Soy protein concentrate: a value-added soy product for aquafeeds

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Background

Aquaculture is the world's fastest-growing industry in the food production sector. It is projected that aquaculture will play a major role in the global food supply by doubling and intensifying its production by 2050 (1). It is well known that the sustainability of aquaculture production heavily relies on the availability and the use of viable compound feeds as well as raw materials. In 2018, the production of the fed-aquaculture species achieved a new record, reaching almost 45.5 million tonnes with a respectively recorded feed consumption of ca. 53 million tonnes (2). In addition, by 2025, fed species' aquaculture production is expected to reach almost 59 million tonnes which consequently means that the aquafeed industry (including ingredient supply) will have to grow annually by 7.7% (2). Fish feed represents up to 60% of the fish farm production costs, while dietary protein accounts for almost half of the cost of aquafeed, resulting as the single most expensive feed component (3). Fish meal is considered as 'the gold standard' and the primary protein source of choice in aquafeeds, especially for the carnivorous and omnivorous fish species. The reasons for its superiority are the high protein quality and content, high nutrient digestibility as well as a general lack of anti-nutrients (4). Despite all the advantages that fish meal comprises as an aquafeed ingredient, the fluctuation of its production due to the changes in the catches of wild fish species (El Niño–Southern Oscillation) impacts its availability as well as its price (5).

Alternative proteins in aquafeeds

The increased feed demand of the fast-growing aquaculture industry has been coupled with advanced efforts of replacing the fishmeal in fish feeds with proteins of plant, animal, and of microbial origin in the past (3). Although land animal proteins are considered to be an economical alternative, their use has been restricted at times by feed regulations (3). Additionally, microbial proteins albeit they have potential, for the time being, have limited availability and remaining rather costly (6). On the other hand, plant proteins are considered the main fish meal alternatives. The plant protein ingredients most commonly used in fish feeds worldwide are produced from soybean, corn, wheat, sunflower, and rapeseed (7). In order to be considered as a candidate fishmeal replacer in fish feeds, an alternative ingredient must possess certain characteristics such as high-quality protein content, high digestibility, low levels of antinutritional factors, etc. (8). In fact, during the past years, many studies have shown detrimental effects on fish growth performance when high-plant diets are fed especially to carnivorous fish species (9,10,11,12).
However, most of the alternative plant ingredients are well-known to contain several antinutritional factors. The antinutritional factors are biological compounds present in the ingredients, which affect the bioavailability and utilization of nutrients and impact intestinal physiology and absorption, and overall, the ultimate animal's metabolic performance. Important antinutrients commonly found in plant protein ingredients are protease inhibitors, non-starch polysaccharides, allergens, lectins, phytic acid, saponins, etc. (13).

Soy protein concentrate: a value-added soy product

Soybean meal is the most common protein source used in aquafeeds and animal diets (7). Although it has a relatively high protein content, a favorable amino acid profile, and is sustainably produced, its use is limited due to its high content of antinutritional factors (8). Numerous studies have shown that high soybean meal inclusion levels in the fish diets resulted in decreased growth performance and feed utilization (3). Baeverfjord and Krogdahl (14) reported that high soybean meal levels in Atlantic salmon diets were the main cause of subacute enteritis (intestinal inflammation) induction in the distal intestine of the fish. Moreover, enteritis is considered a progressive and dose-dependent condition due to the antinutritional compounds found in soybean meal, which leads to slower growth and increased morbidity.

Soy protein concentrate (SPC) is produced by a soybean refining process employing aqueous alcohol extraction which removes a large amount of antinutritional compounds and has a minimum crude protein content of 60%. This process substantially increases the nutritional value of the SPC resulting in a value-added soy product. Results from several studies showed that high inclusion of SPC can replace dietary fish meal without negatively affecting fish performance and health. Kaushik et al. (15) reported that replacement of fish meal with SPC up to 100% in rainbow trout diets did not affect fish growth performance, nutrient utilization, or protein digestibility. Moreover, the incorporation of SPC in the diets of carnivorous juvenile cobia (Rachycentron canadum) up to 75% exhibited outstanding fish growth performance in terms of weight gain feed efficiency, specific growth rate, and survival (16). In line with the previous studies, Kalhoro et al., (17) showed that the dietary substitution of the fish meal up to 82.5 % SPC did not negatively affect the growth performance and feed efficiency of black sea bream fry (Acanthopagrus schlegelii) compared to a fish meal-based diet. Similar results have been reported in Senegalese sole (Solea senegalensis) postlarvae (85.6 mg wet weight) when fed an SPC-based diet (60% inclusion) (18).

Particularly noteworthy is the finding reported by Krogdahl et al. (19), who demonstrated that when Atlantic salmon smolts (Salmo salar) were fed an SPC containing diet and subsequently challenged by Aeromonas salmonicida ssp., presented a significantly higher survival rate compared to the counterparts fed on soybean meal containing diet and a fish meal-based diet.

