Scientific Papers. Series D. Animal Science. Vol. LXVII, No. 1, 2024
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

THE USE OF SALMON AND TUNA BY-PRODUCTS IN FISH CRACKERS MANUFACTURE

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Abstract

Fish by-products have a great potential for use, both for the food industry and for other industries. Salmon and tuna are valuable species for the food industry, especially those sold as fillets or steaks, but the by-products have a low economic value or are turned into waste. The aim of this study is to obtain new foods by salmon and tuna by-products in order to integrate them into human consumption. Five types of biscuits were created with salmon and tuna byproducts added as salmon oil and fish meat. The products were made in the Bakery Pilot Station of the University of Agronomic Sciences and Veterinary Medicine of Bucharest. After creating the recipes and obtaining the products, the degree of consumer acceptance was established by performing tastings and completing evaluation tests. The evaluation criteria were: taste, aroma, color, general appearance and consistency (five-point hedonic scale). The results showed that the biscuits with salmon meat and dehydrated onion were the most appreciated by consumers.

Key words*: acceptance, consumers, fish, new food products, sensory evaluation.*

INTRODUCTION

The processing of fish by-products is a current topic within the food industry. The conversion of by-products into alternative products or their utilization in various industrial applications has the potential to resolve issues and could emerge as a sustainable solution for the industry (Toma (Enache) et al., 2023).

Fish has been and continues to be widely used as food. As consumption is increasing while fish stocks are decreasing, there is a need to enhance processing efficiency. Fish production may involve several technological processes, depending on the type of products being produced (Idzere et al., 2020).

Beyond the technical and technological advancements in transforming fish by-products into useful products, consideration must be given to social, environmental, political, and economic parameters to understand why and how fish by-product conversion technologies are applicable. This is especially important in the current context where the fisheries sector faces various challenges, such as declining wild fish stocks in favor of aquaculture, increased imports in a global market, and shifting consumer behaviors. These parameters affect and complicate the definition of a strategy for creating and developing fish by-products, as they are directly dependent on the processed raw material (Penven et al., 2013).

In the fishing and aquaculture sector, 35% of the global harvest is lost or wasted each year. Therefore, the utilization of marine by-products must be mandatory to ensure global food security and to meet the increasing demand for fish products (Kaanane & Mkadem, 2020).

Fish is a protein-rich food that readily deteriorates after capture due to bacterial activity, enzymatic action, and chemical oxidation of fats (More & Likhar, 2020; Nicolae & Bololoi, 2023).

Fish processing involves fishing, collection, and transportation, stunning, bleeding, chilling, cutting, packaging, and also the recycling of by-products. The cutting technological stage involves a set of operations aimed at dividing the whole fish into smaller pieces (fish fillets, steaks, loins etc.) (Nicolae, 2020). Various techniques and machinery have been introduced to advance and automate cutting operations to increase processing efficiency and reduce fish by-product quantities (Wenbo et al., 2022).

The need for nutritious, safe, and healthy food because of a growing population, coupled with

the pledge to preserve biodiversity and other resources, poses a significant challenge for food industry.

Fish and fish by-products are a natural source of polyunsaturated omega-3 fatty acids, which are highly important in the food and pharmaceutical industries. Conventional fish oil extraction processes include cold pressing, wet reduction, or enzymatic extraction, but the method of supercritical fluid extraction with carbon dioxide under moderate conditions can also be used. Utilizing fish by-products by recovering the oil is particularly interesting when the oil is rich in triglycerides and has a high content of polyunsaturated omega-3 fatty acids (Rubino-Rodrighez et al., 2012).

As food product diversification progresses, various types of foods have been created, including fish biscuits. One variety of this product is represented by biscuits produced with sturgeon *Acipenser sturio* (Linnaeus, 1758) fillet protein concentrate. In this case, the sturgeon fillet protein concentrate was used in biscuit production by replacing low-gluten wheat flour with 5%, 7%, and 10% to ensure biscuit quality and acceptability (Abraha el al., 2018). Another variant of fish biscuits is represented by salt biscuits supplemented with 5% fish protein concentrate, made from Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) by-products. In this case, the fish protein concentrate made from tilapia by-products was used to increase water retention capacity (Ibrahim, 2009). Another variation involved the use of four different recipes containing Nilem carp *Osteochilus vittatus* (Valenciennes, 1842) egg protein concentrate to produce biscuits with better sensory characteristics and higher protein content. (Muslihudin et al., 2021).

Diversifying food sources is essential for ensuring consistent access and sustainability in food supply. Managing and controlling the technological processes in fish processing, inventory, and product quality through traceability leads to increased consumer confidence in food safety, enhanced operational efficiency for all partners in the supply chain, and facilitates potential profit growth for companies in the food industry (Nicolae et al., 2017). Enhancing food production and availability are vital steps toward achieving significant nutritional and economic advancements. It is important to produce a wider variety of foods rich in essential micronutrients, ensuring they're available in ample quantities and accessible to people.

MATERIALS AND METHODS

This scientific study represents a starting point for the creation and development of new technological schemes for producing fish crackers. The proposed and realized crackers were of 5 types: P1 - Crackers with salmon oil, P2 - Crackers with salmon oil and salmon meat, P3 - Crackers with salmon oil and tuna meat, P4 - Crackers with salmon oil, salmon meat, and dehydrated onion, P5 - Crackers with salmon oil, tuna meat, and dehydrated onion (Figure 1).

