Original Research Article

Influence of different species of fish on physicochemical properties of surimi

.

ABSTRACT

|  |
| --- |
| Surimi is a concentrate of myofibrillar proteins obtained from solid residues from fish processing, which is minced, washed, drained and final by the use of stabilizing agents. The aim of this study was to evaluate the influence of using different fish species whitemouth croaker (*Argyrosomus regius*), snapper (*Lutjanus purpureus*), sandperch (*Pseudopercis Numida*) and tilapia (*Oreochromis niloticus*). The surimi preparation method included immersion in an alkaline solution, followed by two immersions in saline solutions, water separation by centrifugation, mass crushing with the addition of cryoprotectants, and storage in ultra-freezer. Physicochemical properties were determined in terms of pH by potentiometric analysis, moisture by desiccation at 105 oC for 24 h, total fat content by the Soxhlet method, crude protein by Kjeldhal method, color by colorimeter, fatty acid profile using gas chromatography, and the texture profile by the texture analyzer. The obtained results ranged from: pH 7.29±0.19 to 7.55±0.43; moisture (%) 77.19±0.55to 81.27±0.85; the protein (%) content ranged from 15.04±0.32to 17.10±0.12and the lipid content ranged from 0.08±0.06 to 1.13±0.10. In addition, sandperch surimi showed the highest whiteness value and intermediate texture, and the color presented adequate whiteness values, with high brightness in sandperch surimi and low brightness for snapper surimi. Therefore, the production of surimi showed to be a rich source of protein and present acceptable texture Characteristics. |

*Keywords: Surimi, tropical fishes, physical and chemical composition, food processing, food analysis.*

1. INTRODUCTION

Brazil has the largest hydrographic network in the region and more than 8500 Km of coastline, making this country the continent’s leader in diversity of species of fish. In addition, the favorable tropical climate, good conditions for aquaculture development, and natural occurrence of aquatic species makes it compatible with zootechnic and market interests, becoming the country a potential to concentrate one of the largest fish reserves in the world (Santos et al. 2023).

The fish consumption is recommended due to the quality of it protein, and provides vitamins, minerals and other nutrients essential to human health (Dias et al. 2023). However, Brazil presents low average rates of fish consumption *per capita per year*, and its can be related to the problem in the distribution and marketing, and the purchasing power of the consumers with lower-income.

Therefore, the use of fillet and the waste of fish for the production of new products as surimi constitutes a technological alternative and diet diversification for the communities. [Surimi](https://www.sciencedirect.com/topics/food-science/surimi) (minced fish) is a stabilized myofibril proteins (MPs) obtained from fish muscles after mechanical mincing, washing, refining, and dewatering (Jiao et al. 2023).The production of the surimi has increased considerably worldwide, ie., it was estimated over one million of surimi was produced globally in 2020 (Yin and Park, 2023).

The literature presents several studies recently published involving the surimi production in Asian countries (Zhang et al. 2024, Sijing et al. 2024, Qiqi et al. 2024, Zhuolin et al. 2024, Ruizhi et al. 2025). However, there are few studies related to surimi production in Brazil (De Oliveira et al. 2020), which justify the existence of few surimi-producing factories, and the known imported product is kani-kama or crabstick, in the shape of a stick and imitation crab aroma (Picardo, 2019).

The productive process of surimi is complex due to its ultra-processed nature, and often, can be produced using different mixes of fish species. The drawback is the possibility of containing allergenic raw materials and dyes used, mainly for the improve the appearance of the product, which can be a risk for the consumers. In addition, he quality of surimi, prepared from various fish species depends on several factors, such as seasonal variations, eating habits, pH levels of the habitat's water, environmental adaptations, temperature, lipid content, sex and spawning patterns. (Bakli et al., 2020). These multifaceted influences underscore the complexity and diversity of surimi production and its resulting characteristics.

Therefore, the production of surimi with the desirable quality attributes, especially in relation to texture and stability during storage, requires knowledge of the basic principles of centesimal composition and textural instrumental properties (hardness and cohesiveness), which correlate with sensory characteristics.

Therefore, this work highlights the production of surimi with four different species of fish as a possible innovative technology without the use of dyes. The main characteristic of surimi is gel-forming, which makes it a valuable ingredient to produce high-quality and value-added seafood products. Thus, surimi-based foods not only offer a unique texture and savory taste but also possess inherent health benefits (Buyruk et al. 2019).

