Nutritional Properties of Fish Meal Produced from Fresh By-Products of *Sardina pilchardus*

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ABSTRACT

In Morocco, fresh by-products of *Sardina pilchardus* from fish canneries are processed into fish meal. These by-products contain proteins, unsaturated fatty acids (omega-3), minerals and other beneficial elements for animal and human nutrition. The objective of our work was to characterize the nutritional properties of this fish meal produced using a low temperature treatment. The analysis of the nutritional composition of several batches produced during different seasons (throughout the year) showed that the composition was relatively constant. The average (mean±standard deviation) protein content (58.41±1.22 %), ash (21.03±2.15 %), fat (9.12±1.02 %), moisture (7.02±0.83 %) and salt (1.62 ±0.39 %) indicate the use of highly osseous and relatively oily raw materials. This fish meal contained a minor amount of histamine (concentration less than 500 $mg \cdot kg^{-1}$), which shows the use of a fresh raw material. The yields were, on average, 21.1±1.5 % for fish meal and 7.1±1.9 % for oil.

Keywords: By-product, Fish meal, Histamine, Protein, *Sardina pilchardus*

INTRODUCTION

During the various operations and stages of processing of fish products, especially filleting, evisceration and trimming, processing establishments generate a very large quantity of by-products. Indeed, according to several authors, half of the world's fish production is degraded as a by-product during processing operations (Mackie, 1982; Jeon *et al*., 1999; Kristinsson and Rasco, 2000). These fish by-products, when recovered, are mainly processed into fish meal, accounting for about 29 to 30 % of the world's production of fish by-products (Rebeca *et al*., 1991; Valdimarsson and James, 2001). It is notable that Morocco has high potential as a producer of fresh *Sardina pilchardus* by-products from processing plants, particularly canning factories. In fact, 1,189,229 tonne of pelagic fish (sardines, anchovies and mackerel) were landed in Morocco's ports in 2018 (ONP, 2019).

On the other hand, it is important to note that this fish meal is primarily intended for animal feed (for fish and crustaceans in aquaculture and for poultry farms). Familiarity with the nutritional composition of fish meal as a potential source of nutrients increases the benefits of using by-products (Ghaly *et al*., 2013). For this reason, and in order to track the concentrations of important elements of this fish meal during the different seasons of the year (winter, spring, summer and autumn), the yields of fish meal and fish oil were measured and the following constituents were analyzed: protein, lipids, ash, NaCl, moisture and histamine. Fish meal is preferred in diets because its protein content is high and is the preferred animal protein supplement (Tome and Bos, 2007). Its amino acid composition is balanced and generates rapid growth (Cho and Kim, 2011). Fish lipids are an important source of polyunsaturated essential fatty acids (omega-3) and their digestibility is greater than 90 % (Miles

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and Chapman, 2006). Calcium and phosphorus constitute the majority of the ash present in fish meal (Miles and Chapman, 2006). Moisture and histamine are feed safety parameters and the yield was used to judge the sanitary conformity of this product (Department of Maritime Fisheries, 2010). The NaCl excess influences the taste characteristics of fish meal.

Our objectives were to determine the average annual values of these parameters for a dried fish meal produced at low temperature and also to discover if these results are constant during the different seasons of the year. Our ongoing work is therefore focused on characterizing nutritional properties to better understand fish meal derived from fresh *Sardina pilchardus* by-products as a nutritional product.

MATERIALS AND METHODS

Fish meal

The fish meal used was prepared in an establishment approved by competent health authorities for the production of fish meal and fish oil from fresh by-products (heads, bones, spine, tails, and viscera) of the species *Sardina pilchardus* obtained from six fish canneries. All establishments (fish meal factory and fish canneries) are located in the city of Agadir in Morocco. By looking at the manufacturing charts at these canneries, it was found that the by-products are removed fresh in the topping-tailing-evisceration step, which is done manually using scissors or knives.

It should be noted that this fish meal is LT type (low temperature), dried at a maximum temperature of 70 °C to prevent the destruction of proteins by excessive heat.

Sample preparation

The by-products are processed into fish meal within 12 h after collection from the fish canning factory. Production steps and the relevant production parameters of the fish meal, which are the subjects of our study, are reported in Appendix 1.

