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ORIGINAL ARTICLE

Nutritional properties of dried salmon silage for broiler feeding

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ABSTRACT

The aim of this study was to evaluate the chemical composition, energy and amino acid profile of dried salmon silage (DSS) for broilers. The DSS was obtained by acid digestion of salmon mortalities and subsequently co-dried with wheat bran in a 70:30 ratio (70 parts silage and 30 parts wheat bran). Samples of DSS were evaluated for chemical composition, gross energy, nitrogen-corrected true metabolizable energy (TME_n), mineral content, total and digestible amino acids for broilers, and amino acid score. The chemical composition of DSS was (mean ± SD): moisture (12.3 ± 0.8%), crude protein (44.0 ± 1.1%), ether extract (5.0 ± 2.4%), crude fiber (3.3 ± 0.4%) and ash (9.4 ± 0.6%). The gross energy and TME_n for broilers were 4 069 kcal/kg and 2 613 kcal/kg, respectively. The DSS mineral composition showed a high content of calcium (1.01%) and phosphorus (1.08%). The DSS had high levels of digestible methionine (0.74%), lysine (2.27%), and threonine (1.16%), and did not present limiting amino acids for broilers. Nutritional composition of DSS showed high protein content with an amino acid profile considered to be suitable as a protein source for broiler feeding.

Key words: *amino acids, broiler, nutritional properties, salmon mortalities, silage.*

INTRODUCTION

The salmon industry plays an important economic and social role in Chile, being the main salmon-producing country in the southern hemisphere and the second largest farmed salmon producer in the world after Norway. The three main salmonid species farmed in Chile are Atlantic salmon (*Salmo salar*), Coho salmon (*Oncorhynchus kisutch*) and rainbow trout (*Oncorhynchus mykiss*). Farming of salmonids is very intensive in Chile, generating a series of potential ecosystem disruptions (Buschmann *et al*. 2006) such as environmental pollution (Naiman *et al*. 2002), chemical and drug contaminants (Cabello 2004), precipitation of organic and inorganic matter in sediment (Tett 2008), and high rates of fish mortality with a consequent accumulation of salmon wastes (Buschmann *et al*. 1996), which have become a management problem today.

The salmon wastes could have a great potential for being used as protein supplement for broilers through an ensiling process. This technology is simple, feasible and more economical than the manufacture of fish meal (Gildberg 1993). The acid fish silage is defined as a liquid product produced from the whole fish, or parts of it, by the action of proteolytic enzymes present in the fish and an acid (e.g. hydrochloric, sulphuric, formic or citric acids), which accelerate the autolysis and help to break down bone, limiting bacterial spoilage (Tatterson 1982; Vidotti *et al*. 2003). To facilitate transport, storage and its inclusion in animal diets, this liquid fish silage has been co-dried with cereals or legumes (Arason 1994; Goddard & Al-Yahyai 2001).

The nutritional properties have been described in several co-dried fish silages based on: rainbow trout (*Salmo gairdneri*) (Hardy *et al*. 1984), salmon (Gao *et al*. 1992; Llanes *et al*. 2011), tilapia (Fagbenro & Jauncey 1994) and others (Goddard & Perret 2005).

Numerous studies have proven that co-dried fish silages can substitute traditional sources of proteins in livestock and aquaculture feeds, by having a high protein content and adequate amino acid profile (Vidotti *et al*. 2002; Goddard & Perret 2005; Brinker & Reiter 2011). Although fish silage has been evaluated for broilers (Machin *et al*. 1990; Vizcarra-Magaña *et al*. 1999), there are no reports on the nutritional evaluation of dried salmon silage for this specie. Therefore, the

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objective of this study was to evaluate the chemical composition, energy and amino acid profile of dried salmon silage (DSS) for broilers.

MATERIALS AND METHODS

DSS preparation

The DSS was provided by Fiordo Austral S.A., Puerto Montt, Chile. The DSS was prepared by thoroughly mixing the whole salmon waste from several species such as Atlantic salmon (*Salmo salar*), Coho salmon (*Oncorhynchus kisutch*) and rainbow trout (*Oncorhynchus mykiss*) with 85% formic acid (40 mL/Kg) (Oxiquim S. A, Santiago, Chile), and stored outside in stainless steel tanks at environment temperatures (range 5-15°C), during 1 to 2 weeks. The DSS was obtained by co-drying the liquid silage with wheat bran (70 parts silage and 30 parts wheat bran) at 100 to 120°C, afterwards ethoxyquin (200 ppm) was added.

