Physico-chemical quality of fish products marketed in Colombia

Calidad fisicoquímica de productos pesqueros comercializados en Colombia

Qualidade físico-química dos produtos pesqueiros comercializados na Colômbia

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Abstract

The nutritional characteristics of fish products have positioned them as one of the fastest growing food categories worldwide. Additionally, for developing innovative foods, it is crucial to understand the physico-chemical properties of commercial products and to be familiar with the food industry regulations that determine the criteria and specifications for new developments. For this purpose, frequency questionnaires were applied to fish products marketed in the retail sector. Additionally, processed products were selected for analytical determinations of moisture, NaCl content, and water activity. The results showed that 80% of the products are marketed in large supermarkets with 20% in local markets. It was also observed that 79% of the products are of national origin. The highest salt contents on a dry basis (~48%) were determined on smoked salmon and salted-smoked herring samples, while tilapia patties showed the lowest NaCl values on a dry basis ~6%. Within the Colombian market, products with a high degree of processing are imported and they contain higher salt contents. The national product offers low processing levels, being mainly frozen fillets. This opens the possibility for the development of innovative products using local raw materials.

Resumen

Las características nutricionales de los productos pesqueros, los ha posicionado entre las categorías de alimentos con mayor crecimiento en el mundo. Adicionalmente, para el desarrollo de alimentos innovadores, es importante conocer los parámetros fisicoquímicos de productos comerciales y la reglamentación de la industria alimentaria, lo que determina los criterios para nuevos desarrollos. Con este propósito, se aplicaron cuestionarios de frecuencia sobre productos de la pesca comercializados en diferentes establecimientos. Además, se seleccionaron productos transformados a los que se les realizaron determinaciones analíticas de: humedad, contenido de NaCl y actividad de agua. Los resultados mostraron que el 80% de los productos se comercializan en grandes superficies, el porcentaje restante en mercados locales. El 79% del pescado comercializado es de origen nacional. Los productos con mayores contenidos de sal en base seca (~48%) fueron el salmón ahumado y el arenque salado-ahumado, las hamburguesas de tilapia mostraron los menores valores de NaCl en base seca ~6%. En el mercado colombiano los productos con alto grado de procesamiento son los importados, los cuales presentan mayores contenidos de sal. El producto nacional ofrece bajos niveles de transformación, comercializándose principalmente filetes congelados. Esto abre la posibilidad al desarrollo de productos innovadores con materia prima local.

Palabras clave: actividad de agua, cloruros, humedad, innovación, transformación

Resumo

As características nutricionais dos produtos de peixe posicionaram-nos entre as categorias alimentares de crescimento mais rápido do mundo. Além disso, para o desenvolvimento de alimentos inovadores, é importante conhecer os parâmetros físico-químicos dos produtos comerciais e os regulamentos da indústria alimentar, que determinam os critérios para novos desenvolvimentos. Para este fim, foram aplicados questionários de frequência aos produtos da pesca comercializados em diferentes estabelecimentos. Além disso, foram seleccionados produtos processados para determinações analíticas de: humidade, teor de NaCl e actividade da água. Os resultados mostraram que 80% dos produtos são comercializados em grandes supermercados, sendo a percentagem restante nos mercados locais. Setenta e nove por cento do peixe comercializado é de origem nacional. Os produtos com o maior teor de sal em base seca (~48%) eram salmão fumado e arenque fumado com sal, os patés de tilápia apresentaram os valores mais baixos de NaCl em base seca ~6%. No mercado colombiano, os produtos com um elevado grau de transformação são produtos importados, que têm um maior teor de sal. O produto nacional oferece baixos níveis de transformação, sendo principalmente comercializado como filetes congelados. Isto abre a possibilidade para o desenvolvimento de produtos inovadores com matéria-prima local.

Palavras-chave: actividade da água, cloretos, humidade, inovação, transformação

Introduction

Fish by-products are considered food products of great importance due to they contain proteins, lipids, minerals, essential fatty acids, and vitamins that improve health and life expectancy (Kwasek *et al.*, 2020). It is estimated that fish and fish products comprise approximately 55% of total per capita animal protein intake; therefore, they are considered the most important source of animal protein in the diet of many countries (FAO, 2020). The processing of raw material to obtain high-quality products with good nutritional value is significantly influenced by the type of processing, the parameters chosen, and their preparation (Karásková *et al.*, 2011). In fish processing, some of the most widely applied methods for preserving its quality are smoking (Ruiz-Alonso *et al.*, 2021), salting (Wawire *et al.*, 2019), and canning (Bell *et al.*, 2019).