During the production, a sample of 200 g of finished fish meal product was taken every 2 h. All the samples obtained during the day were homogenized before analysis to obtain a single result per production day for the following parameters: protein, lipids, ash, NaCl and moisture. For the histamine level, according to the subdivision system adopted by the production establishment, a single analysis was made on a homogenized sample taken from each 100 tonne of finished product.

Physico-chemical analysis

For the histamine assay, the spectro fluorimetric method of Lerk and Bell (Lerk and Bell, 1976) was used. This method consists of extracting histamine with trichloroacetic acid (TCA) and then fixing it on a column filled with an ion exchange resin and diluted with chloridic acid. The assay is carried out by fluorimetry after the addition of ophthaldehyde by measuring the intensity of the fluorescence of three solutions (sample, white, standard). Protein, ash and fat analyses were performed by a device called "NIREX," which works by the principle of Near Infrared Spectrometry (NIR). This technique involves emitting polychromatic infrared rays in the direction of the sample and then studying the absorption of these rays. Salt content was determined by chemical dosing (the chloride ions are precipitated by silver nitrate, after filtration, the excess of Ag^+ ions is determined volumetrically using potassium thiocyanate). The moisture content was determined by drying in an oven at 103 °C to constant weight. Yields of fish meal and fish oil per day of production are expressed as a percentage using the following ratios, respectively: (Weight of fish meal obtained)/(Weight of raw material used) and (Weight of fish oil obtained)/(Weight of raw material used).

RESULTS AND DISCUSSION

The total number of production days analyzed during the year (January to December) was 273. The number of 100 tonne lots of finished product was 83. As a result, 273 test results were obtained for levels of protein, lipid, fat, ash, NaCl, moisture and for yield (fish oil and fish meal),

and 83 results were obtained for histamine level. The average value of each parameter was calculated; means are shown in Table 1 and presented in Figures 1, 2 and 3.

Table 1. Chemical composition of low-temperature fish meal from sardine by-products (mean±standard deviation).

	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	NaCl (%)	Histamine (ppm)
Overall average	7.02±0.83	9.12±1.02	58.41±1.22	21.03±2.15	1.62±0.39	133±44.97

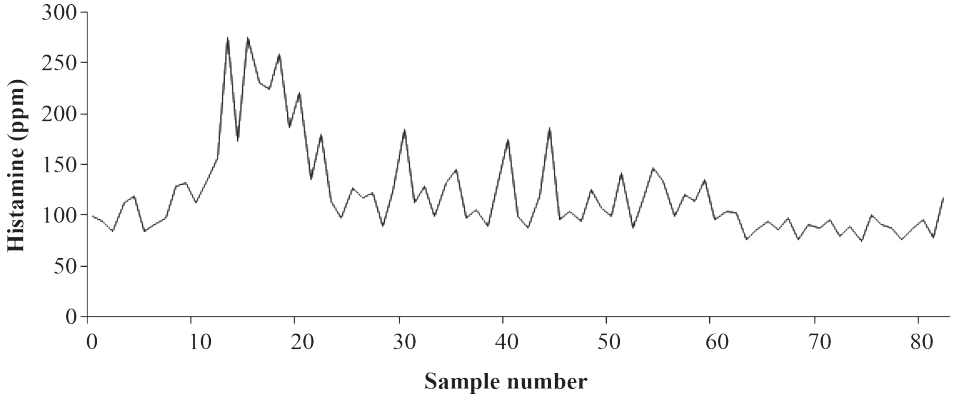

Figure 1. Histamine concentration for each sample during the test period.