Ultimately, a study conducted by Brezas & Hardy (20), employing force-feeding of different ingredients in the rainbow trout and measuring at time intervals post-feeding plasma amino acids concentrations, showed that SPC post-prandially has a higher essential amino acid bioavailability pattern compared to other plant proteins but very similar to fish meal (Figure 1). The above study also concluded that protein and amino acid digestibility, though is a useful assessment tool for evaluating feed ingredient quality, does not provide physiological insights regarding the bioavailability and metabolic utilization of dietary protein. This novel finding is supportive of the fact that SPC is considered one of the most promising and most used single ingredient in the diets of salmon for the last several years (21).

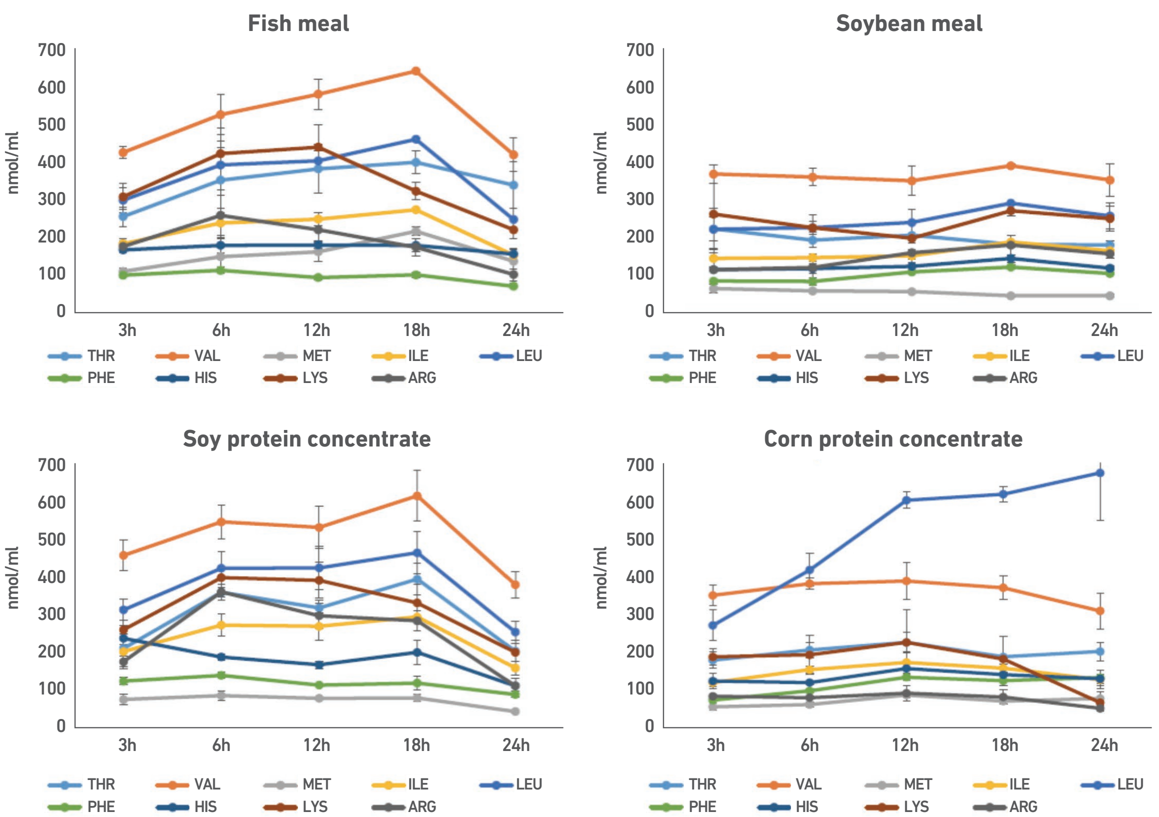

Figure 1. Free essential amino acid mean concentrations in blood plasma (nmol/ml) collected from the caudal vein of rainbow trout during 24 h period after force feeding fishmeal, SPC, soybean meal and corn protein concentrate (adapted from Brezas & Hardy, 2020).

Conclusions

SPC is considered one of the most promising plant protein sources to replace fish meal in aquafeeds. Due to its manufacturing process, SPC has a high protein content, substantially lower antinutritional factors levels without inducing intestinal inflammation compared to soybean meal, high protein digestibility, as well as a higher amino acid bioavailability, compared to other plant protein products. SPC is the major plant ingredient in salmon diets and is widely used in the aquafeeds for carnivorous species. CJ Selecta's SPC is a value-added soy product of high nutritional value that can be defined as an "Aqua Grade" ingredient.