Figure 1. Types of fish crackers: P1 - Crackers with salmon oil P2 - Crackers with salmon oil and salmon meat P3 - Crackers with salmon oil and tuna meat P4 - Crackers with salmon oil, salmon meat, and dehydrated onion P5 - Crackers with salmon oil, tuna meat, and dehydrated onion (own source)

The ingredients used included flour, water, sugar, salt, granulated garlic, dry yeast, and ground white pepper. As innovative ingredients used in the biscuit recipes, fish by-products were employed, namely oil of salmon *Salmo salar* (Linnaeus, 1758) (obtained from fish bellies resulting from salmon filleting) and salmon meat (a by-product from salmon filleting), or tuna *Thunnus thynnus* (Linnaeus, 1758) (a by-product from portioning tuna into steaks). These by-products used in making the biscuits have low economic value if marketed as such. Their utilization in these innovative food products aims to increase economic value and obtain products with novel nutritional and sensory characteristics.

1. Obtaining raw materials from fish by-products

For the production of fish crackers, it was necessary to obtain innovative raw materials: salmon oil, grilled salmon meat, grilled tuna meat.

Salmon oil was obtained through the method of fish oil extraction by wet pressing. This involved qualitatively and quantitatively receiving the salmon by-products, followed by mechanical cleaning and washing. The hygienized by-products underwent mechanical extraction, where the flesh and subcutaneous fat of the salmon were separated from the skin, fins, and other elements that could hinder or impede the fat extraction process. To increase the contact surface of the product with hot air, a grinding step of the fish by-products was necessary. The obtained minced mixture was then heat-treated at a temperature of 95°C, maintaining it for 35 minutes from the moment this temperature was reached at the core of the product (Glowacz et al., 2016). Once the heat treatment was completed, a partial cooling of the obtained product was carried out until it reached 45°C. After reaching the recommended temperature, the product was pressed at a pressure of 25,000 kPa until optimal extraction of the fluid from the product in process was achieved. The resulting fluid was then allowed to settle for one hour, after which the fatty part was centrifuged (FAO, 1986). The obtained oil was cooled to refrigeration temperature, packaged, and stored until use (Figure 2).

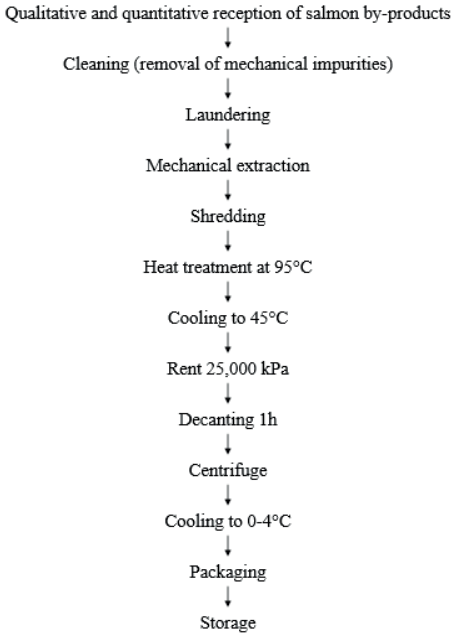

Figure 2. Technological scheme for obtaining salmon oil

The grilled salmon meat was obtained from processing salmon by-products with low-fat content. The meat was extracted mechanically from the salmon skeletons resulting from filleting. First, a qualitative and quantitative reception of the fish by-products was performed, followed by cleaning the by-products by removing any contaminating mechanical impurities and washing the entire mass of the product to chemically remove possible microbiological contaminants. The hygienized by-products were then subjected to mechanical extraction of the meat from the skeletons. The obtained meat was minced to increase its contact surface with the hot air in the oven and was heat-treated at 180°C until it reached proper dehydration, approximately 40% humidity. The product was then cooled to refrigeration temperature, packaged, and stored until use (Figure 3).

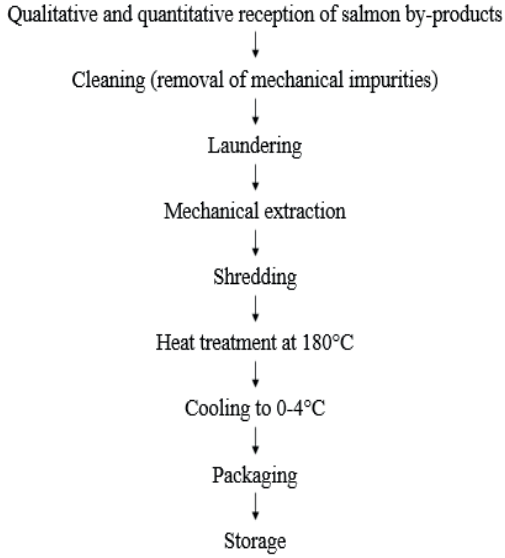

Figure 3. Technological scheme for obtaining grilled salmon meat

The grilled tuna meat was obtained by processing tuna by-products resulting from processing tuna into steaks. The processing procedure was similar to that of salmon, with the exception of the fat content concentration of the meat (Figure 4).