In this sense, the present work aims to produce surimi using different species of fish, such as whitemouth croaker (*Argyrosomus regius*), snapper (*Lutjanus purpureus*), sandperch (*Pseudopercis Numida*) and tilapia (*Oreochromis niloticus*), aiming to correlate macronutrient composition with texture, to diversify the supply of fish products widely marketed at local fairs and markets.

2. material and methods

2.1 Reagents

High purity deionized water (18 MΩ cm resistivity) produced from a Milli-Q® Plus (Millipore Corp, Bedford, MA, USA) was used to prepare all solutions. All glassware and polypropylene vessels were previously decontaminated using detergent and by soaking them in a HNO3 (Synth, Diadema, Brazil, SP) 10% v/v of solution for 24h and rinsed with ultrapure water before use. Aqueous solution of 0.5% w/v of sodium bicarbonate (Sigma-Aldrich, USA) and 0.3% w/v of sodium chloride (Sigma-Aldrich, USA) were used in first, second and third solution washes, respectively. The sorbitol and sodium tripolyphosphate were used to cryoprotectants of surimi, and the petroleum ether was used for the extraction of lipids.

**2.2 Sample acquisition and Surimi preparation**

Four different species of fish, whitemouth croaker (*Argyrosomus regius*)*,* snapper *(Lutjanus purpureus),* sandperch *(Pseudopercis Numida)* and tilapia *(Oreochromis niloticus*) were acquired from the local market (fishmongers) on the same day of capture, with a time lapse of less than 24 h between capture and purchase, as the fishmonger communicated the time of arrival of each fish. During all the time the fish were kept in PVC boxes with ice, including the duration of transport to the laboratory (Food Technology Laboratory - EQ / UFRJ).

The procedure for the surimi production was adapted following the methodology described by Ordonez (2005). The fish fillet was ground, weighed and shared in three basins to receive the distinct washing waters. Three washing cycles (the first aqueous solution of 0.5% w/v of NaHCO3, second and third solution washes with 0.3% w/v of NaCl), in the proportion of 1:3 (fish: water, m/v), 10-15 ºC/10 min of gentle stirring. Next, the dewatered meat in centrifuge (SUGGAR, BR) at 3500 rpm and surimis of each species were chopped in a silent cutter (SIRE, BR), for 1-2 min to add cryoprotectants (5 g/100 g of sorbitol and 0.3 g/100 g of sodium tripolyphosphate). The produced surimi paste was frozen like surimi blocks (100 g of each packed PVC film) were immediately stored in an ultra-freezer (-56 0C). All steps for the production of surimi are described in Figure 1.



**Figure 1.** Productive step process of surimi in laboratorial scale: (A) Entire fishes; (B) fillets, (C) chopped fillet, (D) fillet crushed, (E) mass weighing, (F) solution immersion soaking, (G) packed surimi in film plastic.

**2.3 Surimi analysis**

**2.3.1 Proximate composition, pH determination and yield**

The moisture, total fat and crude protein content, pH and yield were determined for surimi. For moisture determination, approximately 2 g of sample was placed on an aluminum dish spread evenly across the dish and oven-dried at 105 oC for 24 h (AOAC, 2000). Total fat content was determined according to the Soxhlet extraction method with petroleum ether (boiling temperature range 30-60 oC) and expressed as g/100 g (dry and wet weight basis) (AOAC, 2000). Crude protein was quantified by micro Kjeldhal (N x 6.25) (AOAC, 2000). The pH of surimi was determined using a bench pH meter (MS TECNOPON, model mPA210, Brazil). The yield of the treatments (%) was calculated by the ratio between the weight of the raw muscle used and the weight of the final surimi. All analyzes were performed in triplicates.

**2.3.2 Color analysis**

The color analysis was performed employing the method described by Huang et al. (2022) for detecting the color change and calculating the white index (WI) for samples in Minolta Chroma Meter CR-400 colorimeter (Minolta Camera Co. Ltd., Osaka, Japan) calibrated with a standard white plate (Y = 86.7, x = .3161, y = .3232) prior to each measurement.

The reflected light at 6 randomly was measured selecting points for each sample to determine the L, a, and b values that were used to calculate the WI. The samples were equilibrated to room temperature to the color measurement. The color properties of heat-set surimi were determined using a bench colorimeter. At least eight cylindrical gels (height = 2.5 cm, diameter = 2.5 cm) per treatment were used for color measurements. Whiteness of gels was calculated by the following equation (Huang et al. 2023):

𝑊ℎ𝑖𝑡𝑒𝑛𝑒𝑠𝑠=100−[(100−𝐿∗)2+𝑎∗2+𝑏∗2]1/2

Where CIELab color positive/negative values indicate:

brightness/darkness for L,

redness/greenness for a,

yellowness/blueness for b.

