Production and characterization of a snack based on maize flour and Atlantic mackerel (Scomber scombrus)

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ABSTRACT

Maize has antioxidant properties and a high amount of carbohydrates, while fish has high-quality proteins and unsaturated fatty acids. The goal of this study was to prepare a functional food enriched with protein and n-3 fatty acids from Scomber scombrus. A sensory analysis was carried out, along with a texture profile, color and proximate analyses, content of EPA+DHA, and shelf life analyses on five formulations of the snack produced. The best-accepted formula turned out to be the one containing 15% fish, and in comparison with the control, it displayed similar fracturability, less hardness, a higher amount of protein and lipids, and EPA+DHA (p ≤ 0.05), providing 14.6% of the daily recommended intake of EPA+DHA (30 g of product). The development of new products, such as the one proposed in this study, can be a new and healthy alternative to substitute other similar, commercially sold products with a lower amount of nutrients.

KEYWORDS

Snack; tortilla chip; Scomber scombrus; functional food

PALABRAS CLAVE

aperitivo; tostada; Scomber scombrus; comida funcional

1. Introduction

The production of new food products has had different purposes, particularly contributing to the use of raw materials that have not been included in the market, such as materials derived from other processes considered “waste,” but that are still a source of nutrients (Padam, Tin, Chye, & Abdullah, 2014), as well as to improve the nutritional profile of commercialized foods by adding ingredients to the formula (Ramírez, Rodríguez, & Ruiz, 2017). There are currently many products based on maize (Zea mays L.), one of the three most widely grown cereals in the world, which is known for its antioxidant properties (Roh et al., 2016), for having a high content of carbohydrates (58% to 72%), and approximately 5% of lipids, and predominantly unsaturated fats. However, this cereal displays a low content of protein (approximately 10%) which is also considered of little biological value, due to the imbalance between amino acids. For example, it presents a high amount of leucin in comparison with isoleucine (López, García, & Ibarra, 2012). On the other hand, one of the foods with the highest protein content is fish, which contains proteins that are considered to have a high biological value, as well as being a good source of polyunsaturated fats (PUFA). However, its protein and lipid contents depend on the type of fish, the season, feeding and habitat (Aranda et al., 2016). Scomber scombrus, better known as the Atlantic mackerel, reportedly contains important amounts of n-3 polyunsaturated fatty acids (n-3 PUFA) such as eicosapentaenoic acid (C20:5n-3, EPA) and docosahexaenoic acid (C22:6n-3, DHA) fatty acids (Atehortúa Osorno, Velásquez Rodríguez, & López Marín, 2017). The high biological value protein and n-3 PUFA (EPA and DHA) are both considered beneficial for good health. The former, because it is composed of essential amino acids, helping increase muscular mass (Ruiz-Margáin et al., 2018), while n-3 fatty acids confer anti-inflammatory and anti-arrhythmogenic properties, preventing heart diseases and type 2 diabetes mellitus (González, Rodríguez, & Gómez, 2013), and due to these properties, the World Health Organization and the
United Nations Food and Agriculture Organization (OMS/FAO) recommend a daily intake of 250 mg of EPA and DHA (Vargas, Terrazas-Medina, Leyva-López, Peralta-Pería, & Cupu-Uicab, 2018). DHA is a fatty acid that has produced great interest, since it is essential for the development of the central nervous system and the retina during embryonic development, as well as being important throughout life for its neuroprotective function; it is a fatty acid found only in aquatic animals (Echeverría, Valenzuela, Hernandez-Rodas, & Valenzuela, 2017). The consumption of unsaturated fatty acids has been related to the improvement and prevention of various diseases. For example, several studies have shown that supplementation with EPA and DHA reduces hepatic steatosis and plasma enzyme levels such as aspartate aminotransferase, as well as an improvement in insulin resistance (Valenzuela, Ortiz, Hernández-Rodas, Echeverría, & Videla, 2019). On the other hand, proteins are also another essential component in the human diet, animal protein being the highest-quality protein due to its high digestibility and containing all the essential amino acids. An adequate intake of these nutrients is essential to allow the replacement of tissues and other proteins with enzymatic or hormonal functions; however, the high intake of red meat has been related to diseases such as diabetes mellitus 2 and cancer. Milk and shellfish represent good sources of this component, since they contain branched-chain amino acids and taurine, which reduces the risk of communicable diseases. In addition, proteins and fiber are fermented in the large intestine by several bacteria in the microbiota, which leads to the formation of beneficial compounds, such as short-chain fatty acids that act positively on the immune system (Conlon & Bird, 2015; Elmadfa & Meyer, 2017). Due to this, and considering both the world consumption of maize (Roh et al., 2016) and the benefit of protein and n-3 fatty acids, the aim of the present study was to produce a maize flour-based snack enriched with Atlantic mackerel to obtain a food with a higher protein content and n-3 fatty acids.

