on the growth, feed utilisation and tissue histology of rainbow trout (Oncorhynchus mykiss). Aquaculture 235: 411- 422.
12. Pereira TG, Oliva-Teles A (2003) Evaluation of corn gluten meal as a protein source in diets for gilthead sea bream (Sparus aurata, L.) juveniles. Aquacult Res 34: 1111-1117.
13. Robaina L, Corraze G, Aguirre P, Blanc P, Melcion JP, et al. (1999) Digestibility, postprandial ammonia excretion and selected plasma

metabolites in European sea bass (Dicentrarchus labrax) fed pelleted or extruded diets with or without wheat gluten. Aquaculture 179: 191-199.

14. Kaur VI, Saxena PK (2005) Incorporation of maize gluten in supplementary feed and its impact on growth and flesh quality of some carps. Aquacult Int 13: 555-573.
15. Francis G, Makkar HPS, Becker K (2001) Antinutritional factors present in plant-derived alternate fish feed ingredients and their effect in fish. Aquaculture 199: 197-227.
16. Rajeev R and Bavitha M (2015) Lupins - An alternative protein source for aquaculture diets. Int J Appl Res1(3) : 04-08
17. Krogdahl A, Bakke-McKellep AM, Baeverfjord G (2003) Effects of graded levels of standard soybean meal on intestinal structure, mucosal enzyme activities, and pancreatic response in Atlantic salmon (Salmo salar L.). Aquacult Nutr 9: 361-371.
18. Ostaszewska T, Dabrowski K, Palacios ME, Olejniczak M, Wieczorek M (2005) Growth and morphological changes in the digestive tract of rainbow trout (Oncorhynchus mykiss) and pacu (Piaractus mesopotamicus) due to casein replacement with soybean proteins. Aquaculture 245: 273-286.
19. Brown PB, Kaushik SJ, Peres H (2008) Protein feedstuffs originating from soybeans. In: Lim C, Webster CD and Lee C (Eds.), Alternative Protein Sources in Aquaculture Diets, The Haworth Press, Taylor and Francis Group, New York, USA: 205-223.
20. Gatlin DM, Barrows FT, Brown P, Dabrowski K, Gaylord TG, et al. (2007) Expanding the utilization of sustainable plant products in aquafeeds: a review. Aquacult Res 38: 551-579.
21. González-Rodríguez Á, Celada JD, Carral JM, Sáez-Royuela M and Fuertes JB (2015) Evaluation of pea protein concentrate as partial replacement of fish meal in practical diets for juvenile tench (Tinca tinca L.) Aquacult Res DOI: 10.1111/are.12732
22. Day OJ and González HGP (2000) Soybean concentrate as a protein source for turbot Scophthalmus maximus L. Aquacult Nutr 6: 221-228.
23. Deng J, Mai K, Ai Q, Zhang W, Wang X, et al. (2006) Effects of replacing fish meal with soy protein concentrate on feed intake and growth of juvenile Japanesse flounder, Paralichthys olivaceous. Aquaculture 258: 503-513.
24. Bowyer JN, Qin JG, Smullen RP, Adams LR, Thompson MJS, et al. (2013) The use of a soy product in juvenile yellowtail kingfish (Seriola lalandi) feeds at different water temperatures: 2. Soy protein concentrate. Aquaculture 410-411: 1-10.
25. Caruso G, Costanzo MT, Palmegiano GB, Gai F, Genovese L (2005) Blackspot sea bream (Pagellus bogaraveo) fed on rice protein concentrate meal: effect on digestive enzymes. Aquaculture Europe 2005 "Lessons from the past to optimise the future", Trondheim (Norway), 5-9 August 2005, EAS Special Publication 35: 158-159.
26. Palmegiano GB, Daprà F, Forneris G, Gai F, Gasco L, et al. (2006) Rice protein concentrate meal as a potential ingredient in practical diets for rainbow trout (Oncorhynchus mykiss). Aquaculture 258: 357-367.
27. Caruso G, Denaro MG, Genovese L (2009) Digestive enzymes in some Teleost species of interest for Mediterranean aquaculture. The Open Fish Sci J 2: 74-86 doi: 10.2174/1874401X00902010074.
28. Costanzo M, Palmegiano GB, Caruso G, Gai F, Daprà F, et al. (2011) Alternative Dietary Sources in Feeding of the Blackspot Sea Bream Pagellus bogaraveo (Brunnich, 1768). The Open Mar Biol J, Special Issue"New candidate species for intensive Mediterranean aquaculture: studies on reproduction, digestion, response to stress", 5: 12-23.
29. Daprà F, Gai F, Costanzo MT, Maricchiolo G, Micale V, et al. (2009) Rice protein-concentrate meal as a potential dietary ingredient in practical diets for blackspot seabream Pagellus bogaraveo: A histological and enzymatic investigation. J Fish Biol 74(4): 773-789. doi:10.1111/j.1095-8649.2008.02157.x
30. Tacon AGJ and Metian M (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. Aquaculture 285: 146-158.
31. Adamidou S, Nengas I, Henry M, Ioakei Midoy N, Rigos G, et al. (2011) Effects of dietary inclusion of peas, chickpeas and faba beans on growth, feed utilization and health of gilthead seabream (Sparus aurata). Aquaculture Nutrition 17: 288–296.
32. Lazzarotto V, Corraze G, Leprevost A, Quillet E, Dupont-Nivet M, et al. (2015) Three-Year Breeding Cycle of Rainbow Trout (Oncorhynchus mykiss) Fed a Plant-Based Diet, Totally Free of Marine Resources: Consequences for Reproduction, Fatty Acid Composition and Progeny Survival. PLoS ONE 10(2): e0117609. doi:10.1371/journal.pone.0117609