Smoking is a traditional preservation method used for both fish and meat products worldwide (Ledesma *et al.*, 2016). Currently, salted-smoked fish products are widely accepted due to their flavor, aroma, and increase in their shelf life, all due to the combined effects of dehydrating, the antimicrobial, and antioxidant activity resulting from the process (Karásková *et al.*, 2011). There is a wide variety of smoked fish that diversifies the market, not only in its proximal composition but also in other parameters related to conservation and sensory characteristics (Fuentes *et al.*, 2010b). In fish processing the smoking and/or salting methods have been applied in commercial fish species such as tilapia *Oreochromis niloticus* (Ayeloja *et al.*, 2020), salmon *Salmo salar* (Muñoz *et al.*, 2020), and Pangasius *Pangasius hypophthalmus* (Sokamte *et al.*, 2020).

Canning is another popular method for processing and preserving fish (Bell *et al.*, 2019) while maintaining its nutritional value and quality (Usydus *et al.*, 2008). Canned fish are processed in canned or glass containers that are heated to a specific temperature for a specified time and subsequently, hermetically sealed (Elshehawy & Farag, 2019). During the last decades, an increasing part of the diet is composed of fast food and ready-made convenience foods. In this sense, innovations in the fish industry are becoming increasingly popular because consumers demand healthy products that are easy to prepare (Farias *et al.*, 2021) and whose production generates the least possible environmental impact on the same natural resources (Halpern *et al.*, 2019).

Currently, an important percentage of fish is processed by different methods and subsequently packaged, which increases the options of fish-based products available to the consumer (Kilincceker *et al.*, 2009).

These processes tend to modify the physical and chemical properties of the raw material, such as pH, water activity (a_w), color, texture, among others., so, the physicochemical control of these parameters in the finished product is of great importance to ensure the quality of the food industry (Fuentes *et al.*, 2010a).

Chloride content is one of the physicochemical parameters of importance in smoked and/or salted products, due to it has a strong influence on the flavor, a_w, and shelf life (Karásková *et al.*, 2011). Another important parameter is the water retention capacity, which is closely related to the sensory characteristics of the product, and to changes in the muscle proteins of the raw material, which in a certain way determine the juiciness of the meat (Chan *et al.*, 2020), as well as color and flavor (Fuentes *et al.*, 2010b).

For consumers, another relevant criterion for the purchase of a product, apart from its shelf life, is the final appearance. In the food industry, the packaging of products derived from fishing is important, especially in the case of smoked products, where materials that facilitate the appreciation of the product by the consumer should be used (Olsen *et al.*, 2017).

Analytical determinations carried out on fishery products are useful to know their chemical composition and the main quality parameters, as well as to establish common characteristics in these types of products. This information is valuable for producers and researchers in the generation of new products. Additionally, there is a pressing need on the part of consumers to acquire healthier and easily prepared foods, due to the diverse daily activities that modern society develops, mainly in large cities (Berizia _et al._, 2018). This is how fish is considered an excellent source of protein and an important income-generating business, mainly in developing countries, which join the global trend of reducing extractive fishing and making greater investments in aquaculture, which has become a promising and growing activity (Guidini-Lopes _et al._, 2016). Therefore, the present work aimed to evaluate the physicochemical quality of products derived from fishing acquired from several establishments in the Colombian territory, knowing the consumption pattern of processed fish products by determining moisture content (wb, db), NaCl content (wb, db) and w_a, in order to establish parameters in the development of future products.

Materials and methods

Survey design and application
A survey of frequencies was carried out to obtain information between 2018 and 2020, on the different fish-based products found in the national market. The survey was structured in six (6) sections: A) store characteristics, B) type of processing, C) packaging, D) storage conditions, E) origin and F) sodium chloride (NaCl) content.

Analytical determinations
Based on the results of the survey application, nine products with sodium chloride and/or smoke in their composition were selected, and their moisture content was determined on a wet basis (bh) and on a dry basis (bs), as well as their content of NaCl and a_w. For all the analytical determinations, at least four repetitions per sample were carried out, in the Laboratorio de Bromatología de la Universidad Surcolombiana. The nine samples of fish products were identified as smoked salmon (SS), salted-smoked Arenque (SSA), smoked tuna loins (STL), tilapia loins (TL), tilapia sausage (TS), tilapia patty (TP), crab legs (CL), canned pink salmon (CPS) and whole salted fish (WSF).