REFERENCES

1. Glecross B, Frascalossi D, Hua K, Izquierdo M, Mai K, Overland M, et al. Harvesting the benefits of nutritional research to address global challenges in 1 the 21st century. 2020; https://aquaculture2020.org/uploads/gca-tr4-aquaculture-feeds-and-feeding.pdf
2. Tacon AGJ, Metian M, & McNevin AA. Future Feeds: Suggested Guidelines for Sustainable Development, Reviews in Fisheries Science & Aquaculture. 2021; DOI: 10.1080/23308249.2021.1898539
3. National Research Council (NRC). Nutrient Requirements of Fish and Shrimp. National Academic Press, Washington, DC, USA. 2011.
4. Larsen BK, Dalsgaard J. & Pedersen PB. Effects of Plant Proteins on Postprandial, Free Plasma Amino Acid Concentrations in Rainbow Trout (Oncorhynchus mykiss). Aquaculture. 2012; 326–329, 90–98.
5. Food and Agriculture Organization (FAO). The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. 2020; https://-doi.org/10.4060/ca9229en
6. Ritala A, Häkkinen ST, Toivari M. and Wiebe MG. Single Cell Protein—State-of-the-Art, Industrial Landscape and Patents 2001–2016. Fronti ers in Microbiology. 2017; 8:2009.
7. Hardy RW. Utilization of Plant Proteins in Fish Diets: Effects of Global Demand and Supplies of Fishmeal. Aquaculture Research. 2010; 41, 770 –76.
8. Gatlin DM, Barrows FT, Brown P, Dabrowski K, Gaylord TG, Hardy RW, et al. Expanding the Utilization of Sustainable Plant Products in Aquafeeds: A Review. Aquaculture Research. 2007; 38(6):551–79.
9. Panserat S, Kolditz C, Richard N, Plagnes-Juan E, Piumi F, Esquerré D, et al. Hepatic Gene Expression Profiles in Juvenile Rainbow Trout (Oncorhynchus mykiss) Fed Fishmeal or Fish Oil-Free Diets. British Journal of Nutrition. 2008; 100(5):953–67.
10. Martin SAM, Vilhelmsson O, Médale F, Watt P, Kaushik S, and Houlihan DF. Proteomic Sensitivity to Dietary Manipulations in Rainbow Trout. Biochimica et Biophysica Acta. 2003; 1651(1–2):17–29.
11. Davies SJ, & Morris PC. Influence of Multiple Amino Acid Supplementation on the Performance of Rainbow Trout, Oncorhynchus mykiss (Walbaum), Fed Soya Based Diets. Aquaculture Research. 1997; 28, 65–74.
12. Gomes EF, Rema P, & Kaushik SJ. Replacement of Fish Meal by Plant Proteins in the Diet of Rainbow Trout (Oncorhynchus mykiss): Digestibility and Growth Performance. Aquaculture. 1995; 130, 177–86.
13. Francis GH, Makkar PS, and Becker K. Antinutritional Factors Present in Plant-Derived Alternate Fish Feed Ingredients and Their Effects in Fish. 2001; Vol. 199.
14. Baeverfjord G, Krogdahl A. Development and regression of soybean meal induced enteritis in Atlantic salmon, Salmo salar L., distal intestine: a comparison with the intestines of fasted fish. J. Fish Dis. 1996; 19, 375–387.
15. Kaushik SJ, Cravedi JP, Lalles JP, Sumpter J, Fauconneau B, and Laroche M. 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. Aquaculture. 1995; 133(3–4):257–74.
16. Salze G, McLean E, Battle PR, Schwarz MH, Craig SR. Use of soy protein concentrate and novel ingredients in the total elimination of fish meal and fish oil in diets for juvenile cobia, Rachycentron canadum. Aquaculture. 2010; 298: 294–299.
17. Kalhoro H, Zhou J, Hua Y, et al. Soy protein concentrate as a substitute for fish meal in diets for juvenile Acanthopagrus schlegelii: effects on growth, phosphorus discharge and digestive enzyme activity. Aquac Res. 2018; 49: 1896– 1906.
18. Aragão C, Conceição LEC, Dias J, Marques AC, Gomes E, and Dinis MT. (2003), Soy protein concentrate as a protein source for Senegalese sole (Solea senegalensis Kaup 1858) diets: effects on growth and amino acid metabolism of postlarvae. Aquaculture Research. 2003; 34: 1443-1452.
19. Krogdahl A, Bakke-Mckellep AM, RØed KH, and Baeverfjord G. Feeding Atlantic salmon Salmo salar L. soybean products: effects on disease resistance (furunculosis), and lysozyme and IgM levels in the intestinal mucosa. Aquaculture Nutrition. 2000; 6: 77-84.
20. Brezas A, Hardy RW. Improved performance of a rainbow trout selected strain is associated with protein digestion rates and synchronization of amino acid absorption. Scientific Reports. 2020; 10, 4678.
21. Aas TS, Ytrestøyl T, & Åsgård T. Utilization of feed resources in the production of Atlantic salmon (Salmo salar) in Norway: An update for 2016. Aquacult. Rep. 2019; 15, 100216.