Fish products developed from ground rainbow trout and tilapia fillet mixtures: Physico-chemical, microbiological and toxicological analyses

[*Produtos de pescado elaborados a partir de misturas de carne moída de truta-arco-íris* (Oncorhynchus mykiss) *e tilápia* (Oreochromis *sp.*): *análises físico-químicas, microbiológicas e toxicológicas*]

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ABSTRACT

Constant fishing industry innovations in response to consumer demands for novel, balanced healthy products exhibiting high nutritional value, as well as easy to prepare and ready to consume, have led to the emergence of new technologies. Among them, the development of products based on ground beef and fish mixtures are noteworthy. In this context, the purpose of this study was to develop products from different ground rainbow trout and tilapia fillet ratios, in the form of meatballs and nuggets, determining their proximate composition and physico-chemical, microbiological and toxicological characteristics. The average dry matter percentage of the developed products was 29.20±2.30%, while mineral content was 1.45±0.55%, lipid pulp content, 3.70±0.30% and crude pulp protein, 16.60±2.04%. Total psychotropic counts remained below 10^2 CFU/g, for standard counting on aerobic microorganism plates. Histamine and sulfur-based compounds were not detected in any of the prepared samples. The purpose of the work proposal was to develop foods and technologies that can serve as standards, allowing for simple handling products that apply ground meat mixtures from different fish species to maintain adequate nutritional indices after processing.

Keywords: truticulture, fish technology, new products, innocuity

RESUMO

A constante inovação da indústria pesqueira, em resposta às demandas dos consumidores por novos produtos saudáveis, com alto valor nutritivo, balanceados, de fácil preparo e prontos para consumo, levou ao surgimento de novas tecnologias, entre elas o desenvolvimento de produtos à base de mistura de carne moída de pescado. Nesse contexto, a proposta deste trabalho é desenvolver produtos a partir de carne moída de pescado de truta-arco-íris e tilápia, confeccionando almôndegas e *nuggets* em diferentes proporções, com determinação da composição centesimal e de suas características físico-químicas, microbiológicas e toxicológicas. A matéria seca percentual média foi de 29,20±2,30%. Teores de matéria mineral nos produtos estão em 1,45±0,55%. Os teores de lipídeos aferidos na polpa foram de 3,70±0,30%, e os níveis de proteína bruta apresentados na polpa de 16,60±2,04%. A contagem de psicrotróficos totais manteve-se abaixo de 10^2 CFU/g, para contagem padrão em placas de micro-organismos aeróbicos. Nas amostras, não foram detectados níveis de histamina e de compostos à base de enxofre. A proposta de trabalho objetivou, por fim, desenvolver alimentos e tecnologias que possam servir como padrões, permitindo que produtos de manipulação simples e que utilizem misturas de carne moída de diferentes espécies de pescado mantenham índices nutricionais adequados após o processamento.

Palavras-chave: truticultura, tecnologia do pescado, novos produtos, inocuidade

INTRODUCTION

The continuous search for healthier food items by people, associated with practicality concerning their preparation, has become a current demand, mainly due to the various daily activities that are developed by modern society, mainly in large cities (Berizi *et al.,* 2016). In this context, fish are considered both an excellent source of protein and a major income-generating business, mainly in developing countries, through extractive fishing reductions and greater aquaculture investments, which has become a promising and increasing activity (Lopes *et al.,* 2016).

Salmonids are the main group of animals used in cold water fish farming. Among species belonging to the Salmonidae family, the rainbow trout is of paramount importance, as it can be reared worldwide and its industrial aquaculture growth is currently on the rise. Many investments have been made concerning studies to further develop relevant rainbow trout production issues, such as increased stocking density and productive and commercial productivity (Oncorhynchus…, 2017). Tilapia (*Oreochromis* sp.) introduction in Brazil took place in the 20th century, and this species is currently the most produced in the country, due to its genetic and reproductive characteristics (Hilsdorf, 2018).