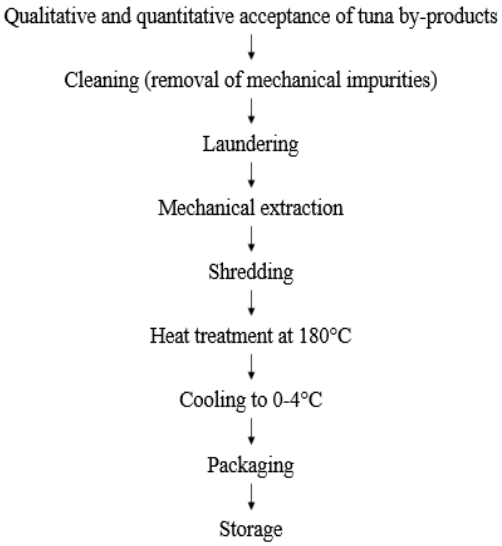

Figure 4. Technological scheme for obtaining grilled tuna meat

2. Consumer acceptance

The sensory evaluation of the fish crackers (with salmon oil and salmon or tuna meat) aimed to determine the sensory impact of including salmon and tuna by-products in the crackers.

The sensory properties of the crackers: external appearance, cross-section appearance, shape, color, taste, aroma, texture, recipe originality, were evaluated using a 5-point hedonic scale. The freshly made products were assessed by 101 participants of different ages, genders, and random social classes. In addition to rating the sensory properties, participants also expressed their decision to purchase or not the products under analysis.

The evaluation sheets were designed in accordance with the acceptability needs of these products in the market.

3. Determining nutritional value

To assess the nutritional and energy contribution of the crackers, as well as their integrity, it was necessary to establish the basic chemical composition, including the content of water, proteins, lipids, and minerals.

The nutritional content was determined utilizing the Softfedima program, a nutritional development tool available at http://softfedima.ro/. This tool facilitates the creation of nutrition facts panels, data sheets, and ingredient statements for various food products. Its formulas can be customized to account for moisture and/or fat content, and the resulting information can be easily printed or saved as a PDF document.

RESULTS AND DISCUSSIONS

1. Developing recipes and products

To streamline the utilization of salmon and tuna by-products, five fish biscuit recipes were created and studied: P1 - Crackers with salmon oil, P2 - Crackers with salmon oil and salmon meat, P3 - Crackers with salmon oil and tuna meat, P4 - Crackers with salmon oil, salmon meat, and dehydrated onion, P5 - Crackers with salmon oil, tuna meat, and dehydrated onion.

Innovation was based on the following considerations:

- Using by-products that could otherwise be lost or turned into waste.
- Using low-value by-products to increase their economic value.
- Innovating and diversifying fish-based products.

The ingredients used in the recipes were purchased from retail or wholesale food stores. After purchase, the fish by-products were processed to obtain the ingredients subsequently used in the biscuit composition.

Crackers are food products with low water content, where wheat flour is the main raw material. They must be crispy, tender, and tasty to be accepted by consumers. The addition of salmon oil, salmon meat, tuna meat, and atypical spices (dehydrated onion - in certain recipes) represents the innovative part of these new recipes.

The ingredient proportion for the salmon oil crackers (P1) was: 57.42% flour, 28.71% water, 8.83% salmon oil, 1.77% sugar, 1.24% salt, 0.88% granulated garlic, 0.62% dry yeast, 0.53% ground white pepper.

To obtain the P1 crackers, flour was placed in a bowl, a well was made in the center, and dry yeast, oil, lukewarm water, and sugar were added. The mixture was kneaded until it started to bind slightly, then salt, granulated garlic, and white pepper were added, and kneading continued until a homogeneous dough was obtained. The dough was covered and left to rise for approximately 1 hour. After rising, the

dough was kneaded, rolled out, perforated, and portioned. The formed biscuits were then placed in a preheated oven at 180°C and baked for 10-12 minutes (until fully cooked). After baking, the biscuits were allowed to cool to room temperature, then packaged and stored until consumed (Figure 5).

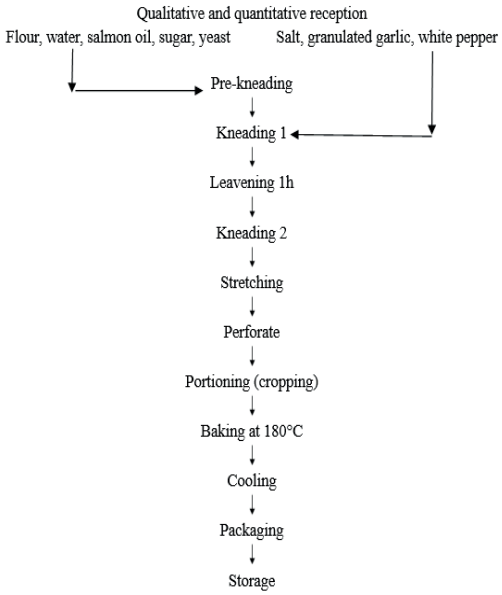

Figure 5. Technological scheme for obtaining crackers with salmon oil - P1

For the salmon oil and grilled salmon meat crackers (P2), the proportion of ingredients was as follows: 47.85% flour, 23.93% water, 16.67% grilled salmon meat, 7.36% salmon oil, 1.47% sugar, 1.03% salt, 0.73% granulated garlic, 0.52% dry yeast, 0.44% ground white pepper.