DSS nutritional characterization

The chemical and nutritional properties of DSS were evaluated in duplicates from 20 representative samples. The chemical composition of the DSS was analyzed at the Faculty of Veterinary and Animal Sciences, University of Chile and at AgriServices Laboratory, University of Georgia according to the methodology proposed by the AOAC (1996) for: moisture, crude protein (N × 6.25), ether extract, crude fiber and ash.

The gross energy content was determined in a bomb calorimeter.

The TME_n was determined by the Sibbald method (1976), modified by Dale and Fuller (1984) using 10 conventional adult Single Comb White Leghorn roosters of 42 weeks of age, between 2400 and 2600 g. The birds were housed in an environmentally regulated room (22-24°C) and kept in individual cages. Feed and water were supplied for *ad libitum* access before the start of the experiments. Following a 30-h period without feed to clean the digestive tract of previous feed, the birds were given 30 g of DSS via crop intubation. Then there was a 42 h excreta collection period after feeding the test material. TME_n was calculated by the method of Parsons *et al.* (1982).

Mineral determinations were conducted at the AgriServices Laboratory, University of Georgia applying the AOAC (1996) standards, with an inducted coupled plasma analysis (Thermo-Fisher Scientific Corp., Pittsburgh, PA, USA).

Total amino acid composition of the DSS was determined by liquid chromatography, using a Beckman 6300 analyzer (Beckman Coulter, Inc., Fullerton, CA, USA) with an ion exchange column (Experiment Station Chemical Laboratories, University of Missouri, Colombia, MO, USA). All amino acid analyses were carried out in duplicate. Amino acid digestibility was determined according to Parsons *et al.* (1997) and Batal and Dale (2006) using the precision-fed cecectomized rooster assay. The same procedure was used for determining amino acid digestibility as for TME_n. Amino acid analyses were conducted by the Experiment Station Chemical Laboratories, University of Missouri.

An amino acid score was computed for the main limiting amino acids for broilers, using Aviagen standards (2007) and requirements listed by the National Research Council (NRC: 1994) by the following equation:

$$\text{Amino acid score} = \frac{\%\ AA\ \ test\ \ protein}{\%\ AA\ \ in\ \ reference\ \ pattern}$$

where: AA is amino acid.

Statistical analysis

Descriptive statistics were calculated for each of the parameters, using mean ± standard deviation (Microsoft Excel 2010 software, Microsoft Corp., Redmond, WA, USA).

RESULTS AND DISCUSSION

Chemical composition of DSS

The chemical composition of the DSS is given in Table 1. The moisture content of the DSS was lower than other fish silages co-dried with wheat bran at different ratios (51.6 to 63.8%) (Goddard & Perret 2005). This aspect is positive as it allows a safe storage extending its useful life. Microorganisms require unbound water to grow and levels greater than 12% can support bacterial, mold and yeast growth (Hardy & Barrows 2002).

As expected, crude protein content of DSS was high (51% dry matter), and similar to that reported by

Table 1 Chemical and mineral composition, and nitrogen-corrected true metabolizable energy (TME_n) of dried salmon silage (DSS)

DSS	Mean ± SD
Moisture (%)	12.3 ± 0.8
Crude protein (%)	44.0 ± 1.1
Ether extract (%)	5.0 ± 2.4
Crude fiber (%)	3.3 ± 0.4
Ash (%)	9.4 ± 0.6
Nitrogen-free extract (%)	26.0 ± 0.8
Gross energy (kcal/kg)	4 069 ± 13
TME_n (kcal/kg)	2 613 ± 24
Calcium (%)	1.01 ± 0.07
Phosphorus (%)	1.08 ± 0.04
Potassium (%)	0.98 ± 0.05
Magnesium (%)	0.22 ± 0.01
Sodium (%)	0.88 ± 0.03
Zinc (ppm)	121 ± 5
Copper (ppm)	8.4 ± 0.6
Iron (ppm)	949 ± 39
Manganese (ppm)	56 ± 2
Aluminum (ppm)	20.5 ± 0.7
Boron (ppm)	1.0 ± 0.1

Goddard and Perret (2005) of 53% for a mixture of sardine silage : wheat bran at 75:25 ratio.

The ether extract and ash fractions of the DSS were lower than other acid fish silages from tilapia (ash, 23.5%; ether extract, 35.4%) (Gerón *et al.* 2007) and mixed fish (ash, 16.9%; ether extract, 21.1%) (Llanes *et al.* 2011). This effect has also been reported by Fagbenro and Jauncey (1994) for co-dried blends of tilapia silage with soybean meal and carbohydrate substrates. On the other hand, the minor ash content of DSS could be explained since salmon contains lower bone ash values compared with other fish species (Toppe *et al.* 2007). The use of wheat bran in the drying process of the DSS also explains the higher crude fiber content in this product.