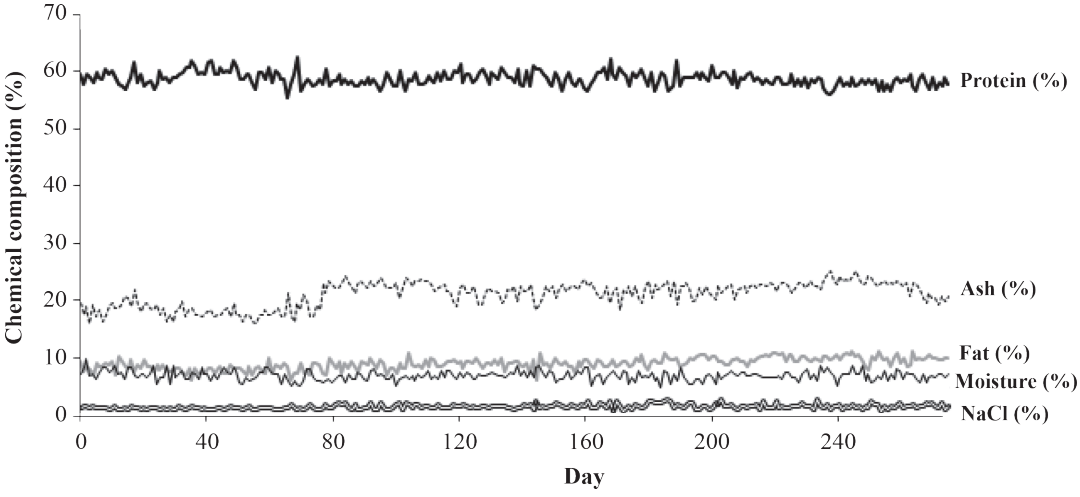

Figure 2. Variation of chemical composition of low-temperature fish meal from sardine by-products during trial period.

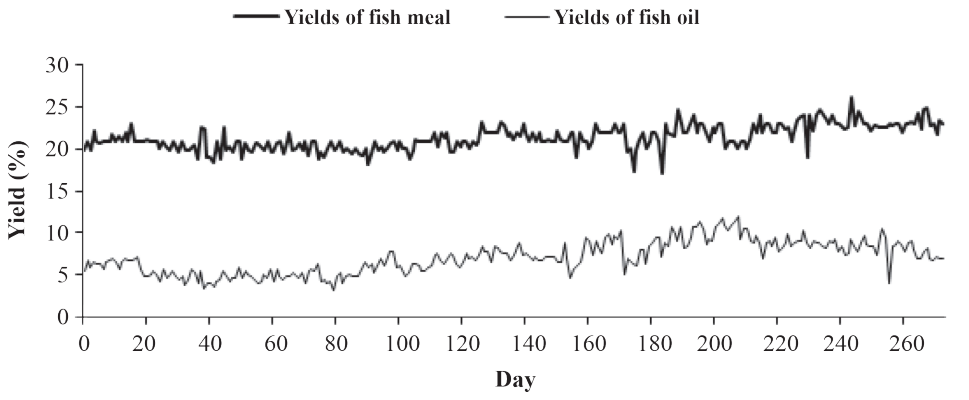

Figure 3. Yields of low temperature fish meal and fish oil from sardine by-products.

Protein

High-quality fish meal contains between 60 and 72 % protein (Cho and Kim, 2011), while the protein content of the fish meal in our study was 58.41 %. This lower value compared to the high-quality range can be explained by the fact that fish by-products (especially heads) are characterized by high levels of connective tissue (Falch *et al*., 2006). It should be noted, however, that the average protein level obtained remains substantial and is satisfactory for the needs of the feed ration.

Lipids

A significant component of the lipid content passes into the liquid phase during the pressing step and is used for the production of fish oil, thus the quantity that remains in the solid phase (press cakes) is relatively important. According to Miles and Chapman (2006), the fat content of fish meal varies from 4 to 20 %, depending on the species used as raw material during production. The average lipid content in our study of 9.12 % indicates that *Sardina pilchardus* by-products are relatively lean. According to Falch *et al*. (2006) the viscera, and especially the liver, which is rich in lipids (Falch *et al*., 2006) is the primary source of lipids observed in this fish meal.

Ash

Normally, the average ash content in good quality fish meal is between 17 % and 25 % (Miles and Chapman, 2006). In our study the average mineral content was 21.03 %; this high rate is the result of a high content of bone elements in the raw material (Toppe *et al*., 2007). From a nutritional point of view, this fish meal could be considered as a very important source of magnesium, calcium and phosphorus, elements which are the main minerals in the bone material derived from fish by-products (Toppe *et al*., 2007). This has been supported by studies that have shown good absorption of calcium from fish bones (Malde *et al*., 2010). Unlike phosphorus in plants, which is in the organic form (phytate), phosphorus in fish meal is in a form highly available for most animal species (Malde *et al*., 2010). The high mineral content shows that the fish meal tested in our study is an excellent source of minerals.

