Effective replacement of blood meal by L-histidine in diets for salmon

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Introduction

Histidine (His) is one of the 10 essential amino acids for fish, and its importance in nutrition expanding the role of this amino acid beyond its function in protein synthesis. It is well recognized that histidine deficiency can impair growth as well as feed conversion in fish (1, 2). Its metabolites, such as carnosine, anserine and NAH (N-acetyl histidine) play an important role in antioxidant capacity, recovery from fatigue and regulation of osmotic pressure in the eye. In addition, histidine is an important amino acid that contributes to the production of erythrocytes and immune cells in the blood and plays a crucial role in enzymatic reactions due to the side chain of imidazole (3-5). Therefore, in view of its versatile role in fish, care in the dietary inclusion of histidine becomes an extra necessity.

Blood meal is considered to be the richest raw material in histidine (4-6% histidine) (6). After the removal of this ingredient in the mid-1990s, due to the potential risk of transmission of Bovine Spongiform Encephalopathy (BSE), a high incidence of cataracts was observed in Atlantic salmon in Europe and South America (7). Salmonidae are visual predators, and fish with severe cataracts are more susceptible to secondary diseases due to decreased food intake, in addition to having less growth performance.

Therefore, the requirement for histidine for growth (8 g kg-1 feed; (6)) does not meet the need to minimize cataracts in diets for Atlantic salmon. According to Remø, Hevrøy (8), the lowest severity of cataracts can be achieved by feeding 13.4 g kg-1 feed. However, those authors also suggest that the need for histidine in the diet to minimize the risk of cataract development is 14.4 g kg-1 feed of histidine.

From a cost perspective, feed is the most important factor in salmon industry. Since feed represents more than 50% of the operating costs of intensive culture, must be given special attention to cost-effective ingredients sources, to keep feed costs more competitive in the face of fluctuations in raw material prices (9). Since histidine can be produced by fermentation, through a technological and ecologically correct process, which guarantees high quality and safe food. Therefore, this study aimed to evaluate the economic viability of the replacement of blood meal with crystalline L-histidine using the Atlantic salmon (Salmo salar) as an experimental model, which is one of the most cultivated species in the world.

Methods

A total of 11 diets were designed to be isoenergetic (20.6 MJ kg-1 DE) and isoproteic/isonitrogenous (40% CP, 35% DP) and to have similar AA profiles. Except for histidine, a balanced simulation diet was formulated to meet the requirement for optimal growth established for Atlantic salmon (Salmon Salar) (10). Histidine level was setup to 1.44% which means that the diets are covering the requirements for ocular health (8). By adopting that approach based on the replacement of BM, protein content and His could be meet by using soy protein concentrate (SPC) as a source of protein, and also increasing levels of crystalline L-histidine. With the replacement of BM by a vegetable protein source, there was a need for supplementation of crystalline Lys, since this amino acid became limiting in the diet. The inclusion of Canola oil to dicalcium phosphate was kept constant in all diets (Table 1).

A simulation was conducted to evaluate the economic feasibility of substituting blood meal by crystalline L-histidine in diets for salmon using a minimum cost formulation program. Diets D1 to D11 contained decreasing levels of crystalline L-histidine (0.48, 0.44, 0.41, 0.38, 0.34, 0.31, 0.28, 0.25, 0.21, 0.18, and 0.17 g kg^{-1} feed).