**2.3.3 Fatty acid profile (FAP) surimi**

Fatty acid profiles in surimi were determined for four varieties of fish (whitemouth croaker, sandperch, snapper and tilapia). The extraction process of lipids was performed using acid hydrolysis with petroleum ether, followed by methylation of fatty acid methyl esters (FAMEs) according to the method described by Hewavitharana et al. (2020). Fatty acid methyl esters were quantified in the gas chromatography (Shimadzu, model GC 2014), coupled to a flame ionization detector (FID), split / splitless injector and a capillary column (Carbowax 20 M). Stationary phase of polyethylene glycol 30 m long internal diameter 0.25 mm and film thickness 0.25 μm, Agilent brand. The operating parameters were: Injected volume: 1 µL; Split injector: 50:1 ratio; injector temperature: 250 ºC; Drag gas: Hydrogen (99.95%), with linear velocity 26.5 cm/s; Column flow: 1 mL/min; Oven temperature setting: 60 °C for 2 min; from 60 °C to 200 °C (gradient of 10 °C per min); from 200 °C to 240 °C (gradient 5 °C/min) and isotherm for 15 min; Detector temperature: 280 ºC; make-up gas was N2 at 30 mL/min, H2 (30 mL/min) and synthetic air (300 mL/min). Qualitative identification of fatty acid methyl esters (fatty acid profile, %) was performed by comparing the retention time of the sample constituents with a mixture of 37 external fatty acid methyl ester standards. Concentration was determined by the percentage of relative areas. The results were expressed as percentages of total, saturated, monounsaturated and polyunsaturated methyl esters present in the lipid extract determined by area normalization, provided by the *software* (GC Solution).

**2.3.4 Texture profile analysis (TPA)**

The TPA protocol was carried out by a Texture Analyzer (CT3 450, Brookfield, USA) using the TA-50 spherical probe (5mm diameter). All analyzes were carried out in eight samples cylinders of 2.5 cm length x 2.5cm diameter for each formulation at 25 °C. The analysis is done in 2 cycles, with 1 mm/s drop speed, 5 g trigger load and 1.2 cm target value. The reading of the results was made by the Texture Pro CT software, of the texturometer itself. Parameters of hardness (g), cohesiveness (m2/m2), springiness (mm), gumminess (g) and chewiness (mJ) were evaluated TPA involves the repeated compression of a sample to its original height between two parallel surfaces, recording force versus displacement. The maximum force of the first compression determines hardness and the ratio of the area under the second cycle compression curve to the area under the first cycle compression curve determines cohesiveness. The hardness and cohesiveness of TPA can be expected to correlate with sensory texture profile evaluation (Park, 2014).

**2.3.5 Statistical analysis**

All data were presented as mean ± standard deviation of triplicates (at least), and was performed for determination of TPA (n=6) cooked surimi gels, and color (n=5) and uncooked surimi gels. ANOVA followed by the Fisher’s Least Significant Difference (LSD) test at a confident level of 95%, p-Values ≤ 0.05 were considered statistically significant. Pearson's linear correlation coefficient (r), for a confidence interval of 95%, was applied to the averages of macronutrients on a dry basis (protein and lipids) and to the texture parameters (hardness, cohesiveness, springiness, gumminess and chewiness). All analysis was performed using SAS software version 10 (SAS Institute Inc., Cary, NC, USA).

3. results and discussion

3.1 Proximate composition, pH and yield

Approximately 1.716 kg of whitemouth croaker fillet used in the preparation of surimi, generated 550 g of final product, including the addition of cryoprotectants (0.3% tripolyphosphate and 5% sorbitol) to perform the analyzes, presenting a 32% yield. The snapper fillet *(Lutjanus purpureus)* from 1.228 kg generated 500 g of surimi in 40.7% yield. The sandperch fillet *(Pseudopercis Numida)* from 1.240 kg generated 650g of surimi, presenting the highest yield among the evaluated fish, reaching the value of 52.4%.

The production process and laboratory scale production equipment were the same for the four fish species and these data confirm that the yield of surimi production varies according to the fish used. The advantage of surimi production compared to other fish processing is that it is a 100% raw material used to make a wide variety. The moisture, protein, lipid and Prot/moist contents in surimi of the 4 species evaluated are presented in Table 1**.** There is a difference (P <0.05) for all evaluated parameters, showing that the washing of the raw material altered the composition of the respective surimi, reducing the protein and lipid contents.