Energy estimations

The gross energy and TME_n value of DSS are showed in Table 1. The gross energy of DSS was lower than a similar product based on tilapia co-dried with soybean meal (4300 kcal/kg) (Fagbenro & Jauncey 1995), mainly due to lower protein contribution of the wheat bran. This is the result of the strong influence that the material used to facilitate the drying process has on the nutritional quality of the final product (Fagbenro & Jauncey 1994).

The TME_n value of DSS was higher than the main protein-based concentrates used in broiler feed, the soybean meal (2485 kcal/kg) (NRC 1994), cottonseed meal (2135 kcal/kg), canola meal (2070 kcal/kg), sunflower meal (2060 kcal/kg) and meat meal rendered with bone (2150 kcal/kg) (NRC 1994). However, the TME_n of DSS was lower than fish meal from different raw materials, where values fluctuate from 3000 to 3700 kcal/kg (Barlow & Windsor 1984). Unfortunately, it was not possible to compare the TME_n value of DSS with a similar product since no information was found in the current literature.

Mineral content

The primary interest was focused on phosphorus and calcium content in DSS, since fish meal has been indicated as an ingredient of high content and excellent availability of both minerals (NRC 1994). Fish silages may be similar due to the presence of spines and bones in the final product. However, the phosphorus content of DSS (Table 1) was lower than that reported for similar products (75:25 fish silage : wheat bran ratio) with 2.2% of phosphorus (Goddard & Perret 2005). The phosphorus and calcium content of DSS was also lower than that found in commercial fish meals (calcium = 3.73 to 5.11% and phosphorus = 2.43 to 2.88%) (NRC 1994). The lower phosphorus and calcium content in the DSS could be explained because salmon bones have the lowest content of both minerals, compared with other fish (Toppe *et al.* 2007), but were still higher than in other protein concentrates used for poultry (NRC 1994; Batal & Dale 2014). Therefore, their use in diets for broilers could decrease the high costs incurred in commercial phosphates supplements, taking into account that it is strictly necessary to supply an adequate balance of phosphorus and calcium in growing poultry in order to ensure adequate skeletal development and high body weight gains (Thorp 1994).

The content of all other minerals analyzed were found within the ranges reported in previous studies for fish meals (Batal & Dale 2014).

Amino acids profiles

Total and digestible amino acids profiles of DSS are presented in Table 2, and for comparison, soybean meal and fish meal were included, since both are considered good sources of amino acids. As expected, DSS had higher levels of methionine (25% more) than soybean meal, which is the first limiting amino acid in broiler feed; and similar content of lysine, which is the second limiting amino acid for broilers (Fernandez *et al.* 1994). However, other essential and non-essential amino acids of DSS were lower than those reported for soybean meal by NRC (1994) and Karr-Lilienthal *et al.* (2005). Compared to fish meal, DSS had considerably lower content of all amino acids (Table 2) (Al-Marzooqi *et al.* 2011; Batal & Dale 2014). The main difference in the amino acid content between both sources elaborated with similar raw materials could be due to the minor protein concentration of DSS compared to the average

Table 2 Total and digestible amino acids composition of dried salmon silage (DSS), compared with total amino acids of soybean meal (SM) and fish meal (FM)

Amino acids	Total (%) DSS	Digestible (%) DSS	Total (%) SM	Total (%) FM
Methionine	0.83 ± 0.01	0.74 ± 0.01	0.62†	1.80§
Lysine	2.67 ± 0.01	2.27 ± 0.04	2.69†	6.60§
Threonine	1.44 ± 0.01	1.16 ± 0.03	1.72†	2.60§
Tryptophan	0.33 ± 0.01	0.29 ± 0.01	0.74†	0.60§
Phenylalanine	1.37 ± 0.01	1.19 ± 0.06	2.16†	2.50§
Isoleucine	1.53 ± 0.00	1.31 ± 0.01	1.96†	3.50§
Leucine	2.60 ± 0.00	2.31 ± 0.04	3.39†	4.90§
Valine	2.07 ± 0.01	1.75 ± 0.03	2.07†	3.33§
Histidine	0.83 ± 0.01	0.66 ± 0.01	1.17†	1.30§
Arginine	2.26 ± 0.01	2.00 ± 0.01	3.14†	4.10§
Cysteine	0.29 ± 0.01	0.21 ± 0.02	0.66†	0.40§
Aspartic acid	3.23 ± 0.01	2.58 ± 0.03	6.09‡	5.54¶
Serine	1.34 ± 0.01	1.18 ± 0.04	2.29†	2.51¶
Glutamic acid	5.29 ± 0.01	4.70 ± 0.08	9.39‡	8.74¶
Proline	1.90 ± 0.01	1.48 ± 0.03	2.93‡	4.25¶
Alanine	2.34 ± 0.02	1.97 ± 0.01	2.27‡	4.72¶
Tyrosine	0.84 ± 0.00	0.72 ± 0.01	1.91†	1.84¶