Moisture content
Moisture determination was performed following the procedures described by AOAC (1990). Three (~3) grams of sea sand were deposited on metal weighing scales and a glass rod and dried in a UF30 plus oven (Memmert GmbH + Co. KG, Germany) at 105 °C for 24 h. Subsequently, they were tempered in a desiccator and weighed on an analytical balance, and ~3 grams of previously crushed samples were added. With the glass rod, the sample was homogenized with the sea sand to favor the exit of water from the product. The samples were taken to 105 °C for another 24 hours, after which period, the weighing scales were tempered in the desiccator, to then record their mass. The moisture percentage was expressed in g of water per 100 g^{-1} of the sample, calculated using the following equations:

$$\% \, Moisture_{wb} = \frac{(m_1 - m_2)}{(m_0)} \times 100$$

$$\% \, Moisture_{db} = \frac{(m_1 - m_2)}{(m_2)} \times 100$$

Where:

m_1: initial mass of the sample, rod and weighing scale in grams.
m_2: initial mass of the sample, rod, and weighing scale in grams.
p_o: mass of the sample in grams.

Content of NaCl
The salt content was calculated using the methodology proposed by Ruiz-Alonso _et al._ (2021) with some modifications. Samples of one (1) of each of the selected products were taken, to homogenize each sample in 100 mL of distilled water employing an Ultra-turrax T-25 (IKA Works Inc., Germany). The supernatant obtained was vacuum filtered and an aliquot of 100 µL was taken to be evaluated in a Sherwood mod 926S chloride analyzer (Sherwood Scientific Ltd., UK). The determination of chlorides on a wet basis ($NaCl_{wb}$) and on a dry basis ($NaCl_{db}$) were determined by using the following equations:

$$NaCl_{wb} = XNaCl \; x \; 0.01 \; x \; \frac{0{,}1}{sample \; mass} \; x \; 100$$

$$NaCl_{db} = \frac{XNaCl}{1 - X_w}$$

Where:
$XNaCL$ = chloride content
X_w = moisture content

Water activity (a_w)
Water activity measurements were performed using an AquaLab® CX-2 dew point hygrometer (Decagon Devices Inc., USA).

Statistical analysis
Descriptive analyses of the information were carried out with the data acquired from the frequency surveys. In the second part of the study, to evaluate the differences in the physicochemical parameters between the selected products, an analysis of variance (Simple ANOVA) was used, with separation of means by Tukey's test, with a confidence level of 95%. For all cases, compliance with the assumptions of homogeneity of variance and normality was verified. The analyses were carried out using Statgraphics 5.0 (Manugistics, Inc., USA).

Results and discussion

Characterization of the fish products market
Information was collected from 168 products including fish, seafood, and/or their processed products, present in the Colombian market (figure 1).
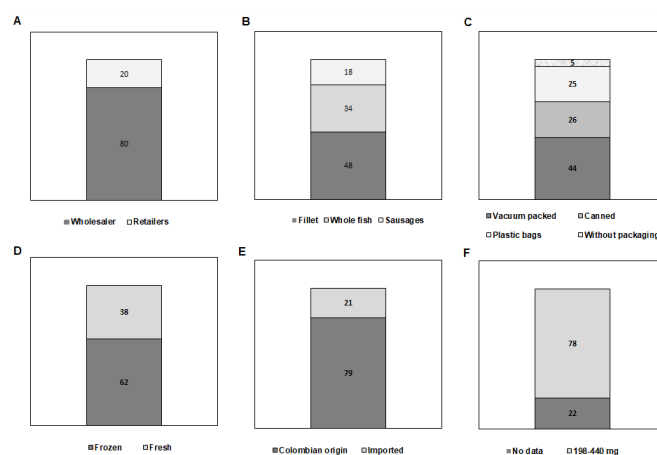

Figure 1. Characterization of the market for fish products: fish, seafood, and/or their processed products.

In the analyzed products, it was observed that the majority are marketed in large supply chains (supermarkets and/or wholesale stores), while the remaining percentage of products are sold in marketplaces or retail stores (figure 1A).