2. Materials and methods

2.1. Sample preparation

The fish was purchased in a commercial establishment in Sugar Land, Texas, U.S.A. Five formulas were produced of a tortilla chip snack, mixing commercial nixtamalized maize flour (purchased in a commercial establishment in Reynosa, Tamaulipas, Mexico), warm water, salt and fish (Table 1). Tortillas were made from each mixture by slow cooking them in a frying pan, then they were then cut into four pieces to form tortilla chips, approximately 2 cm in length, 1.5 cm wide and 1 mm thick. The tortilla chips were placed in an electric oven for 40 min at a temperature of 150°C. A sensory analysis of the products obtained was carried out, along with texture profile, color, proximate analysis, EPA and DHA content, and shelf life.

2.2. Sensory analysis

The sensory analysis was carried out based on the hedonic scale to measure taste, color, appearance, odor and texture with five possible answers, placing a number, 1 to 5, according to the liking towards the product: Dislike (1), Slightly dislike (2), Neither like nor dislike (3), Slightly like (4) and Like (5) (Vásquez, Salhuana, Alvarado, Ludeña, & Jiménez, 2019). A total of 80 untrained and randomly chosen panelists participated in the test (20 children aged 8 to 11, 20 adolescents aged 12 to 15, 20 young adults aged 19 to 23 and 20 adults aged 25 to 50), who were given the five formulas of the snack and asked to eat them with a drink of water in between each, to “cleanse the palate”. The degree of satisfaction of each attribute was obtained by the grade given by the 80 panelists.

2.3. Texture Profile Analysis (TPA)

A CT3 Brookfield texture evaluator was used to analyze the hardness and fracturability of the product. To determine hardness, a cylindrical probe was used, which measured 6 mm in diameter and 35 mm long at a speed of 2 mm/s at a distance of 3.0 mm. To determine fracturability, a shear probe was used (TA7), 60 mm in width, at a speed of 10 mm/s and at a 4.0 mm distance. The 5 product formulas were analyzed in triplicate.

2.4. Color analysis

According to Hernández-Martínez et al. (2016) the color analysis was performed using a previously calibrated Hunter Lab Mini Scan XE Plus colorimeter (model 45/0-L; Hunter Assoc., Reston, VA, U.S.A.). The color variables

### Table 1. Formulations of tortilla chip snack (100 g of product)

| Formulation | Maize (%) | Fish (%) |
|-------------|-----------|----------|
| F1          | 100       | 0        |
| F2          | 90        | 10       |
| F3          | 85        | 15       |
| F4          | 80        | 20       |
| F5          | 70        | 30       |

### Table 2. Sensory evaluation of tortilla chips produced with maize flour and different concentrations of Atlantic mackerel (Scomber scombrus).

| Formulation | Odor (mean±SD) | Taste (mean±SD) | Texture (mean±SD) | Appearance (mean±SD) | Color (mean±SD) |
|-------------|----------------|-----------------|-------------------|----------------------|-----------------|
| F1          | 4.43 ± 0.96a   | 4.23 ± 1.06a    | 3.52 ± 1.43a      | 4.28 ± 1.04a         | 4.07 ± 1.23a    |
| F2          | 3.10 ± 1.42b   | 2.80 ± 1.54b    | 3.53 ± 1.51b      | 3.67 ± 1.34b         | 3.88 ± 1.35b    |
| F3          | 3.20 ± 1.37b   | 3.02 ± 1.37b    | 3.62 ± 1.34a      | 3.77 ± 1.25ab        | 3.83 ± 1.34a    |
| F4          | 3.14 ± 1.45b   | 2.89 ± 1.43b    | 3.46 ± 1.36ab     | 3.49 ± 1.36b         | 3.68 ± 1.35a    |
| F5          | 3.32 ± 1.40b   | 3.00 ± 1.53b    | 3.11 ± 1.56ab     | 3.62 ± 1.23ab        | 3.72 ± 1.42ab   |

A 5-point hedonic scale was used, where 1 = Dislike, 2 = Slightly dislike, 3 = Neither like nor dislike, 4 = Slightly like, 5 = Like. a,bColumns with different letters present statistically significant differences, according to Tukey’s test (p ≤ 0.05). SD: standard deviation. F1-F5 are defined in Table 1.