The moisture content is a key factor affecting the quality of surimi, and can directly affect the gel formation (Duan et al. 2023). In specific case of moisture, the difference can be related to the surimi drying time, and even so, the moisture content in surimi produced from of fillet fish of whitemouth croaker, snapper, sandperch and tilapia the values obtained are within of the acceptable standards of fish, which range from 60 to 85%, as described by Duan et al. (2023). In Japan, surimi produced with Alaska pollock (*Theragra chalcogramma*) is differentiated into four categories: S (superclass), with humidity between 76.1% and 79.0%; class A, between 79.1% and 80.0%; class B, between 80.1% and 81.5%; class C, when it exceeds 81.5% (Fogaça et al. 2015). Sandperch surimi had the lowest moisture content (77.19%) among the species evaluated, followed by whitemouth croaker surimi (79%), snapper surimi (80.22%) and tilapia surimi (81.27%). Considering the standardization stipulated by the Alaska pollock surimi, sandperch and croaker surimi are in the class A category.

**Table 1.** Proximate composition of surimi of different 4 species of fish. Results are expressed as mean ± standard deviation. (\*) = determined by difference calculation, considering the carbohydrate and ash values not experimentally analyses. Mean ± standard deviation that present the same letter in the line do not have significant differences at 5% of confidence level.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | WHITEMOUTH CROAKER(*Argyrosomus regius)* | SNAPPER (*Sparidae Lutjanidae*) | SANDPERCH (*Pseudopercis**Numida*) | TILÁPIA*Oreochromis**niloticus*) |
|  |  |  |  |  |
| Moisture (%) | 79±0.70c | 80.22±0.07b | 77.19±0.55d | 81.27±0.85 a |
| Protein (%) | 17.08±0.35 a | 15.04±0.32c | 16.46 ± 0.44b | 17.10± 0,12a |
| Lipid (%) | 0.67±0.03c | 0.08±0.06d | 0.89±0.04b | 1.13±0.10a |
| Others (\*) | 3.25±0.33c | 4.26±0.34b | 5.46 ± 0.32a | 0.50±0.07d |
| Prot/moist (%) | 0.22±0.01a | 0.19±0.01b | 0.21±0.01a | 0,21± 0,01a |

Three of four fish selected in this study, as expected, have low lipid content, being the captive-bred. Among macronutrients, lipid is the one with the largest variation, as factors, such as time of year, age of the animal, reproduction period and type of feeding have a strong influence on this parameter, ranging from 0.1 to 22%, as described by both in Matos *et al*., (2019), who points to a wide variation in lipid content in fish, from 0.4 to 8.2%. The data of lipid concentration of surimi are presented in Table 1, and the calculations indicated that compared to the respective surimi, the percentage reduction in lipid content was 42.74% for whitemouth croaker, 93.34% in snapper, 17.68% in sandperch and 58.15% in tilapia, i.e., the washing method used, especially in the first cycle, with 0.5% sodium bicarbonate, besides changing the pH of the medium, it reduces the lipid content randomly, indicating that the fish species has a strong impact on the muscle's ability to retain lipid or not. On the other hand, in the sandperch, 82.4% of the lipid was retained in the muscle, in the case of snapper, the retention was only 6.66%, where all lipids present in the snapper fillet was eliminated during the wash steps.

The others are carbohydrates and ashes values obtained by calculating the difference, being found an average reduction of 74.5% ± 0.38 in surimi of the whitemouth croaker, snapper, sandperch and tilapia.

The pH is one of the most important factors in producing strong elastic surimi, and the optimal values for strong gelation is approximately 7.0–7.5 for white meat fishes (Lee, Yoon and Park, 2017). Table 2 shows the results of pH obtained for samples of surimi, and these values are slightly lower than those reported by Gao et al. (2018). The authors reported that the highest value of breaking strength in pollack surimi was exhibited at a pH of 8.0 and pH 8.0 – 8.5 in direct heating and two-step heating conditions. The breaking strength and breaking strain of pollack surimi, both decreased with falling or rising pH values, indicating that neutral pH of salt-ground meat fish is essential for the formation of crosslinked myosin-heavy chains in large quantities that contribute to elastic paste. Moreover, Lee et al. (2017) reported the same results in Alaska pollock surimi, where the authors found that higher pH surimi (7.5–8.0) tend to have higher breaking strength and deformability than lower pH surimi (6.0-6.9), probably due to the myosin-heavy chain crosslinking is higher at pH 7.0 than at lower pH.