Fishing industry maintenance in the current consumer market is directly related to the ability to respond to the new consumer demands, through the development of new products that meet the requirements for healthy, balanced and easy to prepare food items, exhibiting high nutritional value, differentiated and less impactful to the modern routine (Ribeiro *et al.*, 2018; Guimaraes *et al.,* 2018). In this context, the development of new fish-based products is, thus, favored, not only by creating high nutritional value food items but also by taking advantage of a large amount of material that would otherwise be discarded. Technologies have emerged to target and favor the use of fish products as food sources, transforming them into nutritious products with good market acceptance, such as surimi, pates, dumplings, and "fish burgers" (Berizi *et al.*, 2016; Ribeiro *et al.*, 2018; Guimaraes *et al.*, 2018).

Fish processing makes it possible to increase marketing options to different product shapes and sizes through the separation of edible parts, which have been widely applied in trout and tilapia processing, for example (Bykowski, 1994). The concept of Food Security, set by the Food and Agriculture Organization (FAO), is defined as "when everyone, at all times, has physical and economic access to sufficient, innocuous and nutritious food to satisfy their dietary needs and preferences regarding food in order to lead a healthy and active life" (The state…, 2014). When consumed frequently, fish aid in preventing cardiovascular diseases and controlling blood pressure, and also play important roles in lactation and neurological development (Avdalov, 2014).

In this context, this study aimed at the development of two fast-prepared products (meatballs and nuggets) based on a mixture of ground rainbow trout (*Oncorhynchus mykiss*) and tilapia (*Oreochromis* sp.) filets. These products were prepared at different ratios and characterized by determining their centesimal composition and other physicochemical, microbiological and toxicological parameters, to certify their final quality.

MATERIAL AND METHODS

Fresh trout and tilapia specimens were purchased from fish farms located in the city of Nova Friburgo, in the state of Rio de Janeiro, Brazil, between August and September 2019. Species were identified through specialized literature and by comparisons (Oncorhynchus…, 2018). The specimens were placed in an isothermal container with abundant ice and taken to the Fish and Aquatic Health Laboratory belonging to the Federal Fluminense University. At the laboratory, they were washed and biometric parameters were determined (weight and total length). The specimens were then skinned, eviscerated, beheaded and filleted. Each fillet was then ground in a manual meat grinder. Samples (250g) from the processed (base of the preparations) and cooked (meatballs and nuggets) samples were separated and vacuum packed for the physico-chemical, microbiological and toxicological analyses. All samples were analyzed in triplicate.

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The mixture between the two ground fish meats were tested at the following ratios: 100% tilapia and 100% trout (Control - C1 and C2, respectively), 90% trout and 10 % tilapia (Treatment 1 - T1), 80% trout and 20% tilapia (Treatment 2 - T2), 70% trout and 30% tilapia (Treatment 3 - T3) and 60% trout and 40% tilapia (Treatment 4 - T4). After establishing the proposed mixtures (C1, C2, T1, T2, T3, and T4), the products were adjusted to two general product formulations (Tables 1 and 2). Due to product characteristics, the nuggets were breaded after mixing using wheat flour and maintained chilled until preparation.

About 250g of processed fish meat yielded ten meatballs and nuggets for each preparation (25-gram portions).

The prepared products were placed in an insulated container and transported to the State Center for Research and Food Quality (CEPQA) belonging to the Agricultural Research Corporation of the State of Rio de Janeiro (PESAGRO-RIO) for physico-chemical and toxicological analyses. The microbiological analyses were performed at the Laboratory of Microbiological Control of Products of Animal Origin (LCMPOA), at the Federal Fluminense University.

Table 1. General meatball formula containing different ground trout (*Oncorhynchus mykiss*) and tilapia (*Oreochromis* sp.) meat ratios

Ingredients	Percentual Ingredients (%)	Adding in grams
Sodium chloride	0.7	1.62
Onions	7.0	16.20
Garlic	3.0	6.94
Basil	0.1	0.23
Oregano	0.1	0.23
White pepper (powder)	0.1	0.23
Turmeric	0.5	1.00
Ground fish fillet	88.5	234.54

Table 2. General nugget formula containing different ground trout (*Oncorhynchus mykiss*) and tilapia (*Oreochromis* sp.) meat ratios

Ingredients	Percentual Ingredients (%)	Adding in grams
Sodium chloride	0.6	1.62
Onions	6.2	16.20
Garlic	2.7	6.94
Chives	0.1	0.23
Parsley	0.1	0.23
Black pepper (powder)	0.1	0.23
Wheat flour	0.1	0.26
Lemon juice	0.1	1.00
Ground fish filet	89.9	236.24

For the physico-chemical analyses, sample were pre-dried at 105° C and the following tests were carried out in triplicate, following Brazilian legislation established by the Ministry of Agriculture, Livestock and Supply (MAPA) (Brazil, 2018), based on the AOAC manual (Official…, 2005): dry matter; ash; crude protein (Micro Kjeldahl), hydrogen potential (pH); aqueous activity (Aw) (infrared assessments, Aqualab®); ether extract (Soxhlet method); BVT (total volatile bases); sodium contained in the obtained mineral matter (UV spectrophotometry at 593nm, Shimadzu® - Ks, USA).