Se utilizó una escala hedónica de 5 puntos, en la que 1 = desagradable, 2 = ligeramente desagradable, 3 = Ni agradable ni desagradable, 4 = Agradable, 5 = muy agradable. a,bLas columnas con letras diferentes presentan diferencias estadísticamente significativas según la prueba de Tukey (p ≤ 0.05). SD: desviación estándar. F1-F5 se definen en la Tabla 1.
lightness ($L^*$), $a^*$ (positive values = red color; negative values = green color) and $b^*$ (positive values = yellow color; negative values = blue color) were obtained. Measurements were taken in triplicate for each snack formulation. Values $a^*$ and $b^*$ were used to calculate the parameters of hue angle ($H^* = \tan^{-1} b^*/a^*$) and chroma ($C^* = [(a^*)^2 + (b^*)^2]^{1/2}$).

### 2.5. Proximate analysis

The proximate analysis was carried out based on official AACC methods (1995). The total protein content was determined using Kjeldhal's method (official method 950.36), along with moisture (official method 935.36), ash (official method 930.22), fats (official method 935.38) and crude fiber (official method 950.37). Carbohydrates were calculated by difference.

### 2.6. Fatty acids analysis

Fatty acids were extracted using the Sigma Aldrich extraction kit (Cat. No. MAK174), and boron trifluoride-methanol was used for the preparation of the fatty acid methyl ester (FAME). Fatty acids EPA and DHA were analyzed in triplicate in an Agilent Technologies 6890N gas chromatograph, equipped with an HP-88 capillary column (100 m x 0.25 mm x 0.2 µm, Agilent Technologies) and a flame ionization detector. The temperature of the injection port was 250°C, and of the detector, 260°C. The initial temperature of the oven was set to 100°C for 5 min and was then increased by 4°C every minute until it reached 240°C, where it was kept for 15 min. The carrier gas was helium and the injection Split 100:1. The identification of the FAMES was carried out by comparison in the retention times of the peaks in the sample with the Supelco 37 FAME mix pure standard by Sigma Aldrich (product number CRM47885), from which a calibration curve was created to calculate the concentration of fatty acids.

### 2.7. Microbiological analysis and shelf life

Microbiological analysis and shelf life were determined by counting aerobic mesophylls, following NOM-092-SSA1-1994; fungi and yeasts, following NOM-111-SSA1-1994 and total coliforms following NOM-112-SSA1-1994. All samples were prepared following NOM-110-SSA1-1994 (Jiménez et al., 2019; Márquez-Rios et al., 2011; Reyes, Trejo, Lira, & Pacual, 2015). For the shelf life analysis, the tortilla chip products were stored at room temperature (25°C) in airtight polyethylene bags in a dry place and away from sunlight.

### 2.8. Statistical analysis

The statistical analysis was carried out using the program IBM SPSS Statistics V20. A variance analysis (ANOVA) was applied on one factor, along with Tukey’s test with a level of significance of $p \leq 0.05$, in order to determine the differences between the tortilla chip formulas.

### 3. Results

#### 3.1. Sensory analysis

For every formula, an average of acceptance was calculated for each attribute evaluated (Table 2). Formula 3, with 15% fish, presented similar acceptability values to the control sample in three of five attributes (texture, appearance and color), in addition to higher rating in flavor amongst all tortilla chips with fish (although without statistically significant difference). Due to this, product F3 was considered the most widely accepted.

#### 3.2. Texture Profile Analysis (TPA)

Hardness and fracturability were measured for each of the formulas (Table 3); results showed that hardness decreased as the percentage of fish increased, and therefore the control sample obtained the highest values (12.15 N), displaying a statistically significant difference from the formula produced with 15% of fish (F3). Regarding fracturability, all formulas maintained similar values to the control sample ($p \geq 0.05$).

