Acta Scientiarum. Technology
ISSN: 1806-2563
ISSN: 1807-8664
actatech@uem.br
Universidade Estadual de Maringá
Brasil

Development and characterization of fresh sausages made with marine catfish Sciades herzbergii (Bloch, 1794)

Vieira, Pedro Henrique de Sá; Barrros, Carolina Notaro de; Mendes, Emiko Shinozaki; Maciel, Maria Inês Sucupira; Andrade, Humber Agrelli de; Oliveira Filho, Paulo Roberto Campagnoli de

Development and characterization of fresh sausages made with marine catfish Sciades herzbergii (Bloch, 1794)
Acta Scientiarum. Technology, vol. 41, 2019
Universidade Estadual de Maringá, Brasil
Available in: https://www.redalyc.org/articulo.oa?id=303260200054
DOI: https://doi.org/10.4025/actascitechnol.v41i1.40299

Ciência, Tecnologia de Alimentos e Engenharia de Alimentos

Development and characterization of fresh sausages made with marine catfish Sciades herzbergii (Bloch, 1794)

Pedro Henrique de Sá Vieira
Universidade Federal Rural de Pernambuco, Brasil

Carolina Notaro de Barrros
Universidade Federal Rural de Pernambuco, Brasil

Emiko Shinozaki Mendes
Universidade Federal Rural de Pernambuco, Brasil

Maria Inês Sucupira Maciel
Universidade Federal Rural de Pernambuco, Brasil

Humber Agrelli de Andrade
Universidade Federal Rural de Pernambuco, Brasil

Paulo Roberto Campagnoli de Oliveira Filho
Universidade Federal Rural de Pernambuco, Brasil
paulocoliveira79@hotmail.com

DOI: https://doi.org/10.4025/actascitechnol.v41i1.40299
Redalyc: https://www.redalyc.org/articulo.oa?id=303260200054

Received: 01 November 2017
Accepted: 11 September 2018

Abstract:

This study developed fresh marine catfish (*Sciades herzbergii*) sausages with boneless fillets using up to 30% of smoked pork back fat (SPF) and evaluated the nutritional (protein, fat, moisture, ash, carbohydrates and energy value), physicochemical (weight loss, shrinkage, water holding capacity, instrumental texture and color and water activity), microbiological and sensory characteristics. The addition of up to 30% SPF in the sausages increased fat, ash, energy value, and decreased moisture and water activity. Concerning the physicochemical aspects, the increase in SPF increased the weight loss during cooking, shrinkage, lightness, redness and yellowness, and improved sensory properties of odor, flavor and overall acceptance. The sausages presented microbial counts according to the limits allowed for human consumption. Therefore, sausages made with marine catfish fillets presented suitable nutritional, physicochemical, microbiological, and sensory characteristics. However, although higher global acceptance scores were observed with the increase in SPF levels, no significant differences were detected from the inclusion of 10% SPF. Therefore, it is possible to produce fresh marine catfish sausages with a minimum of 10% SPF, to maintain satisfactory technological and sensory characteristics and a healthier appeal.

Keywords: fish processing, meat emulsion, pork fat.

Introduction

The fishing activity in Brazil is focused on obtaining some target species as shrimp, however a great variety of organisms called accompanying fauna or by-catch are also captured. Most of by-catch is discarded by fishermen at sea, resulting in environmental pollution, negative impacts on fish stocks, and losses among fish catches rich in protein, lipids, vitamins, and minerals. In this context, marine catfish is among fish frequently

Author notes

paulocoliveira79@hotmail.com

discarded due to their unattractive features, which ranks 11th among the most caught fish in Brazil (Brasil, 2011).