The microbiological analyses were performed as described in the Compendium of Methods for the Microbiological Examination of Foods (Compendium…, 2015), following Brazil (2001). Coliforms were enumerated at 45°C/g, coagulase-positive *Staphylococci*/ g, *Salmonella* spp./25g were evaluated in the prepared products and *Salmonella* sp./25g, and coagulase-positive *staphylococci*/g counts were investigated in fresh fish. Additionally, for comparative purposes, the concentrations of mesophilic and psychotropic organisms were evaluated to highlight the sanitary quality of the developed products.

Toxicological analyses comprised the evaluation of the presence of hydrogen sulfide gas (H_2S) and histamine, according to Brazil (2018).

Data were evaluated using parametric parameters (mean, standard deviation, maximum and minimum values) and tables. The statistical treatment was performed by comparing means and frequencies, considering statistical comparisons by the Tukey test and frequency assessments (ANOVA), at a significance level of 5% ($p \leq 0.05$) for comparison between treatments and experimental groups (Agresti, 2002).

RESULTS AND DISCUSSION

The fish specimens ranged between 32 and 45cm total length, with an average of 35.22±5.0cm and between 350.6g (trout) and 1187.6g (tilapia) total weight. Fillet yields of the gutted fish ranged between 28.08 and 48.87 %, averaging 38.02±6.99%. Regarding total weight, yields varied between 27.04 and 47.06%, averaging 36.23 ± 6.65%. The biometric parameters of both the tilapia and trout fillets were in accordance with FIPERJ (Relatório…, 2014), which describes specimens with total lengths between 19.0 and 60.0cm and weight between 0.711 and 2.186kg.

The fillet yields of gutted trout fillets varied between 39.08% and 48.87%, averaging 42.02%±5.99%, while tilapia fillets ranged between 37.04 and 57.06%, averaging 46.23%±6.65%. The yields obtained in this study exhibited high commercial potential when compared to Signor *et al.* (2010), who described values of 48.50% for pacu fillets (*Piaractus mesopotamicus*), and 28.00% for Nile tilapia (*Oreochromis niloticus*), as reported by da Silva *et al.* (2016) in later studies.

The average proximate composition values of the prepared products and their controls are displayed in Table 3.

Table 3. Centesimal composition of ground tilapia (*Oreochromis* sp.) and trout (*Oncorhynchus mykiss*) pulp, fish meatballs, and fish nuggets.

Samples (*)	Dry matter (%)	Crude Protein (%)	Lipids (%)	Mineral (%)
Tilapia pulp (C1)	27.20±1.30	15.60±1.04	4.80±0.30	1.35±0.04
Trout pulp (C2)	27.90±1.10	17.80±2.16	4.20±0.80	1.55±0.05
Tilapia pulp meatballs (C1)	30.10±1.10	14.90±2.12	4.20±0.60	1.47±0.05
Trout pulp meatballs (C2)	30.40±1.20	15.00±2.00	4.50±0.60	1.87±0.05
Mixed pulp meatballs (T1)	31.20±1.00	14.50±1.00	4.40±0.60	1.92±0.05
Mixed pulp meatballs (T2)	29.50±1.00	15.00±1.00	4.40±0.60	1.92±0.05
Mixed pulp meatballs (T3)	31.10±1.00	14.30±1.00	4.40±0.60	1.92±0.05
Mixed pulp meatballs (T4)	29.10±1.00	15.10±2.10	4.40±0.60	1.92±0.05
Tilapia pulp nuggets (C1)	29.10±1.10	14.90±2.00	4.20±0.60	1.47±0.05
Trout pulp nuggets (C2)	30.40±1.20	13.90±2.00	4.50±0.60	1.87±0.05
Mixed pulp nuggets (T1)	30.20±1.00	13.10±2.10	4.40±0.60	1.92±0.05
Mixed pulp nuggets (T2)	29.20±1.00	13.10±2.10	4.40±0.60	1.92±0.05
Mixed pulp nuggets (T3)	29.10±1.00	13.10±2.10	4.40±0.60	1.92±0.05
Mixed pulp nuggets (T4)	29.20±1.00	13.10±2.10	4.40±0.60	1.92±0.05