### Table 3. Texture profile for tortilla chips produced with maize flour and different concentrations of Scomber scombrus (mean±SD).

| Formulation | Hardness (N) | Fracturability (N) |
|-------------|-------------|--------------------|
| F1          | 12.15 ± 1.63<sup>a</sup> | 3.38 ± 0.39<sup>a</sup> |
| F2          | 10.64 ± 1.99<sup>b</sup> | 3.10 ± 0.49<sup>b</sup> |
| F3          | 8.28 ± 1.12<sup>c</sup> | 2.74 ± 0.54<sup>c</sup> |
| F4          | 6.75 ± 1.24<sup>c</sup> | 2.78 ± 0.57<sup>c</sup> |
| F5          | 5.34 ± 1.36<sup>c</sup> | 2.72 ± 0.90<sup>c</sup> |

<sup>a,b,c</sup>Columns with different letters present a statistically significant difference, according to Tukey's test ($p \leq 0.05$). SD: standard deviation.

### Table 4. Color parameters of different tortilla chip formulations (mean±SD).

| Formulation | $L^*$ | $a^*$ | $b^*$ | Chroma | Hue |
|-------------|-------|-------|-------|--------|-----|
| F1          | 63.73 ± 1.60<sup>a</sup> | 9.89 ± 0.66<sup>a</sup> | 41.65 ± 1.66<sup>a</sup> | 42.82 ± 1.59<sup>a</sup> | 1.33 ± 0.01<sup>a</sup> |
| F2          | 63.23 ± 0.78<sup>b</sup> | 9.84 ± 0.21<sup>b</sup> | 40.89 ± 1.39<sup>b</sup> | 42.06 ± 1.37<sup>b</sup> | 1.33 ± 0.00<sup>b</sup> |
| F3          | 62.29 ± 1.26<sup>c</sup> | 9.74 ± 0.45<sup>c</sup> | 37.28 ± 1.37<sup>c</sup> | 38.54 ± 1.37<sup>c</sup> | 1.31 ± 0.01<sup>c</sup> |
| F4          | 62.21 ± 0.69<sup>c</sup> | 9.55 ± 0.45<sup>c</sup> | 37.20 ± 0.75<sup>c</sup> | 38.41 ± 0.75<sup>c</sup> | 1.31 ± 0.01<sup>c</sup> |
| F5          | 61.86 ± 1.43<sup>c</sup> | 9.43 ± 0.32<sup>c</sup> | 36.92 ± 0.23<sup>c</sup> | 38.10 ± 0.29<sup>c</sup> | 1.31 ± 0.00<sup>c</sup> |

<sup>a,b,c</sup>Columns with different letters present a statistically significant difference, according to Tukey's test ($p \leq 0.05$). SD: standard deviation.

<sup>a,b</sup>Las columnas con letras diferentes presentan diferencias estadísticamente significativas según la prueba de Tukey ($p \leq 0.05$). SD: desviación estándar. F1–F5 se definen en la Tabla 1.
3.3. Color analysis

Table 4 shows the averages and standard deviation of the different formulas when placed under a color analysis. Luminosity decreased with the addition of the fish; however, statistically significant differences were only observed between the formula with the greatest concentration of fish (F5) and the control sample. Parameter a* of the control sample 9.89 ± 0.66 with a tendency towards the color red and parameter b* indicated a tendency towards yellowish tones, finding a significant difference only in parameter b* from formula 3 (F3), produced with 15% of fish. Regarding Hue, the angle in which the samples were viewed displayed a reddish to yellowish tone, although formulas 3 (15% fish), 4 (20% fish) and 5 (30% fish) displayed a difference with the control sample. The Chroma values were inversely proportional to the concentration of fish.

3.4. Proximate analysis

Table 5 shows the proximate composition of the different formulations. The contents of fat, protein and moisture of the control sample were 3.48%, 7.35% and 5.79%, respectively. The content of fat of the formulas with fish varied between 9.32% and 15.82%; protein, between 11.28% and 20.67% and moisture, between 6.75% and 10.52%, displaying an increase proportional to the addition of fish.

3.5. Content of fatty acids

The content of EPA and DHA between all formulations was statistically different (p ≤ 0.05), displaying an EPA contribution of 71.70 ± 3.4 mg/100g, and for DHA, of 70.9 ± 1.3 mg/100g of product for the best-accepted formula in the hedonic scale (F3). In addition to EPA and DHA, other PUFAs identified were linoleic and linolenic fatty acids in F1 to F5. The SFA identified in all formulations were myristic, palmitic and stearic. Regarding MUFAs, palmitoleic, cis-11-eicosenoic and cis-13-docosenoic, were not detected in the control sample but in all fish formulations (Table 6).