Regarding the type of processing (figure 1B), it was found that fish fillet (fresh or frozen) is the preferred format for sale; whole fish and sausage products are also marketed, which are made with the part of the fish that remains after filleting. Regarding packaging (figure 1C), the products are sold vacuum-packed, canned, in ordinary bags, or without any type of packaging. Regarding storage conditions (figure 1D), the products are sold frozen or fresh. Additionally, in relation to the origin of the raw material (figure 1E), most of the products found are national, i.e. grown, processed, and packaged in the country; imported products present a higher degree of processing with more elaborate packaging. Regarding NaCl content (figure 1F), it was found that many of the products analyzed had information related to sodium chloride content printed on their packaging. Vacuum-packed products reported NaCl concentrations between 198-440 mg, with frozen shrimp reporting the lowest values and canned products the highest values. In Colombia, the technical regulation, resolution 810 of 2021 of the "Ministerio de Salud y Protección Social" on nutritional labeling requirements to be met by packaged or packaged foods for human consumption was recently established, which includes among others the sodium chloride content. However, since 2018, information on the chemical composition of food is consigned following the parameters given by resolution 1407 of the "Ministerio de Ambiente y Desarrollo Sostenible", which regulated the use of paper, cardboard, plastic, glass, and metal packaging, and which has a direct impact on the industrial sector. In many countries, food products available in supermarkets are tracked through an online database including nutritional information (Kretser *et al.*, 2017) allowing easier control of sodium chloride levels (Cardoso *et al.*, 2019). In Colombia, INVIMA is the national regulatory agency for surveillance and control that works for the protection of individual and collective health, through the application of health standards associated with the consumption and use of food, medicines, medical devices, and other products subject to health surveillance.

Analytical determinations of evaluated products

Figure 2 shows the moisture contents on a wet and dry basis for the analyzed products.
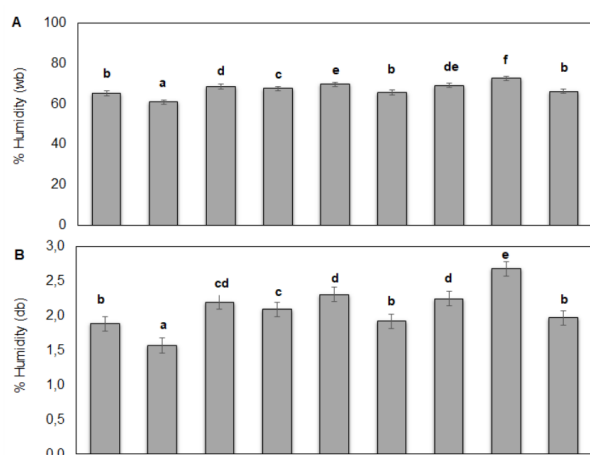
Figure 2. Moisture content of fish products: fish, seafood, and/ or their processed products. Similar letters indicate homogeneous groups.

Statically significant differences were found for moisture content in both cases ($p < 0.05$). Water was the component found in the highest proportion in all the analyzed samples varying from 72.76 ± 0.65 in CPS and from 61.06 ± 0.16 in TP (figure 2A). When studying the moisture content on a dry basis (figure 2B), the same behavior was observed, finding the highest results in SER (2.67 ± 0.08) and the lowest value in TP (1.56 ± 0.01).

Table 1 shows the results obtained for chloride mass fractions and water activity.

Table 1. Physicochemical analysis of fish-based products marketed in Colombian territory. w_a: Water activity; $NaCl_{wb}$: Sodium chloride on a wet basis; $NaCl_{db}$: Sodium chloride on a dry basis.

Product	w_a	$NaCl_{wb}$ (%)	$NaCl_{db}$ (%)
SSA***	0.982 ± 0.003^{bc}	16.68 ± 0.52^a	48.17 ± 2.14^a
TP***	0.982 ± 0.001^{bc}	6.23 ± 0.29^d	16.02 ± 0.79^d
STL***	0.982 ± 0.002^{bc}	9.72 ± 0.24^c	31.07 ± 0.81^c
TL***	0.993 ± 0.000^a	10.26 ± 0.42^c	31.71 ± 1.27^c
WSF***	0.985 ± 0.001^b	12.61 ± 0.20^b	41.70 ± 0.86^b
CL***	0.976 ± 0.001^{cd}	15.08 ± 0.17^b	44.04 ± 0.55^{ab}
SS***	0.975 ± 0.004^d	15.01 ± 0.45^b	48.70 ± 1.34^a
CPS***	0.989 ± 0.001^{ab}	7.60 ± 0.18^d	27.99 ± 1.26^c
TS***	0.986 ± 0.001^b	10.46 ± 1.13^c	31.03 ± 3.31^c