**Table 2.** Results of pH obtained in surimi samples of four (4) different species of fishes. Data are given as mean ± SD (n=8)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | WHITEMOUTH CROAKER(*Argyrosomus regius)* | SNAPPER (*Sparidae Lutjanidae*) | SANDPERCH (*Pseudopercis**Numida*) | TILÁPIA (*Oreochromis**niloticus*) |
| pH | 7.35±0.51 | 7.55±0.43 | 7.29±0.23 | 7.29±0.19 |

**3.2 Fatty acid profile (FAP) of surimi**

The results of the fatty acid composition analysis of surimi are presented in Table 3. The results showed a reduction in triglyceride levels, justified by the washing method used. In addition, there was a reduction in saturated fatty acids of 0.08% for whitemouth croaker, 5.56% in snapper, 15.06% in sandperch and 2.28% in tilapia. While monounsaturated showed reduction of 16.46% in croaker, 7.35% in snapper, 3.34% in sandperch and 1.13% in tilapia. For polyunsaturated reductions were 17.31% for croaker, 4.4% in snapper, 8.99% in sandperch and 1.23% in tilapia. These results indicate that lipid levels are not eliminated during surimi processing using three wash cycles.

The main fatty acids identified in surimi of the four fish species evaluated were myristic (C14:0), palmitic (C16:0), palmitoleic (C16:1), stearic (C18:0), oleic (C18:1), linoleic (C18:1), and Arachidonic (C20:4), Docosapentanoic acid (C22:5) in surimi of some species. The saturated content was higher than the monounsaturated and polyunsaturated contents, however, when added, the sandperch presented higher unsaturated values than croaker and snapper, but similar value to tilapia. However, among the identified fatty acids, the omega-3 docosahexaenoic acid (DHA) value for the health benefits was only identified in the croaker. The sandperch presented the lowest total polyunsaturated content, while the croaker presented the highest value among the studied fishes.

**Table 3.** Fatty acid profile (FAP) of surimi of 4 different species of fish. The data are given as mean ± SD (n=8)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fatty acids in percentage areas (%) | WHITEMOUTH CROAKER (Argyrosomus regius) | **SNAPPER**(*Lutjanus purpureus)* | **SANDPERCH** (*Pseudopercis Numida*) | **TILAPIA**(*Oreochromis niloticus*) |
| Mirístic C14:0 | 20.43 | 3.28 | 4.2 | -- |
| Palmitic C16:0 | 26.81 | 26.76 | 20.47 | 50.04 |
| Palmitoleic C16:1 | 13.20 | 9.72 | 6.59 | -- |
| Stearic C18:0 | 7.66 | 7.66 | 6.67 |
| Oleic C18:1n9 | 11.26 | 24.73 | 23.30 | 24.47 |
| Cis-vaccine C18:1 | 6.10 | -- | -- | -- |
| Linoleic C18:2n6 | -- |  -- | 1.37 | 10.40 |
| Linolenic C18:3 |  -- | -- | -- |
| Arachidonic C20:4 |  -- | 1.82 |  -- | 12.04 |
| Eicosatrienoic C20:2 |  -- | -- | -- |  -- |
| Erucic C22:1n9 | -- |  1.50 | 1.62 | -- |
| Cid-13,16 Docosadienoic C22 | -- | -- | -- | -- |
| Docosapentanoic C22:5 | 16.23 | -- | -- |  -- |
| Docosahexaenoic C22:6 | 1.44 | -- | -- |  -- |
| C22:5 n6 | -- | -- | -- | 8.79 |
| Tricosanoic C23:0 |  -- | -- | 1.89 |  -- |
| Lignoceric C24:0 | 1.35 |  2.08 | 1.39 |  -- |
| Total saturates | 56.25 | 41.63 | 32.73 | 50.04 |
| Monounsaturated totals | 30.56 |  34.45 | 31.26 |  34.87 |
| Total polyunsaturated | 27.67 |  3.32 | 1.62 |  20.83 |
| Total fatty acids | 114.48 |  79.4 | 65.61 |  105.19 |

**3.3 Color properties of surimi**

Functional properties such as color and texture are the major factors responsible for the final acceptance of surimi-based products by consumers. Traditionally, the WI of a surimi product is considered a critical indicator of quality, and higher WI values indicate better quality. However, in the case of innovative food development, intense and vibrant colors can improve both the characteristics and consumer appeal of the product (Liang at al. 2020).