3.6. Microbiological analysis and shelf life

The results of the microbiological analysis for aerobic mesophyils, fungi and yeasts, and total coliforms registered below the limits indicates in NOM-247-SSA1-2008, after having been quantified after 48 h, 120 h and 48 h, respectively. Shelf life was evaluated after 7 and 14 days, recording a lower count than the maximum values allowed for each microorganism (50 000 UFC/g for aerobic mesophyils, 1000 UFC/g for fungi and yeasts, and 100 UFC/g for total coliforms).

| Fatty acids | F1 | F2 | F3 | F4 | F5 |
|-------------|----|----|----|----|----|
| SFA         | 131.7 | 93.1 | 121.8 | 147.7 | 214.5 |
| Palmitoleic | C16:0 | ND | 26.8 ± 0.6 | 36.5 ± 0.6 | 46.0 ± 1.8 |
| Oleic       | C18:1n9 | 48.0 ± 1.9 | 75.5 ± 2.2 | 102.1 ± 5.7 | 109.6 ± 7.1 |
| Cis-11-eicosenoic | C20:1 | ND | 30.1 ± 1.2 | 41.0 ± 1.6 | 44.9 ± 2.3 |
| Cis-13-docosenoic | C22:1n9 | ND | 53.2 ± 0.8 | 61.5 ± 1.5 | 101.2 ± 1.8 |
| Σ MUFA      | 48.0 | 185.6 | 241.1 | 301.7 | 493.7 |
| Linoleic    | C18:2n6 | 119.6 ± 5.9 | 177.7 ± 5.4 | 239.3 ± 14.1 | 212.0 ± 14.6 |
| α-linolenic | C18:3n3 | 16.3 ± 0.4 | 39.4 ± 0.4 | 50.4 ± 2.2 | 66.7 ± 0.3 |
| EPA         | C20:5n3 | ND | 39.9 ± 0.2 | 71.7 ± 3.4 | 104.8 ± 16.3 |
| DHA         | C22:6n3 | ND | 50.2 ± 1.0 | 70.9 ± 1.3 | 96.5 ± 0.15 |
| EPA + DHA   | ND | 90.1 | 142.6 | 201.3 | 339.2 |
| Σ PUFA      | 136.5 | 307.2 | 432.3 | 480.0 | 720.3 |

**Note:** Rows with different letters present a statistically significant difference, according to Tukey’s test (p ≤ 0.05). SD: standard deviation, ND: not detected. F1-F5 are defined in Table 1.

| Fatty acids | F1 | F2 | F3 | F4 | F5 |
|-------------|----|----|----|----|----|
| Palmitic    | 49.8 ± 2.3 | 42.9 ± 0.4 | 56.5 ± 2.0 | 64.8 ± 2.7 | 94.6 ± 2.9 |
| Oleic       | C18:1n9 | 66.7 ± 0.3 | 45.3 ± 1.0 | 63.3 ± 0.4 | 169.1 ± 4.7 |
| Cis-11-eicosenoic | C20:1 | ND | 30.1 ± 1.2 | 41.0 ± 1.6 | 44.9 ± 2.3 |
| Cis-13-docosenoic | C22:1n9 | ND | 53.2 ± 0.8 | 61.5 ± 1.5 | 101.2 ± 1.8 |
| Σ SFA       | 131.7 | 93.1 | 121.8 | 147.7 | 214.5 |
| Palmitoleic | C16:0 | ND | 26.8 ± 0.6 | 36.5 ± 0.6 | 46.0 ± 1.8 |
| Oleic       | C18:1n9 | 48.0 ± 1.9 | 75.5 ± 2.2 | 102.1 ± 5.7 | 109.6 ± 7.1 |
| Cis-11-eicosenoic | C20:1 | ND | 30.1 ± 1.2 | 41.0 ± 1.6 | 44.9 ± 2.3 |
| Cis-13-docosenoic | C22:1n9 | ND | 53.2 ± 0.8 | 61.5 ± 1.5 | 101.2 ± 1.8 |
| Σ MUFA      | 48.0 | 185.6 | 241.1 | 301.7 | 493.7 |
| Linoleic    | C18:2n6 | 119.6 ± 5.9 | 177.7 ± 5.4 | 239.3 ± 14.1 | 212.0 ± 14.6 |
| α-linolenic | C18:3n3 | 16.3 ± 0.4 | 39.4 ± 0.4 | 50.4 ± 2.2 | 66.7 ± 0.3 |
| EPA         | C20:5n3 | ND | 39.9 ± 0.2 | 71.7 ± 3.4 | 104.8 ± 16.3 |
| DHA         | C22:6n3 | ND | 50.2 ± 1.0 | 70.9 ± 1.3 | 96.5 ± 0.15 |
| EPA + DHA   | ND | 90.1 | 142.6 | 201.3 | 339.2 |
| Σ PUFA      | 136.5 | 307.2 | 432.3 | 480.0 | 720.3 |

**Note:** Rows with different letters present a statistically significant difference, according to Tukey’s test (p ≤ 0.05). SD: standard deviation, ND: not detected. F1-F5 are defined in Table 1.