(*) Average (n = 3) of triplicate analyses. Control (C1 and C2); Treatment 1 (T1) 90% trout and 10% tilapia; Treatment 2 (T2) 80% trout and 20% tilapia; Treatment 3 (T3) 70% trout and 30% tilapia; Treatment 4 (T4) 60% trout and 40% tilapia.

The importance of homogenizing the fish base mass (fish pulp) for product preparation is highlighted, due to the lack of any type of change in the final product appearance. The ground fish meat was mixed to obtain C1, C2, T1, T2, T3, and T4. The products did not have any strong characteristic odor, presenting a homogeneous aspect, without the presence of any solid residue resulting in handler or consumer risks.

No statistical differences between physical-chemical parameters between T1, T2, T3, and T4 were observed (p>0.05), considering that the proposed mixtures did not significantly influence nutritional indices when comparing treatments and the individual fresh ground trout and tilapia meat indices. This indicates that the processed meat mixtures may be a viable technological process.

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The average pH values of the ground fish meat samples and the finished products remained close to 6.20±0.30, determined in the chilled samples and at the end of their processing. Aw values in the ground trout and tilapia meat and finished products averaged 0.90±0.15, with a mean BVT value of 21.44±9.76mg N/100g.

All determined BVT values remained close to the average value, although some outliers were responsible for increased standard deviation. As fish is a highly perishable raw material, heterogeneity in single fish batches is noted. The observed deviation may also be associated with differences between specimens and the time between fish acquisition and processing. Some authors believe that a BVT analysis is one of the main methods to assess fish freshness. To Fontes *et al.* (2011), this method was crucial in assessing the quality of fish marketed in Portugal, widely applied worldwide for fish quality control. Similarly, values within established standards were reported by Guimaraes *et al.* (2018), of pH 6.15±0.40 and BVT of 21.44±9.76mg N/100g.

BVT levels and pH indicate processing and food matrix quality. According to the Brazilian legislation, the maximum permitted BVT limit allowed for this type of product is 30mg of N/100g and pH, between 6.5 to 6.8 (Brasil, 2018). Thus, despite the outliers detected herein, the developed products exhibited satisfactory quality levels.

The dry matter content detected in the ground meat and proposed formulations was 29.20%±2.30%. Similar studies with washed fish mechanically separated meat (MSM) report an average moisture content of 80.98%. Moisture values in washed MSM can differ significantly, depending on the types of fish used to form the material (Sary *et al.*, 2009).

Regarding the proposed meatballs and nuggets, dry matter content values were of 28.90%±1.10% and 29.10%±2.10%, respectively. Therefore, a significant variability in moisture content and, consequently, dry matter was noted. As these products are a very hygroscopic material, handling care is necessary to maintain their quality, since nutritional product quality varies greatly with technological processing and species (Berizi *et al.*, 2016).

The mineral matter content of the fish pulp was of 1.45%±0.55%. Sodium and potassium evaluations based on the mineral contents obtained herein considered percentage values of 0.05%±0.03% and 0.06%±0.03%, respectively. Despite the addition of other raw materials during processing, no significant increase in sodium and potassium values were observed. The sodium content present in the final product is directly associated to several cardiovascular problems, being regulated by several agencies. The content determined in this study is in accordance to that proposed by the World Health Organization (WHO), which recommends a daily maximum sodium consumption of 5g per day (Précoma and Oliveira, 2019).

However, according to the Brazilian Society of Cardiology (SBC), Brazil displays a sodium consumption of 2 g per capita per day, which is equivalent to approximately 5.0 g of salt per day (Précoma and Oliveira, 2019). If WHO standards were followed, a 15% reduction in deaths due to strokes and a 10% reduction of infarction episodes would occur in the country. In addition, according to the SBC, if sodium consumption were decreased, 1.5 million hypertensive individuals would no longer have to use antihypertensive drugs and their life expectancy would be increased by over four years (Tratamento…, 2021).