Generally, the demand is higher for surimi with high lightness (L\*), low yellowness (b\*) and high whiteness (W). The results evaluated in the CIE L \* a \* and b \* system are presented in Table 4, andthere is significant difference (p <0.05) in the lightness value (L\*) between the surimi produced by fish fillet fresh varieties. The surimi of the snapper with the lowest L\* value is numerically darker compared to the **s**andperch, which are the lightest among the samples.

Coincidentally the protein / moisture ratio of sandperch is the same. The coordinates of a\* (the negative sign tends to green) and the b\* coordinates (positive tends to yellow), the values may indicate that the red color (sarcoplasmic proteins, carotenoids and other pigments) was eliminated during the wash step, showing to be more effective for the snapper. The whiteness found in the samples is desirable, as surimi-derived products are commonly added with pigments and flavors (Oliveira et al. 2017), so the whiter the base, the better. Among the fish evaluated, the highest WI values were for sandperch and tilapia surimi, indicating that it would have the best acceptance in the market. However, industrially, titanium dioxide and calcium carbonate are used as surimi whiteness enhancers (Park 2014). The results of the color analysis are in agreement to those values of L \*, a \* and b \* obtained by Hernández-Briones et al. (2009), where it was studied the addition of fish gelatin in Alaskan Polish surimi.

**Table 4.** The color parameters (*L* – lightness, *a\** – redness, *B* – yellowness) of the surimi. Results are expressed as mean ± standard deviation, and the same letter in the column do not have significant differences at 5% of confidence level.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Surimi | L\* | a\* | b\* | Whiteness |
| Whitemouth croaker (*Argyrosomus regius*) | 62.05 ± 0.31c | -1.85 ± 0.05b | 3.55 ± 0.19ª  | 62.00±0.27b |
| Snapper (*Lutjanus purpureus)* | 52.63 ± 0.28d | -5.91 ± 0.13d | 2.47 ± 0.10b | 52.44±0.17c |
| Sandperch (*Pseudopercis Numida*) | 77.80 ± 0.47a | -2.08 ± 0.08c | 1.70 ± 0.07c | 77.77±0.23ª  |
| Tilapia (*Oreochromis niloticus*) | 76.15 ± 0.38b | -1.52 ± 0.11a | 1.15 ± 0.03d | 76.05±0.16ª  |

**3.4 Texture properties of surimi**

Texture analysis by TPA involves the repeated compression of a sample at its original height between two parallel surfaces, recording force versus displacement. The maximum force of the first compression determines the hardness and the ratio of the area under the second cycle compression curve to the area under the first cycle compression curve determines the cohesion. TPA hardness and cohesiveness values correlate with the evaluation of the sensory texture profile (Park, 2014).

Massingue et al. (2021) describe that the texture of surimi depends on the species of fish used in the preparation of surimi, concentration of the salt used for protein solubilization, the temperature and time of the heat treatment, as well as the moisture content and pH.

Based on the results of TPA presented in Table 5, the analyzed parameters (hardness, cohesiveness, springiness, gumminess, and chewiness), showed significant differences (p> 0.05) in confidence level, specifically for surimi samples cooked from croaker snapper and **s**andperch. The hardness values of the croaker and sandperch samples are within the same magnitude range, like the values described by Park (2014). However, the tilapia and snapper cooked surimi gels presented discrepant values, and the mean and standard deviation values of the tilapia surimi sample were very high, which may show a lack of homogeneity between the analyzed samples or even a difference in the adjustment’s equipment data.

Snapper and sandperch cooked surimi gels in the springiness parameter, as well as sandperch in the cohesiveness parameter, showed no statistically significant difference (p > 0.05) between the samples in the Fisher Test (F < F critical). The gumminess parameters in all surimi samples oscillated in their values. According to Yang et al (2022) the oscillations occurred in the parameters because the texture of the surimi gels promotes the unfolding of the myosin molecule, which produces an increase in semi gel fluidity that can separate some already formed protein networks. In addition, the air inside the gel interferes with the TPA, since the pressure increase during the test causes the structure interruption. The improved characteristics of cooked gels are due to washing which enhanced the removal of tropomyosin, troponin and myosin light chains in the first two washes that may interfere with protein-protein interactions involved in gel formation.