**Table 5.** Proximate analysis on dry basis of different tortilla chip formulations (%).

| Protein (%) | Moisture (%) | Ash (%) | Fat (%) | Fiber (%) | CH (%) |
|-------------|--------------|---------|---------|-----------|-------|
| F1          | 7.35 ± 0.26a | 5.79 ± 0.33a | 2.75 ± 0.04a | 3.48 ± 0.45a | 0.78 ± 0.14a |
| F2          | 11.28 ± 1.51b | 6.75 ± 0.24ab | 2.72 ± 0.02a | 9.32 ± 1.71b | 0.50 ± 0.04b |
| F3          | 16.77 ± 0.94c | 7.84 ± 0.75bc | 2.67 ± 0.03bc | 9.77 ± 0.80bc | 0.48 ± 0.02bc |
| F4          | 17.9 ± 1.15d | 8.39 ± 0.27c | 2.67 ± 0.01d | 12.52 ± 0.10d | 0.45 ± 0.03d |
| F5          | 20.67 ± 0.61d | 10.52 ± 0.38e | 2.6 ± 0.00e | 15.82 ± 0.05d | 0.41 ± 0.03b |

**Note:** Columns with different letters present a statistically significant difference, according to Tukey’s test (p ≤ 0.05). F1-F5 are defined in Table 1.

**Table 6.** Fatty acid content in tortilla chips formulation, mg/100 g (mean±SD).
4. Discussion

4.1. Sensory analysis

Out of all the different chips produced, the formula with the highest acceptance was the one with a considerable percentage of fish (15%). This tendency in the acceptance of foods produced with fish was also observed in a study carried out by Nayak, Raju, Lakshmisha, Singh, and Sofi (2015) in which empanada dough was prepared with Sutchi catfish (Pangasius hypophthalmus), observing a higher preference for the dough prepared with 64% of fish. On the other hand, Lopez-Alarcón, Montalvo-Velarde, Bernal-Gracida, and Barbosa-Cortés (2018) produced a tortilla with sardine protein, which the panelists graded the parameter of odor as not undesirable, despite being predominant. According to Beveridge et al. (2013), the intake of fatty fish is recommended two to three times a week to consume enough amounts of long-chain polyunsaturated fatty acids, and therefore this type of snacks in the diet may be a feasible option.

4.2. Texture profile

The analysis of texture represents a crucial parameter for the consumer, particularly when it comes to crunchy products (Granados, Acevedo, Cabeza, & Lozano, 2014). In the chips produced, hardness and fracturability decreased with the addition of fish. In this regard, it is known that the measure of hardness can be affected by many factors, including moisture (Zúñiga, Ciro, & Osorio, 2007). This effect has been reported for several studies related to the development of corn snacks (Chiu, Peng, Tsai, Tsay, & Lui, 2013; Navarro-Cortez et al., 2016; Seth, Badwai, & Ganapathy, 2015), and fish contains important amounts of moisture. Amador-Rodríguez et al. (2015) obtained similar results to the ones in the present study and found a reduction of the parameters mentioned earlier in their product (baked nixtamaлизed maize flour tortilla chips) when adding corn smut paste. It is worth mentioning that corn smut and fish have similar contents of moisture (80% to 86% and 60% to 80%, respectively) (Beas et al., 2011; Olagunju et al., 2012). Bainy, Berton, Corazza, and Lenzi (2015) analyzed the texture of a fish hamburger and reported lower firmness values than meat products without fish.

4.3. Color analysis

Regarding color analysis, the tortilla chips became darker as the concentration of fish increased. Scomber scombrus is a blueback species of fish (El Oudiani, Chetoui, Darej, & Moujahed, 2019), which can have up to 48% of its weight composed of dark muscle. However, in the production of tortilla chips, light muscle was used, and it was observed that the coordinates that characterize color, in the case of F3, showed no statistically significant difference with the control in L and a*, but only in b*. In this regard, it is known that, if the color of a new product to its commercially approved predecessor, the probability of acceptance will increase, since it has been proven that, when the color of a food changes, there is a response of rejection by the consumers, although no other attributes change (Mathias-Rettig & Ah-Hen, 2014).