The technology for obtaining the P2 crackers was similar to that of the salmon oil crackers until after rising. During the second kneading, the grilled salmon meat was added. The dough was then rolled out, perforated, and portioned, and subsequently baked at 180°C for 10-12 minutes. After baking, the biscuits were cooled to room temperature, packaged, and stored (Figure 6).

For the salmon oil and grilled tuna meat crackers (P3), the proportion of ingredients was as follows: 47.85% flour, 23.93% water, 16.67% grilled tuna meat, 7.36% salmon oil, 1.47% sugar, 1.03% salt, 0.73% granulated garlic, 0.52% dry yeast, 0.44% ground white pepper.

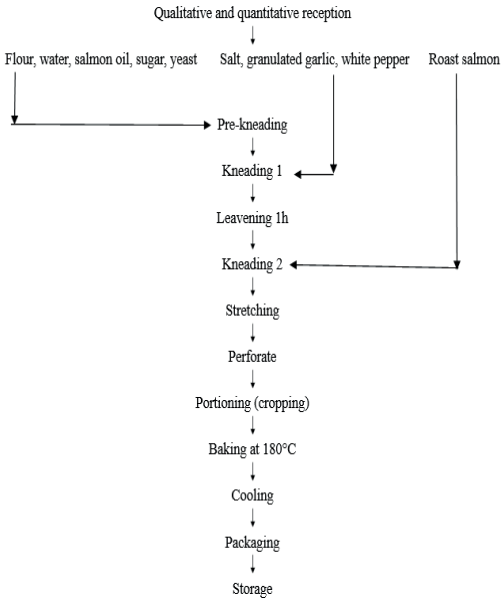

Figure 6. Technological scheme for obtaining crackers with salmon oil and salmon meat - P2

The technology for obtaining the P3 crackers was similar to that of the salmon oil and grilled salmon meat crackers. The difference lied in the type of meat added during the second kneading (Figure 7).

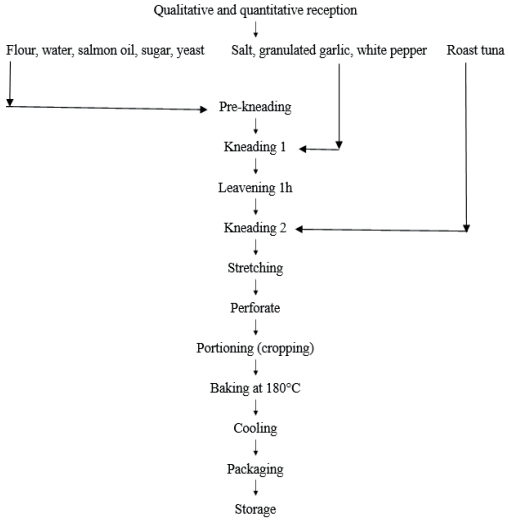

Figure 7. Technological scheme for obtaining crackers with salmon oil and tuna meat - P3

For the salmon oil, grilled salmon meat, and dehydrated onion crackers (P4), the proportion of ingredients was as follows: 45.94% flour, 22.97% water, 16% grilled salmon meat, 7.06% salmon oil, 4% dehydrated onion, 1.42% sugar, 0.99% salt, 0.7% granulated garlic, 0.5% dry yeast, 0.42% ground white pepper.

In terms of execution, the technology for obtaining the P4 crackers was similar to that of the salmon oil and grilled salmon meat crackers. The difference lied in adding dehydrated onion during the second kneading (Figure 8).

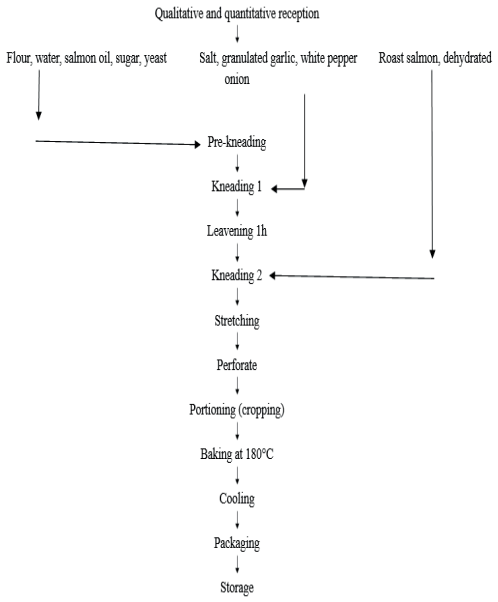

Figure 8. Technological scheme for obtaining crackers with salmon oil, salmon meat, and dehydrated onion - P4

For the salmon oil, grilled salmon meat, and dehydrated onion crackers (P5), the proportion of ingredients was as follows: 45.94% flour, 22.97% water, 16% grilled tuna meat, 7.06% salmon oil, 4.00% dehydrated onion, 1.42% sugar, 0.99% salt, 0.70% granulated garlic, 0.50% dry yeast, 0.42% ground white pepper.

The technology for obtaining the P5 crackers was similar to that of the salmon oil, grilled salmon meat, and dehydrated onion crackers, with the difference lying in the type of meat added during the second kneading (Figure 9).