Table 1. Main ingredients and proximate composition of the diets

Diets	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Ingredients formulation (g/kg feed)											
SPC	192	179.3	164	148.7	133.4	118.1	102.8	87.5	72.2	57.8	51.2
Wheat flour	34.8	36.1	38.7	41.2	43.8	46.3	48.9	51.5	54	56.3	56.9
Blood Meal	0	10.9	22.6	34.4	46.2	58	69.8	81.6	93.4	105.1	110.1
Fish Oil	111	112.3	113.9	115.6	117.3	118.9	120.6	122.3	123.9	125	125.9
Canola oil	170	170	170	170	170	170	170	170	170	170	170
Fish meal	130	130	130	130	130	130	130	130	130	130	130
Poultry Byproduct Meal	120	120	120	120	120	120	120	120	120	120	120
Soybean Meal (45%)	90	90	90	90	90	90	90	90	90	90	90
Meat and Bone Meal (44%)	50	50	50	50	50	50	50	50	50	50	50
Feathers Meal	45	45	45	45	45	45	45	45	45	45	45
Squid liver meal	20	20	20	20	20	20	20	20	20	20	20
Dicalcium phosphate	10	10	10	10	10	10	10	10	10	10	10
L-Lysine HCl	8.02	7.65	7.34	7.03	6.72	6.42	6.11	5.8	5.49	5.18	5.03
L-Histidine	4.76	4.43	4.1	3.77	3.44	3.11	2.79	2.46	2.13	1.8	1.66
L-Threonine	1.43	1.37	1.3	1.22	1.15	1.07	0.99	0.92	0.84	0.76	0.72
Premix Vitamin and mineral	13	13	13	13	13	13	13	13	13	13	13
Proximate composition											
Digestible Energy	4941	4941	4941	4941	4941	4941	4941	4941	4941	4941	4956
Digestible Protein	355	355	355	355	355	355	355	355	355	355	355
Fat	327	328.1	329.9	331.6	333.4	335.2	336.9	338.7	340.4	341.6	342.3
Digestible Energy (MJ g kg^{-1})	206.7	206.7	206.7	206.7	206.7	206.7	206.7	206.7	206.7	206.7	206.7
EAA (g kg^{-1} dry matter)											
Arginine	27.1	26.8	26.5	26.2	25.9	25.6	25.3	25	24.6	24.3	24.2
Histidine	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Isoleucine	17.4	17.1	16.7	16.4	16	15.7	15.4	15	14.7	14.3	14.3
Leucine	29.4	29.9	30.4	30.9	31.4	31.9	32.4	32.9	33.4	33.9	34.1
Lysine	30	30	30	30	30	30	30	30	30	30	30
Methionine	7	7	7	7	7	7	7	7	7	6.9	6.9
Phenylalanine	18.2	18.4	18.6	18.8	19	19.2	19.4	19.6	19.7	19.9	20
Threonine	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Valine	20.4	20.7	21	21.4	21.8	22.1	22.5	22.8	23.2	23.5	23.7

Results

The economic evaluations were based on the actual feed market prices (11). In all diets, crystalline L-histidine and/or BM contributed at least 32.5% of total dietary histidine. Formulation cost (USD) decreased in response to graded levels of dietary histidine (Figure 1). The D11 diet had the highest formulation cost reaching US$ 1,124.72, and the difference between the diet D1 was being around US$ 24.35.

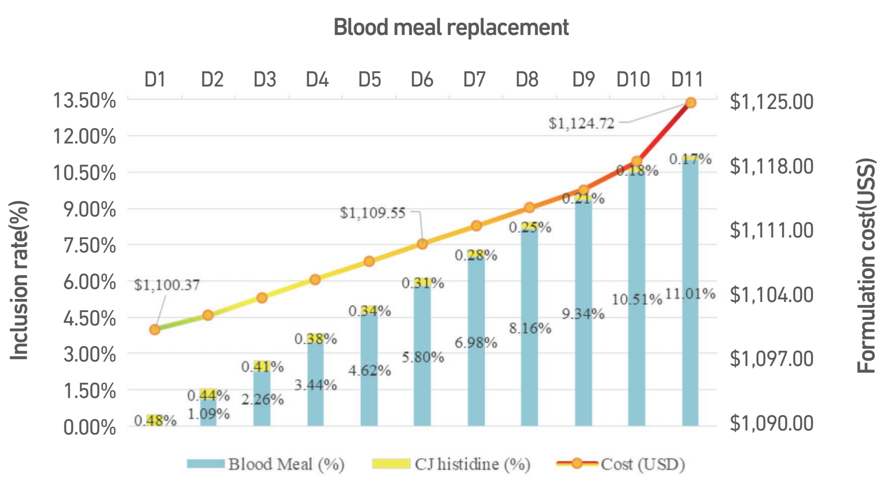

Figure 1. Effect on formulation cost of blood meal replacement by L-histidine in salmon feed

Discussion

The supplementation of crystalline L-histidine in feeds for salmon represents an opportunity to reduce formulation costs in the face of traditional commodity market of protein ingredients. An approach to meet the requirements for histidine in Atlantic salmon, while reducing feed costs is achieved through food supplementation with crystalline histidine. Despite the inclusion levels of BM used by the salmon industry not reaching values as high as the maximum proposed in the present study, the total replacement of BM by crystalline L-histidine presented the best formulation cost. With the replacement of BM, there was a need to include soy protein concentrate, since this ingredient is considered a good source of protein-rich ingredient and has the highest apparent digestibility coefficients in salmonids, in addition to the lowest cost (12).

According to Parker (13), the use of animal by-products in feed for farmed Atlantic salmon has a substantial effect on environmental profile and is associated with most of the impacts of feed production. Animal by-products-free diets can result in substantial improvements, including a 70% reduction in greenhouse gas emissions. Consequently, its use can fuel an important debate focus on possible alternatives to reduce the aquaculture industry's dependence on this resource. In addition, such a source has often been linked to contaminants, such as pathogens (eg salmonella), which are potentially harmful to fish welfare (14).