Table 5. Analysis of parameters (hardness, cohesiveness, springiness, gumminess, and chewiness)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Surimi(Cooked) | Hardness(g) | Cohesiveness | Elasticity(mm) | Gummy(g) | Chewable(mj) |
| Croaker | 72.50 ±12.12ª  | 0.66 ± 0.06b | 3.14 ± 0.11a | 46.09 ± 6.58a | 1.48 ± 0.29b |
| Snapper | 9.19 ±1.64d  | 0.88 ± 0.2ª | 2.12± 0.15c | 7.45 ± 1.41d | 0.14 ± 0.04d |
| Sandperch | 33.00 ±5.25b | 0.45 ± 0.06c | 2.10 ± 0.16c | 14.88 ± 2.59c | 0.31± 0.07c |
| Tilápia | 27.31±10.37c | 0.42 ± 0.07c | 2.79 ± 0.22b | 30.92±7.12b | 8.16 ± 1.63a |

4 Conclusion

This study contributed to obtain a better comprehension regarding the use of different species of fishes for the production of surimi. Based on the obtained results, was possible to understand the influence of different treatment in the quality of surimi proprieties, showing the -variations of physicochemical properties in surimi after all production stages. Nevertheless, surimi constitutes a good source of macronutrients and an alternative diversity to supply the fish products and ensure a balanced diet for the consumers.

Besides that, this study demonstrated the possibility to produce the surimi without adding dyes to improve color and using a unique specie of fish for each type of surimi produced, being an alternative for food industries in the production of this type of product, contributing to a better quality of life for the population.

Moreover, more studies, such as water-holding capacity, SEM analysis and Sensory analysis are necessary for analysis and investigate the new possibilities to produce of surimi for the production employing other or similar species.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors declare that no generative ai technologies such as large language models (chatgpt, copilot, etc) and text-to-image generators have been used during writing or editing of this manuscript.

References

Association Official Analysis Chemical – AOAC (2000). Official Methods of analysis (16ª ed.). Washington: Association of Official Analytical Chemists.

Bakli, S., Nath S., Pati S. C. (2020) Surimi powder: Processing technology and potencial application. Journal if Entomology and Zoology Studies, 8:850-859.

Buyruk, G., Çelik, M., Küçükgülmez, A., Kadak, A. E. The chemical composition, sensory properties, and myofibrillar proteins of surimi produced from tilapia (Oreochromis niloticus) meat. Marine Science and Technology Bulletin. 12(3), 402-410.

De Oliveira D. L., et al. (2020). Enrichment of fishburgers with proteins from surimi washing water. Food Science and Technology, 40:822-826.

Dias, G. K. S., Siqueira-Souza, F. K., Souza, L. A., Freitas C. E. C. (2023). The consumption of fish by the riverine population of the lower Solimões River, Amazonas, Brazil. Brazilian Journal of Biology, 83:e271572.

Duan, W., et al. (2023). Correlation between Water Characteristics and Gel Strength in the Gel Formation of Golden Pompano Surimi Induced by Dense Phase Carbon Dioxide. Foods, 12:1090.

Fogaça, F. H. S., Otani, F. S., Portella, C. G., Dos Santos-Filho, L. G. A., & Sant’Ana, L. S. (2015). Characterization of surimi obtained from meat mechanically separated from Nile tilapia and fish burger elaboration. *Seminar:* *Sciences Agrarian*, 36, 765-776.

Gao, [Y.](https://pubmed.ncbi.nlm.nih.gov/?term=Gao+Y&cauthor_id=30238581), Fukushima, [H.](https://pubmed.ncbi.nlm.nih.gov/?term=Fukushima+H&cauthor_id=30238581), Deng, [S.](https://pubmed.ncbi.nlm.nih.gov/?term=Deng+S&cauthor_id=30238581), Jia, [R](https://pubmed.ncbi.nlm.nih.gov/?term=Jia+R&cauthor_id=30238581)., Osako, [K.](https://pubmed.ncbi.nlm.nih.gov/?term=Osako+K&cauthor_id=30238581), Okazaki, [E](https://pubmed.ncbi.nlm.nih.gov/?term=Okazaki+E&cauthor_id=30238581). (2018) Effect of pH and heating conditions on the properties of Alaska pollock (Theragra chalcogramma) surimi gel fortified with fish oil. Journal of Texture Studies, 49(6):595-603.  doi: 10.1111/jtxs.12365.

Hernández-Briones, A., Velázquez, G., Vázquez, M., & Ramírez, J. A. (2009). Effects of adding fish gelatin on Alaska pollock surimi gels. *Food hydrocolloids*, 23:2446-2449. <https://doi.org/10.1016/j.foodhyd.2009.07.002>.