4.4. Proximate analysis

The proximate analysis displayed an increase in the content of lipids (mainly unsaturated fatty acids, see Table 6) and protein in direct proportion to the addition of fish. Variable amounts of protein and lipids have been reported for Scomber scombrus depending on the season of the year in a range of 18.20% to 22.03% for males and 18.00% to 22.07% for females for protein, and 5.37% to 18.86% for males and 3.39% to 13.21% for females for lipids (El Oudiani et al., 2019). The results were similar to those obtained by El-Beltagi, El-Senousy, Ali, and Omran (2017), who reported a higher concentration of protein and fat when adding dried carp (Cyprinus carpio) powder in a mixture for pizza. In comparison with similar products for commercial sale, which contain unsaturated fats and protein, the tortilla chips produced in the present study (and with the best organoleptic acceptance, F3) provide up to twice as many proteins as any commercial product, and more lipids in comparison with products fortified with cactus (plus linseed or sesame); quantities were only surpassed by those without cactus, but with added linseed, sesame and chia (Table 7).

Fish is an easily digestible food and it contains proteins of high biological value, since it contains all the essential amino acids, as well as monounsaturated and polyunsaturated fatty acids, vitamins and minerals (Flores, 2015). Therefore, the product developed may represent a healthy alternative to increase protein intake, particularly in Latin American countries, where the prevalence of overweight and obesity is important, while the prevalence of malnutrition, although it has decreased, remains a public health problem, related to eating patterns characterized by high energy-dense diets, with an increase in the intake of processed foods that contain large amounts of refined sugars and saturated fats, and the low intake of fiber, micronutrients and proteins (Fisberg et al., 2017). In countries such as Mexico, child malnutrition is still a major problem, especially in rural areas, where less than 50% of the population has been observed to consume quality protein, which could have repercussions on the growth of schoolchildren and adolescents (Shama-Levy, Cuevas-Nasu, Rivera-Dommarco, & Hernández-Ávila, 2018). Products with added fish could contribute to the solution of this health problem, according to López-Alarcón, Montalvo-Velarde, Bernal-Gracida and Barbosa-Cortés (2018), who added a sardine protein concentrate to cornmeal to improve the biological quality of tortillas. They fed rats and observed that the growth of rats fed with fortified tortillas was greater than that of those fed with non-fortified tortillas.

**Table 7. Comparison of the content of protein and lipids of the product produced with other products commercially for sale.**

| Product based on maize flour with another added ingredient | Amount in a 30 g portion |
|-----------------------------------------------------------|------------------------|
| Tortilla chip produced with Atlantic mackerel (F3)         | 5.0                    |
| Tortilla chips with linseed and sesame                     | 2.0                    |
| Tortilla chips with cactus and linseed                     | 2.4                    |
| Tortilla chips with sesame, linseed, chia and rice flour   | 2.2                    |
| Tostadas with cactus and sesame                           | 2.5                    |
| Tostada with cactus                                       | 2.0                    |

Las etiquetas revisadas de los alimentos descritas en la tabla son las que aparecen en los productos.

Food labels described in the table were reviewed directly from the products.
Table 8. Content of EPA and DHA of different fish species.

| Fish                | EPA (mg/100 g) | DHA (mg/100 g) | DHA + EPA (mg/100 g) |
|---------------------|---------------|---------------|---------------------|
| Fresh tuna          | 1070          | 2280          | 3350                |
| Fresh salmon        | 700           | 2410          | 3110                |
| Sardine             | 660           | 1900          | 2560                |
| Smoked herring       | 1942          | 326           | 2268                |
| Anchovy             | 763           | 1292          | 2055                |
| Atlantic mackerel   | 710           | 1100          | 1810                |
| Pompano             | 440           | 549           | 989                 |
| Swordfish           | 323           | 665           | 988                 |
| Trout               | 259           | 677           | 936                 |
| Kawakawa            | 93            | 551           | 644                 |

Source: Mozaffarian and Wu (2012); Lorenzo et al. (2018); Gribble et al. (2016).
Fuente: Mozaffarian y Wu (2012); Lorenzo et al. (2018); Gribble et al. (2016).

flour; the difference was significant starting at concentrations of 3.75% (p < 0.05).