SS: Smoked salmon; SSA: Salted-smoked Arenque; STL: Smoked tuna loins; TL: tilapia loin; TS: tilapia sausage; TP: tilapia patty; CL:crab legs; CPS: Canned pink salmon; WSF: Whole salted fish. Similar letters in the same column indicate homogeneous group membership. Significance level (α): ***p < 0.001

Significant differences (p < 0.001) were found for the three variables in the different products selected. Canning is one of the most important means of fish preservation in which two thermal steps are included (cooking and sterilization); both fish enzymes and bacteria must be permanently inactivated by heat (Rodriguez *et al.*, 2009). The relationship between NaCl content, water activity, and shelf life in products that have been industrially processed has an effect on factors such as packaging, production method, and product quality (Karásková *et al.*, 2011). The preservative role of sodium chloride in food is attributed to a reduction in water activity (w_a), which decreases enzymatic activity and water available as a nutrient for microorganisms (Amorim-Gomes *et al.*, 2021). Regarding the water activity parameter, values ranging from ~0.993 for TL to ~0.975 for SS samples were determined. The spoilage of refrigerated and minimally processed fresh fish is mainly attributed to bacterial activity. The reduction of water activity to a value below 0.95 has a pronounced effect on the growth rate of bacteria (Tsironi & Taoukis, 2014), as well as there is also a prevalence of lactobacilli to grow rapidly in anaerobic conditions and at low temperatures so it is common for them to develop in vacuum-packed foods (González-Rodríguez *et al.*, 2002)

The values obtained for the mass fraction of sodium chloride on a wet basis ($xNaCL_{wb}$) was 16.68% ± 0.52 for SSA, whose preparation requires a brine bath, which is why it could present the highest levels of chlorides; similar results were found in fish products by Koral *et al.* (2010). The results with the lowest values

of about 6.23% ± 0.29 were presented in the TP samples. Sodium chloride is the main factor that prevents bacterial growth and provides product safety; although salt content retards bacterial spoilage, studies have shown that there are a number of bacteria that can grow in high salt concentrations such as Lactobacillus (Liu *et al.*, 2021).

The sodium chloride content has a strong influence on the flavor of the product, as well as on the decrease in the water activity and, consequently, on the shelf life. In this regard, it has been shown that the shelf life of processed smoked fish can vary between two to three weeks depending on the concentration of sodium chloride in the aqueous phase (4.6 or 2.2%, w/w) (Hansen *et al.*, 1995). For this reason, controlling the sodium chloride content during fish processing is one of the priorities for the fishing industry. Currently, the demand for salted fish is driven more by the aroma and flavor of the product than by its preservation (Mujaffar & Sankat, 2006). As an alternative, studies have been conducted substituting sodium chloride with potassium chloride (KCl) (Rodriguez *et al.*, 2006) mainly because it has been shown to have fewer negative effects on human health (Kimura *et al.*, 2004). However, in Colombia, the use of KCl as a substitute for NaCl in any type of food has not yet been regulated. Sodium and chloride ions are necessary for the human body because they play important roles in the circulatory and digestive systems. Sodium ions are necessary to maintain blood pressure and volume and chloride ions maintain the acid-base balance necessary for the formation of hydrochloric acid in the stomach for the digestive process (Galvis-Sánchez *et al.*, 2011).

The form of processing has been shown to have a crucial impact on the quality and nutritional value of the final product. However, if preservation and processing techniques are combined and applied in an innovative way, high-quality products with adequate nutritional value can be obtained (Dama *et al.*, 2021). Given that aquaculture is the fastest-growing agro-industrial sector worldwide and that consumers are increasingly interested in obtaining high quality, nutritious, healthy, and easy-to-prepare products, the transformation of raw material by salting-smoking methods can result in innovative products that meet consumer expectations and in turn favor the growth of the aquaculture industry. From the results observed, the samples analyzed presented NaCl values above 3.5%, the minimum content recommended by the Codex Alimentarius (Betancourt-Sambony *et al.*, 2020) to provide safety in refrigerated foods derived from fish; however, the products studied presented levels higher than 5% NaCl, which can affect consumer health.

Conclusion

The Colombian market for fish by-products is mostly of national origin; imported products, although they present a more complex degree of processing, they include contents of NaCl above the recommendations of international organizations. Therefore, it is necessary to encourage the national industry, by applying salting and/ or smoking procedures to local raw materials, and controlling the salt content in order to offer innovative developments that comply with the parameters recommended by Codex Alimentarius.

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