Because dietary preferences for salty foods and overall dietary habits are formed in childhood, it is logical to intervene concerning sodium consumption reduction and stimulation of fish consumption at this age, to avoid consuming a poorer quality diet overall, which puts children at risk for obesity and adult hypertension. Reducing the population-level consumption of processed foods high in sodium may be particularly impactful. Pediatric health care providers must understand the concerns regarding high dietary sodium, counsel families to reduce intake levels and support government and public health strategies to reduce high amounts of dietary sodium.

It is vital to encourage more varied diets, including quality proteins and, especially, adequate nutritionally, with the focus of this study developing processes that can encourage the adequate consumption of fish-based products.

It is important to consider these data, since products able to unify easy technological processing, satisfactory nutritional value and practical consumption may be considered to assist in preventing both the consumption of products containing excess sodium chloride, such as sausages, and fish products, due to their nutritional characteristics, associated with foods indicated for the prevention of heart and vascular diseases.

The amount of lipids in the fish pulps and products were 3.70%±0.30%, in the meatballs, 3.20%±0.80% and in the nuggets, 3.90%±0.60%. Gryschek *et al.* (2003) reported lipid contents of 4.23% and 1.70% in unwashed and washed Nile tilapia MSM, respectively, demonstrating that processing can interfere in material characterization, mainly concerning homogenization. In subsequent studies, Rebouças *et al.* (2012) reported lipids levels in the order of 4.46%, and indicated that the difference in the author's observed levels and literature data is associated to several intrinsic and extrinsic fish specimen factors. Visentainer *et al.* (2007) reported comparative lipid indices for Brazilian marine fish and continental fish farming, indicating mostly values below 10%. This evidences that the food items and seasonal conditions of the fishing process can influence fish nutritional parameters. Chemical lipid reactions are mainly favored by heat treatments, displaying technological importance in innumerable fish production stages, including raw material selection, product development, storage, processing and distribution, and are relevant in product technological development (German, 2012).

In the present study, crude protein was of 16.6±2.04% in fish pulp, and did not vary significantly between the ground meat immediately after preparation and the processed products. Moura *et al.* (2014) reported 15.61% of crude protein in breaded yellow hake fried for three minutes and 30 seconds at approximately 195° C, similar to the values observed herein, mainly in the formulated nuggets. Contreras-Guzmán (1994) when assessing tilapia pulp, consider NNP values around 344mg NNP/100g in Nile tilapia muscle as acceptable post-processing values.

Ribeiro *et al.* (2018) considered that fish processing can influenced final product quality, demonstrating that good processing practices result in adequate final product quality through protein index maintenance and other data. Berizi *et al.* (2016) state that the application of mixtures or bioactive products in rainbow trout pulp or fillets do not significantly influence nutritional parameters of processed fish.

In the present study, fecal coliforms and *Staphylococcus aureus* counts were below the limit of detection ($<10^1$ CFU/g). Furthermore, the absence of *Salmonella* spp. in the raw material, from the handling to the storage period, were all within Brazilian legislation standards as can be seen in Table 4 (Brasil, 2001).

Regarding safety parameters, despite the risk of post-processing contamination, all products were considered safe according to recommended microbiological and toxicological standards (Brasil, 2001, 2018). The choice of applying a quality standard for products aimed at human consumption to the raw materials is due to the need to ensure final product safety, since raw material selection is an important factor in highly manipulated products.

Although not established in current legislations, the psychotropic bacteria count observed herein corroborate the hygienic quality of the developed products, indicating the possibility of chilled storage for a long period of time. However, comparative studies report that processing leads to microbiota food variations. For example, Gümüş *et al.* (2008), reported total aerobic mesophilic bacteria counts ranging from 3.16±0.04 to 2.84±0.05 log CFU/g and total coliform counts ranging from 2.73±0.01 to 2.43±0.02 log CFU/g both before and after product processing.