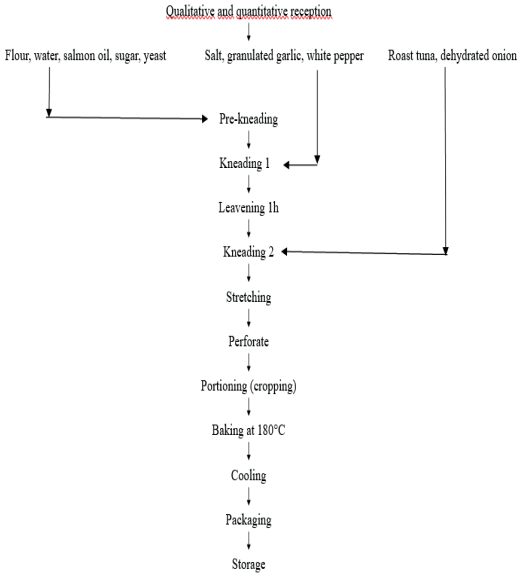

Figure 9. Technological scheme for obtaining crackers with salmon oil, tuna meat, and dehydrated onion - P5

2. Consumer acceptance

In the sensory evaluation study, all products were considered suitable for consumption and received positive evaluations. The majority of the evaluators expressed their willingness to purchase (100% for the salmon oil, grilled salmon meat, and dehydrated onion crackers - P4, 93.07% for the salmon oil crackers - P1, and the salmon oil and grilled salmon meat crackers - P2, 91.09% for the salmon oil and grilled tuna meat crackers - P3, and the salmon oil, grilled tuna meat, and dehydrated onion crackers - P5), supporting the proposal of these crackers for the food industry market.

Sample P1 (salmon oil crackers) was characterized by evaluators as having a pleasant appearance both externally and in cross-section, with the shape being relatively appropriate, and the characteristic color of the biscuits (Figure 10). The taste, aroma, and texture were what set these biscuits apart from regular ones. The taste of the fish oil crackers received a lower score. The aroma was evaluated similarly to the taste. The texture was deemed appropriate by the evaluators, being rated quite similarly across all five types of crackers.

The originality of the recipe received a high score due to its creative and innovative nature. Participants in the sensory evaluation considered sample P1 suitable for commercialization.

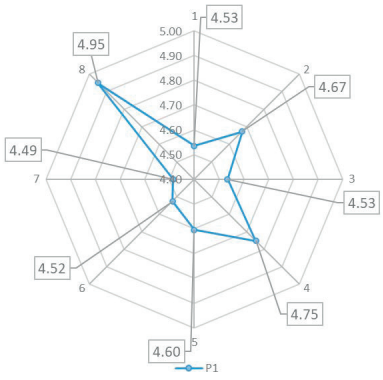

Figure 10. Sensory analysis of crackers with salmon oil (P1)

Sample 2 (salmon oil and grilled salmon meat crackers) was evaluated as having a pleasant appearance both externally and in cross-section, with the shape being relatively appropriate, and the characteristic color of the biscuits (Figure 11). The taste, aroma, and texture of this product were rated higher than in the previous case, being improved by the use of meat and fat from the same fish species. Like in the previous case, the product was considered original, and the purchase decision was favorable.

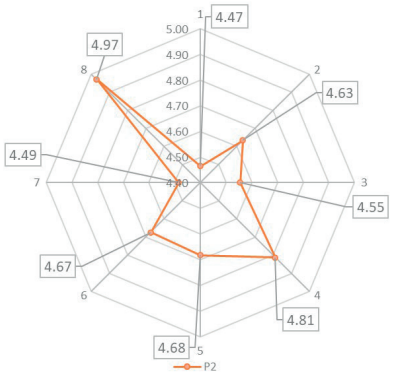

Figure 11. Sensory analysis of crackers with salmon oil and salmon meat (P2)

Sample 3 (crackers with salmon oil and tuna meat) was characterized as having a pleasant appearance both externally and in cross-section, with the shape being relatively appropriate. However, the color was noted to be more grayish compared to the previously described biscuits (Figure 12). The taste of the crackers was considered pleasant but less so than the previous ones. The aroma was appreciated as pleasant, and the texture was noted to be similar to sample P2. The product was deemed original, and the purchase decision was favorable.

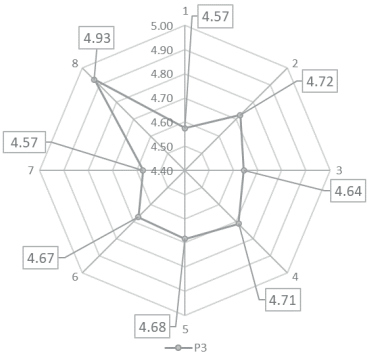

Figure 12. Sensory analysis of crackers with salmon oil and tuna meat (P3)

Sample 4 (crackers with salmon oil, salmon meat, and dehydrated onion) was evaluated as the best product among those analyzed (Figure 13). The product was characterized as having a pleasant appearance both externally and in cross-section, with a suitable shape, and a much more pleasant color than the previously analyzed samples. The taste was considered the most complex, being pleasant and unique. The aroma was deemed very pleasant, with the onion aroma complementing the intense salmon scent. The texture of the biscuits was also highly appreciated. As before, the product was valued as authentic, leading to a positive purchase decision.