NaCl

The levels of sodium chloride obtained are acceptable and do not hinder the rate of ingestion of the compound food; in addition, it contributes to the good palatability of feed (Miles and Chapman, 2006). The ideal rate in some terrestrial animals ranges from 2 to 3.6 $g \cdot kg^{-1}$ dry matter (Phillips *et al*., 2000).

Moisture

Although it is a fish meal that has been dried at low temperature (LT), the moisture values obtained are far below the sanitary limits allowed by the good hygiene practices guide (Department of Maritime Fisheries, 2010).

Histamine

To have a fish meal of good sanitary and nutritional quality, the raw material used for its manufacture must be fresh. It was therefore very important to measure the level of histamine (biogenic amine), which reflects the quality and freshness of the raw materials as well as that of the finished product (Visciano *et al*., 2012). According to Prester (2011), the main factors affecting the production of histamine in fishery products are the manufacturing practices, the storage temperature of the raw material in the fresh stage, the bacteria that have decarboxylase production activity, and free histidine content. A quantity of 1,000 mg of histamine causes serious intoxication (Rauscher-Gabernig *et al*., 2009). The levels obtained during our study are very satisfactory and reflect the good organoleptic quality of the raw material used (Shalaby, 1996; Department of Maritime Fisheries, 2010). The notable variation in histamine levels can be explained by the variation in waiting times and storage temperature of the by-products before their transformation.

Yields of fish meal and fish oil

The variation in daily yields of fish meal and oil obtained during this work is shown in Figure 3. The average yields of fish meal and fish oil obtained were 21.1 % and 7.1 %, respectively. In our study, the raw material used for making fish meal and fish oil consisted of by-products from *Sardina pilchardus*. This type of raw material is known for being rich in connective tissue and bone (Toppe *et al*., 2007). Despite this, the yields were relatively high (Department of Maritime Fisheries, 2010).

From the results given above, it can easily be deduced that fish meal (dried at low temperature) derived from *Sardina pilchardus* by-products under the conditions of our study is relatively constant in terms of nutritional composition and yield.

Its protein content is substantial, and it contains a very large amount of minerals. The safety of this fish meal was confirmed by its low histamine content, which indicates a very low level of microbial degradation of proteins (especially enzymatic) in the fresh by-products that were used as raw material for its production.

In general, this fish meal is an excellent source of nutrients with interesting nutritional characteristics and can be used beyond the animal feed domain. In some countries, fish meal has been accepted for human consumption by their health authorities (e.g., Norway) (Ola *et al*., 2017). However, in Morocco, as well as in many other countries, it is mainly used as a product for animal consumption (animal feed). According to the FAO (2006), in 2050 the demographic growth of the population of developing countries (Morocco as an example) will generate a very strong demand for protein of animal origin. To this end, nutritional alternatives must be provided to meet the evolving needs that increase each year (Boland *et al*., 2013). Therefore, fish meal produced from fresh *Sardina pilchardus* by-products is highly recommended for future use in human nutrition, while ensuring good hygiene and manufacturing practices along the stages of collection, transportation and processing fresh by-product, to ensure the safety and nutritional quality of fish meal.

CONCLUSION

Analytical monitoring of the nutritional parameters of fish meal derived from fresh by-products of *Sardina pilchardus* throughout the year revealed that its composition is balanced and relatively stable. The average (mean±standard deviation) protein content (58.41±1.22 %), ash (21.03±2.15 %), fat (9.12±1.02 %), moisture (7.02±0.83 %) and salt (1.62±0.39 %) indicate the use of highly osseous and relatively oily raw materials. This fishmeal was made from a good quality raw material, finding which was approved

by the low histamine content which did not exceed 300 ppm. The yields were, on average, 21.1±1.5 % for fish meal and 7.1±1.9 % for oil. However, we recommended study of the antioxidant, bioactive and functional properties of this fish meal to further justify its usefulness as a food additive (Lordan *et al*., 2011; Šližytė *et al*., 2009).

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Appendix 1. Stages and parameters of production of fish meal and fish oil.