L-histidine is produced by environmentally friendly fermentation technology, through the fermentation of ecological materials. In addition, this amino acid has excellent stability, therefore, its purified crystalline form can be stored in a stable manner at room temperature and also exhibits excellent safety, even in high temperature feed production environments, which is an important point to be considered in the feed salmon production.

Amino acids can cause causing important chemical signals, which stimulate various behavioral reactions, and give an attractive flavor to fish (15). In addition, it is believed that the response of gustatory chemoreceptors in fish is more efficient are fed diets supplemented with crystalline L-histidine (16). Therefore, crystalline L-histidine contributes to increase the attractiveness of diets for animals.

Conclusion

Results of this study clearly indicate that blood meal could be successfully replaced by L-histidine, and can be considered a correct environmental strategy in salmon nutrition, since it is produced by environmentally friendly fermentation technology. Since, blood meal could be associated with impacts on the production of salmon feed, and animal by-products could be associated with contaminants that are potentially harmful to animal welfare, L-histidine can be a key strategy to be safely used in fish feed. The total replacement of blood meal with crystalline L-histidine has substantially improved formulation costs by up to US$ 24.35.

REFERENCES

1. Gao Y-J, Liu Y-J, Chen X-Q, Yang H-J, Li X-F, Tian L-X. Effects of graded levels of histidine on growth performance, digested enzymes activities, erythrocyte osmotic fragility and hypoxia-tolerance of juvenile grass carp Ctenopharyngodon idella. Aquaculture. 2016;452:388-94.
2. Zhao B, Feng L, Liu Y, Kuang SY, Tang L, Jiang J, et al. Effects of dietary histidine levels on growth performance, body composition and intestinal enzymes activities of juvenile Jian carp (Cyprinus carpio var. Jian). Aquaculture Nutrition. 2012;18(2):220-32.
3. Khan MA, Abidi SF. Dietary histidine requirement of Singhi, Heteropneustes fossilis fry (Bloch). Aquaculture Research. 2014;45(8):1341-54.
4. Abe H, Ohmama S. Effect of starvation and sea-water acclimation on the concentration of free L-histidine and related dipeptides in the muscle of eel, rainbow trout and Japanese dace. Comparative Biochemistry and Physiology Part B: Comparative Biochemistry. 1987;88(2):507-11.
5. Waagbø R, Tröße C, Koppe W, Fontanillas R, Breck O. Dietary histidine supplementation prevents cataract development in adult Atlantic salmon, Salmo salar L., in seawater. British Journal of Nutrition. 2010;104(10):1460-70.
6. NRC. Nutrient Requirements of Fish and Shrimp. Washington, DC: The National Academies Press; 2011. 392 p.
7. Breck O, Bjerkås E, Sanderson J, Waagbø R, Campbell P. Dietary histidine affects lens protein turnover and synthesis of N-acetylhistidine in Atlantic salmon (Salmo salar L.) undergoing parr–smolt transformation. Aquaculture Nutrition. 2005;11(5):321-32.
8. Remø S, Hevrøy E, Olsvik P, Fontanillas R, Breck O, Waagbø R. Dietary histidine requirement to reduce the risk and severity of cataracts is higher than the requirement for growth in Atlantic salmon smolts, independently of the dietary lipid source. British Journal of Nutrition. 2014;111(10):1759-72.
9. Shepherd CJ, Monroig O, Tocher DR. Future availability of raw materials for salmon feeds and supply chain implications: The case of Scottish farmed salmon. Aquaculture. 2017;467:49-62.
10. IAFFD. International Aquaculture Feed Formulation Database (IAFFD). https://www.iaffd.com/ https://www.iaffd.com/2021 [cited 2021 01/10/2021].
11. URUMOL. Descartes Datamyne LatAm. http://datamynelatam.com/ 2021 [cited 2021 01/10/2021].
12. Bureau D, Harris A, Cho C. Apparent digestibility of rendered animal protein ingredients for rainbow trout (Oncorhynchus mykiss). Aquaculture. 1999;180(3-4):345-58.
13. Parker R. Implications of high animal by-product feed inputs in life cycle assessments of farmed Atlantic salmon. The International Journal of Life Cycle Assessment. 2018;23(5):982-94.
14. Pickova J, Sampels S, Berntssen M. Minor Components in Fish Oil and Alternative Oils with Potential Physiological Effect. Fish Oil Replacement and Alternative Lipid Sources in Aquaculture Feeds. 2010;351.
15. Hara T, Evans D. Chemoreception [in fish]. CRC Marine science series 191-218. 1993.
16. Ogata H. Muscle buffering capacity of yellowtail fed diets supplemented with crystalline histidine. Journal of Fish Biology. 2002;61(6):1504-12.