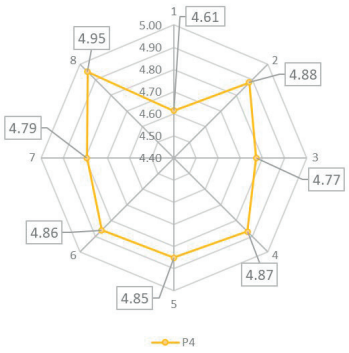

Figure 13. Sensory analysis of crackers with salmon oil, salmon meat, and dehydrated onion (P4)

Sample 5 (crackers with salmon oil, tuna meat, and dehydrated onion) was evaluated as the second-best in terms of quality (Figure 14). The external and cross-sectional appearance were considered very good, with a suitable shape. The color was more grayish than in sample 4 but more pleasant than in the other cases. The taste and aroma were considered of lower quality than sample 4 but higher than the other samples analyzed. The texture was deemed appropriate. As in previous cases, the product was considered original, with a favorable purchase decision.

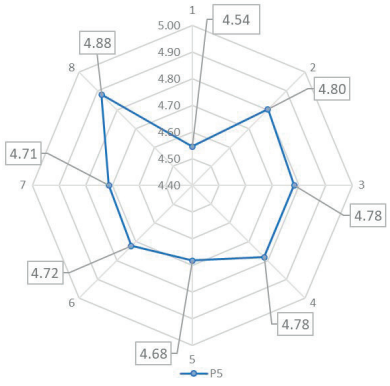

Figure 14. Sensory analysis of crackers with salmon oil, tuna meat, and dehydrated onion (P5)

Following the sensory analysis, it was found that all newly created products were accepted by consumers. Upon comparing all sensory analyses, it was found that the crackers with salmon oil, salmon meat, and dehydrated onion were considered the most relevant variant of fish crackers (Figure 15). They received an overall score of 4.82 out of a maximum of 5 points. In second place, with a score close to that of the crackers with salmon oil, salmon meat, and dehydrated onion, were the crackers with salmon oil, tuna meat, and dehydrated onion, which obtained an average score of 4.74. Crackers with salmon oil and tuna meat obtained an average score of 4.69 and were considered a middle-quality recipe. The second-to-last recipe in terms of quality was that of the crackers with salmon oil and salmon meat, with an average score of 4.66. Crackers with salmon oil proved to be the weakest in terms of quality, obtaining an average score of 4.63.

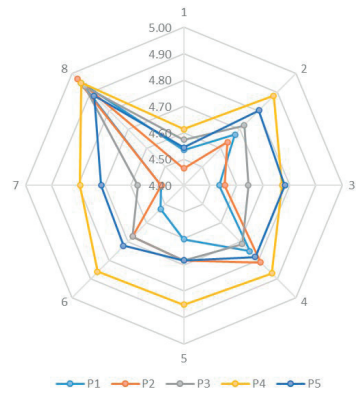

Figure 15. Comparative analysis of the five types of crackers from a sensory perspective

From the perspective of external appearance, crackers with salmon oil, salmon meat, and dehydrated onion obtained the highest average score (4.61), being considered the most appealing crackers. This result was followed by crackers with salmon oil and tuna meat (4.57), crackers with salmon oil, tuna meat, and dehydrated onion (4.54), crackers with salmon oil (4.53), and the weakest sample was that of crackers with salmon oil and salmon meat (4.47).

In terms of appearance in section, the best results were obtained by crackers with salmon oil, salmon meat, and dehydrated onion (4.88), followed by crackers with salmon oil, tuna meat, and dehydrated onion (4.8), crackers with salmon oil and tuna meat (4.72), crackers with

salmon oil (4.67), and crackers with salmon oil and salmon meat (4.63).
The most appreciated shape was that of crackers with salmon oil, tuna meat, and dehydrated onion, with an average score of 4.78, followed by crackers with salmon oil, salmon meat, and dehydrated onion (4.77), crackers with salmon oil and tuna meat (4.64), crackers with salmon oil and salmon meat (4.55), and crackers with salmon oil (4.53).
The most preferred color was that of crackers with salmon oil, salmon meat, and dehydrated onion (4.87), followed by crackers with salmon oil and salmon meat (4.81), crackers with salmon oil, tuna meat, and dehydrated onion (4.78), bisc crackers uits with salmon oil (4.75), and crackers with salmon oil and tuna meat (4.71).
In terms of taste, the most appreciated crackers were those with salmon oil, salmon meat, and dehydrated onion (4.85), followed by crackers with salmon oil and salmon meat, crackers with salmon oil and tuna meat, and crackers with salmon oil, tuna meat, and dehydrated onion (4.68), and crackers with salmon oil (4.60).
The most appreciated aroma was that of crackers with salmon oil, salmon meat, and dehydrated onion (4.86), followed by crackers with salmon oil, tuna meat, and dehydrated onion (4.72), crackers with salmon oil and salmon meat, and crackers with salmon oil and tuna meat (4.67), and crackers with salmon oil (4.52).
In terms of texture, the most appreciated crackers were those with salmon oil, salmon meat, and dehydrated onion (4.79), followed by crackers with salmon oil, tuna meat, and dehydrated onion (4.71), crackers with salmon oil and tuna meat (4.57), and crackers with salmon oil and salmon meat (4.49).
Regarding the originality of the recipe, crackers with salmon oil and salmon meat (4.97) were considered the most appropriate, followed by crackers with salmon oil, salmon meat, and dehydrated onion, and crackers with salmon oil (4.95), crackers with salmon oil and tuna meat (4.93), and crackers with salmon oil, tuna meat, and dehydrated onion (4.88).
In terms of expressing the buying decision, crackers with salmon oil, salmon meat, and dehydrated onion had a percentage of 100%, crackers with salmon oil, and crackers with salmon oil and salmon meat had a percentage of 93.07%, and crackers with salmon oil and tuna meat, and crackers with salmon oil, tuna meat, and dehydrated onion had a percentage of 91.09%.
Taking into account the rankings formed, but also the small differences between scores, it is considered that all products were suitable for consumption, but the most appreciated recipe was that of crackers with salmon oil, salmon meat, and dehydrated onion.
Analyzing Figure 15, it was concluded that crackers with salmon oil, salmon meat, and dehydrated onion (P4) were considered better than the other biscuit samples. Comparing the results obtained in the study with the results obtained by crackers with Nilem carp fish egg protein concentrate (Muslihudin et al., 2021), it is found that the crackers with salmon and tuna were appreciated as having more pleasant sensory characteristics.