It is worth mentioning that the fiber content in the tortilla chips produced in the present study decreased with the addition of fish. The intake of foods with low fiber contents is related to overweight and obesity and fiber are involved in the regulation of type II diabetes and cardiovascular disease (Vílchez-Pérez & Vilchez-Perales, 2017). Therefore, as a proposal for another study, the challenge of increasing the fiber content in this snack remains ongoing.

4.5. Content of fatty acids

The content of EPA+DHA for every 100 g of product of F3 was 142.6 mg, and so one serving of 30 g of tortilla chips would provide 42.8 mg of both fatty acids, amount which equals 17.1% of the daily intake recommended by the WHO/FAO of 250 mg per day (Vargas et al., 2018). According to Kaur, Chugh, and Gupta (2014), fish and fish oil are the richest sources of EPA, whether saltwater or freshwater fish, whereas DHA is not only found in reddish-brown algae, but also in fish oil, and therefore, an intake of up to two or three times a week of fish has been recommended (Nguyen, Malau-Aduli, Cavaliere, Nichols, & Malau-Aduli, 2019). In this regard, Scomber scombrus (Atlantic mackerel) contains important levels of EPA and DHA (El Oudiani et al., 2019) (Table 8). It is worth mentioning that the importance of the intake of both fatty acids is due to their benefits to health, since they help control blood pressure, alleviate symptoms of rheumatoid arthritis and depression, as well as slowing down the progress of Alzheimer’s (Russell & Bürgin-Maundier, 2012). In addition, DHA is involved in the development of nervous tissue (brain and retina) and its preservation during aging. In western countries, DHA intake via fish (such as salmon, tuna and mackerel) is very low (Valenzuela & Videla, 2011). Barrera et al. (2018) reported the consumption of EPA and DHA during pregnancy and lactation in 50 women yet observed a low consumption of both fatty acids that continued to decrease during months 1 and 6 of lactation. Therefore, the development of new products, such as the one proposed in this study, can be a new and healthy alternative to increase the intake of these fatty acids.

In the SFA family, palmitic acid (C16:0) was the most abundant fatty acid in fish formula, as well as in freshwater fish species like salmon, cod, sole, flounder, catfish, rainbow trout, tilapia and pangasius (Luczyński, Paszczyk, & Łuczyński, 2014).

Regarding MUFAs, oleic acid was one of the most abundant; this result was also observed by El Oudiani et al. (2019) in both female and male Scomber scombrus fillets, especially in autumn season. Oleic acid has been observed to improve insulin sensitivity and endothelium-dependent vasodilation mediated by flux, decreasing LDL values and increasing HDL (Hostmark & Haug, 2013). Moreover, the intake of oleic acid seems to be associated with reduced blood pressure, possibly leading to reduced cardiovascular disease risk (Hostmark & Haug, 2014).

4.6. Microbiological analysis and shelf life

With the results obtained for the microbiological analysis and shelf life, it is concluded that the product obtained continued to be adequate for consumption up to 14 days after production at room temperature (25°C). Innocuity is one of the four basic groups of characteristics that, along with nutritional, organoleptic and commercial characteristics, make up the total quality of foods (De la Fuente & Barboza, 2010). Baked foods have an adequate taste and they develop a golden and crunchy shell during production due to the dehydration of the surface (Rodríguez & De Hernández, 2006). Sanz, Castells, Freixanet, and Lagares (2016) produced a snack based on lean meat (similar to dehydrated chips), with a shelf life of up to 4 months at room temperature (25°C). The dehydration of a food helps reduces bacterial and fungal growth (Embús-Clavijo, 2017). However, the appearance of bacteria is also related to the inadequate handling of food and to favorable conditions for the multiplication of microorganisms (Chekol, Melak, Belew, & Zeleke, 2019).

5. Conclusion

The sensory evaluation of products development with fish showed a high acceptance, similar to the control (F1). The F3 showed higher acceptance levels in sensory analysis, although proximate analysis showed a high content of protein and lipids, compared to the control. Snacks based on maize flour fortified with Atlantic mackerel (Scomber scombrus) could be considered a healthy alternative to similar commercial products. This study concludes that snacks with Atlantic mackerel have acceptable amounts of protein and could be a good source of n-3 PUFA (EPA+DHA).

Disclosure statement

No potential conflict of interest was reported by the author.

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