Hewavitharana, G. G., Perera, D. N., Navaratne, S. B., Wickramasinghe, I. (2020) Extraction methods of fat from food samples and preparation of fatty acid methyl esters for gas chromatography: A review. Arabian Journal of Chemistry 13:6865-6875.

Huang, P., Cheng, Y., Chan, Y., Lu, W.-C., & Li, P. (2022). Effect of heat treatment on nutritional and chromatic properties of mung bean (Vigna radiata L.). Agronomy, 1, 12(6), 1365. <https://doi.org/10.3390/agronomy12061365>.

Huang, P., Cheng, Y., Hsieh, H., Ko, W., Lu, W., Li, P. (2023). Effects of transglutaminase on the physicochemical properties of surimi and kamaboko prepared by thermal and low level-pressure treatments. LWT, 183, 114863.

Jiao, X. (2024). Green and sustainable microwave processing of surimi seafood: A review of protein component interactions, mechanisms, and industrial applications. Trends inFood Science and Techonoloy, 143:104266.

Lee, M. G., Yoon, W. B., Park, J. W (2017). Combined effect of pH and heating conditions on the physical properties of Alaska pollock surimi gels. Journal of Texture Studies. 48(3):215-220.  doi: 10.1111/jtxs.12230.

Liang, F., Lin, L., He, T., Zhou, X., Jiang, S., & Lu, J. (2020). Effect of transglutaminase on gel properties of surimi and precocious Chinese mitten crab (Eriocheir sinensis) meat. Food Hydrocolloids, 98, Article 105261. https://doi.org/10.1016/j. foodhyd.2019.105261.

Massingue, A. A., Paula, M. M. O., Rocha, A. P. R., Haddad, G. B. S., Carmo, E. L., Ramos, A. L. S., Ramos, E. M. (2019) Perfil de textura de concentrados proteicos tipo surimi elaborados com carne mecanicamente separada de peru. Brazilian Journal of Food Technology, 24, e2019345. <https://doi.org/10.1590/1981-6723.34519>.

Matos, A. P., Matos, A. C., & Moecke, E. H. S. (2019). Polyunsaturated fatty acids and nutritional quality of five freshwater fish species cultivated in the western region of Santa Catarina, Brazil. Brazilian Journal of Food Technology, 22, e2018193.

Oliveira, D. L., Grassi, T. L. M., Santo, E. F. E., Cavazzana, J. F., Marcos, M. T. S., Ponsano, E. H. G. (2017). Washings and cryoprotectants for the production of Tilapia Surimi. Food Science and Technology, 37(3): 432-436.

Park, J. W. (2014). *Surimi and surimi seafood*. CRC Press, Third edition.

Picardo, J. J. (2019). *Avaliação e influência nas propriedades físicas e químicas do surimi produzidos a partir de diferentes espécies de peixes: corvina (Argyrosomus regius), pargo (Lutjanus purpureus), namorado (Pseudopercis numida) e tilápia (Oreochromis niloticus*. Dissertação de Mestrado, Universidade Federal do Rio de Janeiro.

Qiqi, L. et al. (2024). A comprehensive unraveling of the mystery of reduced-salt surimi gels: From molecular mechanism to future prospects. Trends in Food Science and Technology, 154:104783.

Ruizhi et al. (2025). Factors influencing surimi gelling properties and natural additive–based gel fortification strategies: A review. Comprehensiv Reviews in Food Science and Food Safety, 24:e70067.

Santos, J P. et al. (2023). Fisheries monitoring in Brazil: How can the 2030 agenda be met without fisheries statistics? Biota Neotropica, 23:e20221439.

Sijing, et al. (2024). A mini review on manipulation of carbohydrate for better use in surimi and surimi products: modification and compounding. Journal of the Science of Food and Agriculture, 104:14-20.

Yang, Y., Meng, L., Wang, Y., Yan, B. (2022). Effects of exogenous lipids on gelling properties of silver carp surimi gel subjected to microwave heating. Food Science and Nutrition, 10(12), 4296-4307.

Yin, T., Park, J. W. (2023). Comprehensive review: by‑products from surimi production and better utilization. Food Science and Biotechnology, 32:1957-1980.

Zhuolin, W. et al. (2024). Silver carp (Hypophthalmichthys molitrix) utilization: Surimi innovations based on seasonal variation in muscle proteins. Trends in Food Science and Technology, 153:104737.