3. Determining storage period based on packaging

The shelf life of fish crackers is crucial from both a food safety and economic perspective. Therefore, the duration during which the crackers maintained their consumption characteristics was determined. The newly created products were packaged and stored for 5 months at a temperature of 20-25°C.
All products underwent sensory analysis to determine their shelf life. Three types of packaging were used: paper, high-density polyethylene, and aluminum foil. All analyzed products exhibited similar sensory behavior.
The paper packaging proved to be inadequate and aesthetically unpleasing because the paper absorbed oil from the product. Additionally, its air permeability led to the oxidation of fats in the crackers.
Polyethylene packaging proved to be the most suitable packaging for biscuits as it did not absorb grease and was impermeable. Two packaging variants were tested: under normal atmosphere and under modified atmosphere (70% N2, 30% CO2).
The aluminum foil packaging was not suitable as it interacted with the biscuits, altering their color. Additionally, it was found to be not resistant to prolonged handling.
The polyethylene packaging was considered the most suitable option. The products retained

their sensory characteristics for 2 months under normal atmosphere and for 5 months under modified atmosphere.

4. Nutritional values

Nutritional values represent the ability of foods to provide the body with the nutrients it needs. They are an indicator of the quality of food products. In the case of fish crackers, according to the recipe and technological scheme, food ingredients with their own nutritional values have been introduced.

The basic chemical elements of salmon oil crackers (P1) have been determined (Table 1). Therefore, P1 crackers have a content of 6.8% protein, 10.2% lipids, 46.7% carbohydrates, 1.6% dietary fiber, and 1.3% mineral salts. After determining the basic chemical composition of the salmon oil biscuits, their energy value was calculated, which is 1299.7 kJ/309 kcal.

Table 1. Nutrition declaration of crackers with salmon oil (P1)

Nutritional values per 100 g	
Energy(calories)	1299.7 kJ
	309 kcal
Fat	10.2 g
- of which saturates	1.9 g
Carbohydrate	46.7 g
- of which sugars	1.9 g
Fiber	1.6 g
Protein	6.8 g
Salt	1.3 g

Following the determination of the basic chemical elements of salmon oil and salmon meat crackers (P2), it was found that they contain 10.1% protein, 9.7% lipids, 38.9% carbohydrates, 1.3% dietary fiber, and 1.1% mineral salts (Table 2). The energy value of the salmon oil and salmon meat biscuits was calculated to be 1202.3 kJ/285.9 kcal.

Table 2. Nutrition declaration of crackers with salmon oil and salmon meat (P2)

Nutritional values per 100 g	
Energy(calories)	1202.3 kJ
	285.9 kcal
Fat	9.7 g
- of which saturates	1.5 g
Carbohydrate	38.9 g
- of which sugars	1.5 g
Fiber	1.3 g
Protein	10.1 g
Salt	1.1 g

The crackers with salmon oil and tuna meat (P3) were analyzed for their content of basic chemical elements, resulting in the following composition: 11.6% protein, 9.8% lipids, 38.9% carbohydrates, 1.3% dietary fiber, and 1.1% mineral salts. Their energy value was calculated to be 1231.5 kJ/292.8 kcal (Table 3). Following the determination of the basic chemical elements of crackers with salmon oil, salmon meat, and dehydrated onion (P4), it was observed that they contain 10.3% protein, 9.4% lipids, 39.7% carbohydrates, 1.3% dietary fiber, and 1% mineral salts. The energy value of crackers with salmon oil, salmon meat, and dehydrated onion was calculated to be 1208.2 kJ/287.2 kcal (Table 4).

Table 3. Nutrition declaration of crackers with salmon oil and tuna meat (P3)

Nutritional values per 100 g	
Energy(calories)	1231.5 kJ
	292.8 kcal
Fat	9.8 g
- of which saturates	1.5 g
Carbohydrate	38.9 g
- of which sugars	1.5 g
Fiber	1.3 g
Protein	11.6 g
Salt	1.1 g

Table 4. Nutrition declaration of crackers with salmon oil, salmon meat, and dehydrated onion (P4)

Nutritional values per 100 g	
Energy(calories)	1208.2 kJ
	287.2 kcal
Fat	9.4 g
- of which saturates	1.5 g
Carbohydrate	39.7 g
- of which sugars	3.4 g
Fiber	1.3 g
Protein	10.3 g
Salt	1 g

The analysis for determining the basic chemical elements of crackers with salmon oil, tuna meat, and dehydrated onion (P5) revealed that they contain 11.7% protein, 9.5% lipids, 39.7% carbohydrates, 1.3% dietary fiber, and 1% salt, with an energy value of 1235.7 kJ/293.7 kcal (Table 5).