Table 4. Microbiological counts (log CFU/g) of fecal coliforms, *S. aureus* and *Salmonella* spp.in fish pulp and the processed meatballs and nuggets developed herein

Samples (*)	Fecal coliforms		*S. aureus*		*Salmonella* spp	
	Initial	Storage after 30 days	Initial	Storage after 30 days	Initial	Storage after 30 days
Tilapia pulp (C1)	1.0	1.0	1.0	1.0	Absence	Absence
Trout pulp (C2)	1.0	1.0	1.0	1.0	Absence	Absence
Tilapia pulp meatball (C1)	1.0	1.0	1.0	1.0	Absence	Absence
Trout pulp meatball (C2)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp meatball (T1)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp meatball (T2)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp meatball (T3)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp meatball (T4)	1.0	1.0	1.0	1.0	Absence	Absence
Tilapia pulp nugget (C1)	1.0	1.0	1.0	1.0	Absence	Absence
Trout pulp nugget (C2)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp nugget (T1)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp nugget (T2)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp nugget (T3)	1.0	1.0	1.0	1.0	Absence	Absence
Mixed pulp nugget (T4)	1.0	1.0	1.0	1.0	Absence	Absence

(*) Average for the samples (n = 3) analyzed in triplicate; LOD: log 1.0 CFU/g

The total psychotropic count observed in the present study (Table 5) was of 2.5 ± 1.00 log UFC/g, below the limit allowed by APHA for standard counting on aerobic microorganism plates (Compendium…, 2015). Total psychotropic counts were similar in the processed material and in the base fish pulp.

Higher initial psychotropic counts were reported by Guimarães *et al.* (2018), who demonstrated the need for this analysis to complement the RDC No. 12 set by ANVISA (Brasil, 2001). Total aerobic mesophilic counts were always below 2.00 log CFU/g.

Table 5. Total psychotropic counts (log CFU/g) in fish pulp and the processed meatballs and nuggets developed herein

Samples (*)	Initial	Storage after 30 days
Tilapia pulp (C1)	1.0	1.05±1.00
Trout pulp (C2)	1.0	1.0
Tilapia pulp meatball (C1)	1.0	1.05±1.00
Trout pulp meatball (C2)	1.0	1.45±1.00
Mixed pulp meatball (T1)	1.10±1.00	1.55±1.00
Mixed pulp meatball (T2)	1.0	1.05±1.00
Mixed pulp meatball (T3)	1.0	1.05±1.00
Mixed pulp meatball (T4)	1.0	1.45±1.00
Tilapia pulp nugget (C1)	1.0	1.05±1.00
Trout pulp nugget (C2)	1.0	1.0
Mixed pulp nugget (T1)	1.10±1.00	1.55±1.00
Mixed pulp nugget (T2)	1.0	1.05±1.00
Mixed pulp nugget (T3)	1.10±1.00	1.55±1.00
Mixed pulp nugget (T4)	1.0	1.05±1.00

(*) Average for the samples (n = 3) analyzed in triplicate; LOD: log 1.0 CFU/g

The results obtained in the present study can be compared to those reported by Al-Asous and Al-Harbi (2017) who, when evaluating these microorganisms in post-processed fish, obtained 4.15 ± 0.06 and 4.08 ± 0.04 log CFU/g for mesophilic and psycrotropic bacteria,

respectively, corroborating the quality of good manufacturing practices employed in fish-based product development.

No histamine and sulfur-based compounds were detected in any of the samples. Thus, the

histamine values detected in freshly processed ground meats and products are also in accordance with the Brazilian standard of 10 mg/100g (Brasil, 2017) and the North American standard of 5 mg/100g (Food…, 2004). In the literature, findings ranging from 2 to 5mg/100g in codfish (Mársico *et al*., 2009) and less than 3 mg/100g in processed fish (Tsai *et al*., 2005) are available. Therefore, both the raw material and the processed products developed in the present study presented satisfactory hygienic-sanitary conditions, with no significant handling and processing interferences in product safety.

CONCLUSIONS

The aim of the present study was to develop foods exhibiting high nutritional potential and technologies capable of using processed fish products, resulting in standardized and practical foods products without losing functional and nutritional characteristics. In addition, the use of two food matrices may also be applied by producers in case of trout shortages, as tilapia is more abundant. The final products, despite being prepared from highly perishable raw material and undergoing numerous manipulations, displayed adequate microbiological counts, nutritional parameters and protein and lipid values, demonstrating the importance of applying good manufacturing practices when preparing fish-based foods to maintain product quality and avoid contamination.

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