Superscript numbers indicate the source for reference values. †Soybean meal solvent extracted (88.2% dry matter, 44% crude protein) (NRC 1994). ‡Soybean meal prepared from commercial US soybean processing plants (Karr-Lilienthal *et al.* 2005). §Fish meal, red fish (92% dry matter, 57% crude protein) (Batal & Dale 2014). ¶Fish meal (95% dry matter, 63.1% crude protein) (Al-Marzooqi *et al.* 2011).

value of fish meal near to 60% of crude protein (Barlow & Windsor 1984). Another factor influencing these results could be the chemical treatment of fish wastes required for production of acid silage, which alters the amino acid profile (Vidotti *et al*. 2003). Finally, it is important to emphasize the dilution effect on nutrients as a result of the blending with wheat bran.

The digestibility coefficients of amino acids in DSS for methionine, lysine and threonine were 89%, 85%, and 81%, respectively; and the majority of the others amino acids were above 85%. Similar results were also observed by Al-Marzooqi *et al*. (2011) in fish silage.

The composition of digestible essential amino acids of DSS is shown in Table 3. The requirements for broiler Ross 308 suggested by Aviagen (2007) was also included for comparison. Aviagen (2007) requirements were used since it has higher nutritional requirement values for broilers than those proposed by the NRC (1994). According to the requirements suggested by Aviagen (2007), for digestible amino acids, at different production stages of broiler Ross 308, the DSS covered all requirements. The DSS had high levels of methionine, lysine and threonine, which are the three main limiting amino acids in broilers, and similar sulfur-amino acids (methionine and cysteine) contents for the starter stage (0–10 days), but were higher than the requirements for growth (11–24 days) and finalization (>25 days) stages. The DSS also showed high levels of the other essential amino acids.

The nutritive value of protein of any ingredient depends mainly on the protein's capacity to fulfill the needs of the organism in relation to essential amino acids. A parameter called "amino acid score" has been used to evaluate the nutritive value of a protein (Vidotti *et al*. 2003). Table 4 compares DSS amino acid scores with the Aviagen standard (2007) for broilers Ross 308 and broiler requirements listed by the NRC (1994). Amino acid scores (>1) are considered above standards. Results showed that the essential amino acids are present in high concentrations in DSS and were above Aviagen (2007) and the NRC (1994) standards, especially in the case of lysine and valine. From these results it can be seen that DSS did not present limiting amino acids for broiler.

Table 3 Comparison of digestible essential amino acids of dried salmon silage (DSS), and Aviagen (2007) suggested requirements for broilers Ross 308 mixed (2.0–2.5 kg)

Amino acids	DSS (%)	Digestible amino acids suggested requirement		
		0-10 days	11-24 days	>25 days
Methionine (Met)	0.74	0.47	0.42	0.38
Lysine	2.27	1.27	1.10	0.97
Threonine	1.16	0.83	0.73	0.65
Met + Cysteine	0.94	0.94	0.84	0.76
Tryptophan	0.29	0.20	0.18	0.16
Isoleucine	1.31	0.85	0.75	0.67
Valine	1.75	0.95	0.84	0.75
Arginine	2.00	1.31	1.14	1.02

Table 4 Amino acid score of the main limiting amino acids according to Aviagen standards (2007) for broilers Ross 308 mixed (2.0–2.5 kg), and the requirements for broiler chicks according to the NRC (1994)

Amino acids	Aviagen (days)			NRC (weeks)		
	0-10	11-24	>25	0_3	3-6	6-8
Methionine (Met)	1.77	1.98	2.18	1.66	2.18	2.59
Lysine	2.10	2.43	2.75	2.43	2.67	3.14
Threonine	1.73	1.97	2.22	1.80	1.95	2.12
Met + Cysteine	1.18	1.32	1.46	1.23	1.54	1.85
Tryptophan	1.65	1.83	2.06	1.65	1.83	2.06
Isoleucine	1.80	2.04	2.28	1.91	2.10	2.47
Valine	2.18	2.46	2.76	2.30	2.52	2.96
Arginine	1.73	1.98	2.22	1.81	2.05	2.26

Conclusions

The DSS studied showed a high protein and TME_n content with a good amino acid profile, and can be used as a good source of protein for feeding broilers. The conversion of salmon wastes into a new feed ingredient for poultry can contribute to overcoming protein shortages in areas where soybean production is lacking, or could be used to partiality replace the soybean meal utilized in the broiler diets.

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