Table 5. Nutrition declaration of crackers with salmon oil, tuna meat, and dehydrated onion (P5)

Nutritional values per 100 g	
Energy(calories)	1235.7 kJ
	293.7 kcal
Fat	9.5 g
- of which saturates	1.5 g
Carbohydrate	39.7 g
- of which sugars	3.4 g
Fiber	1.3 g
Protein	11.7 g
Salt	1 g

Comparative analysis of the five biscuit samples from a nutritional perspective (Table 6) revealed that the most energy-rich biscuits were those with salmon oil, followed by biscuits with salmon oil, tuna meat, and dehydrated onion, biscuits with salmon oil and tuna meat, and biscuits with salmon oil, salmon meat, and dehydrated onion. The least energy-rich were biscuits with salmon oil and salmon meat.

In terms of protein content, the richest in protein were biscuits with salmon oil, tuna meat, and dehydrated onion, followed by biscuits with salmon oil and tuna meat, biscuits with salmon oil, salmon meat, and dehydrated onion, and biscuits with salmon oil and salmon meat, with the least protein being in biscuits with salmon oil.

Regarding lipid content, the richest in lipids were biscuits with salmon oil, followed by biscuits with salmon oil and tuna meat, biscuits with salmon oil and salmon meat, biscuits with salmon oil, tuna meat, and dehydrated onion, with the least lipids being in biscuits with salmon oil, salmon meat, and dehydrated onion.

In terms of carbohydrate content, the richest in carbohydrates were biscuits with salmon oil, followed by biscuits with salmon oil, salmon meat, and dehydrated onion, and biscuits with salmon oil, tuna meat, and dehydrated onion, with the least carbohydrates being in biscuits with salmon oil and salmon meat and biscuits with salmon oil and tuna meat.

Regarding dietary fiber content, the richest in fiber were biscuits with salmon oil, while the others were equally poor in dietary fiber.

In terms of mineral salt content, the richest in salts were biscuits with salmon oil, followed by biscuits with salmon oil and tuna meat, and biscuits with salmon oil and salmon meat, while the poorest in salts were biscuits with salmon oil, tuna meat, and dehydrated onion, and biscuits with salmon oil, salmon meat, and dehydrated onion.

Table 6. Comparative analysis of crackers from a nutritional perspective

Specification	Nutritional values per 100 g				
	P1	P2	P3	P4	P5
Energy(calories)	1299.7 kJ	1202.3 kJ	1231.5 kJ	1208.2 kJ	1235.7 kJ
	309 kcal	285.9 kcal	292.8 kcal	287.2 kcal	293.7 kcal
Fat	10.2 g	9.7 g	9.8 g	9.4 g	9.5 g
- of which saturates	1.9 g	1.5 g	1.5 g	1.5 g	1.5 g
Carbohydrate	46.7 g	38.9 g	38.9 g	39.7 g	39.7 g
- of which sugars	1.9 g	1.5 g	1.5 g	3.4 g	3.4 g
Fiber	1.6 g	1.3 g	1.3 g	1.3 g	1.3 g
Protein	6.8 g	10.1 g	11.6 g	10.3 g	11.7 g
Salt	1.3 g	1.1 g	1.1 g	1 g	1 g

Following the nutritional analysis of biscuits with added salmon and tuna, it was found that the resulting biscuits were improved, as they had recipes without additives and were rich in nutrients. Compared to crackers with salmon and tuna by-products, crackers made from sturgeon fillet protein concentrate (Abraha et al., 2018) had a higher percentage of protein (14.63-19.52%) and fat (16.20-16.50%). Additionally, salted biscuits with tilapia protein concentrate (Ibrahim, 2009) had higher protein content (12.50 ± 0.07%) and fat (22.65 ± 0.19%) compared to crackers with salmon oil and salmon or tuna meat. Analyzing the newly created biscuits and comparing them with those in the specialized literature, it was found that the obtained recipes had lower nutritional values.

CONCLUSIONS

Fish by-products are a very good source of food ingredients.

The five newly created types of fish biscuits have been accepted by consumers and can be introduced into the food chain.

Biscuits with salmon oil, salmon meat, and dehydrated onion were the most highly appreciated by consumers, excelling in external appearance, cross-section appearance, color, taste, aroma, and texture, as well as in the expression of purchase decisions.

Biscuits with only salmon oil were rated the lowest, with low scores in all criteria except

external appearance, cross-section appearance, color, and product originality.

Packaging in polyethylene packaging proved to be the optimal option for product protection. Packaging in a modified atmosphere extended the shelf life from 2 months to 5 months due to the inability of microorganisms to develop and the prevention of fat oxidation in the product due to the lack of oxygen.

ACKNOWLEDGEMENTS

This research work is part of the elaboration of the PhD thesis and was carried out with the support of the Faculty of Animal Production Engineering and Management, University of Agronomic Sciences and Veterinary Medicine Bucharest.

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