The marine catfish *Sciades herzbergii* are commonly found in soft bottoms (include environments where the seabed consists of fine grain sediments, mud and sand), feeding on crustaceans, fish, polychaetes, oligochaetes and algal fragments (Ribeiro, Almeida, & Carvalho-Neta, 2012). Adults tolerate changes in salinity and occur in estuaries, muddy sediments, mangroves, and in the benthic zones of rivers. The presence of thorns, the unattractive appearance, and the large variability in size result in low commercial acceptance of catfish, which are usually consumed by fishermen (Vasconcelos-Filho et al., 2017).

Although Brazil is a coastal country, the apparent national fish consumption (10 kg per capita^{-1} year^{-1}) is below the minimum portion of 12 kg per capita^{-1} year^{-1} recommended by WHO (Food and Agriculture Organization [FAO], 2018). Several factors are responsible for the low consumption of fish, including lack of product options, fear of choking on fish bones, and the high price. Thus, an alternative to increase fish consumption in Brazil may be the elaboration of products well-accepted in the market, such as meat sausages and hamburgers (Sleder et al., 2015).

Meat sausage is a product made with meat or edible organs, cured or not seasoned cooked or uncooked smoked and desiccated stuffed in natural or artificial casings. Fat is one of the ingredients of major importance in meat processed products for providing improved aroma, flavor, and tenderness (Cortez-Vega, Fonseca, Feisther, Silva, & Prentice, 2013). However, many industries have reduced the amount of fat in the formulation due to the consumer's requirement to purchase foods with better nutritional quality, with the great challenge of maintaining good sensory acceptance of the processed products. In this sense, studies have been carried out to evaluate the effect of fat reduction on conventional sausage formulations made with meat of terrestrial animals (Nassu, Gonçalves, & Beserra, 2002).

There are few studies on the amount of external fat in fish sausages (Marques, Nunes, Castro, Araujo, & Sales, 2012; Sleder et al., 2015). Therefore, the objective of the present study was to develop marine catfish sausages using different proportions of smoked pork back fat (SPF), and to evaluate the technological, nutritional, microbiological, and sensory characteristics of the processed product.

Material and methods

To prepare the formulations, 44.28 kg of marine catfish *Sciades herzbergii* with an average weight of 221.2 ± 102.0 g were used. Fish were obtained from artisanal fishermen in the municipality of Sirinhaem, State of Pernambuco, packed in boxes with ice and transported to the Fish Technology Laboratory of the Fisheries and Aquaculture Department at UFRPE. In the laboratory, fish were washed in chlorinated water (5 ppm) to remove superficial mucus, and later gutted and filleted (fillet yield of 27.1%). The meat raw material was kept frozen in commercial freezer (-20ºC) until the sausage manufacture.

The formulations were calculated to obtain 3,000 g of sausage per treatment, differing for the addition of smoked pork fat (SPF) (0, 10, 20, 30%). The other ingredients (salt – NaCl; curing salt - Master cura, BRC®, containing salt and sodium nitrite; antioxidant - Master Fix, BRC®, containing sugar, sodium erythorbate and ascorbic acid; stabilizer - Master Fos, BRC®, containing sodium tripolyphosphate; sausage seasoning - Tuscan seasoning, Kraki®, containing refined salt, natural spices, and natural flavorings) were used in the same proportions for all treatments (Table 1).

The fillets were thawed for approximately 24 hours at 6 ± 2ºC, weighed, and ground in a meat grinder with 6 mm disc. Then the milled fillets were mixed manually with the other ingredients, filled into previously desalted natural casings (30-32 mm in diameter), and hand tied so that each sausage had approximately 6 cm in length. The sausages were packed in polyethylene bags (Nylon Poly - 18 x 25 x 0.12 cm, 120 µ), each containing 3 units, which were subjected to a vacuum of 720 mm Hg for 25 s, and stored at -20 ± 2°C until analysis.

Nutritional analysis

The nutritional characterization of sausages was performed according to the official methodology of Association of Official Analytical Chemists (AOAC, 2012). The crude protein was estimated using the Kjeldahl method (N x 6.25); fat was extracted with petroleum ether, in a Soxhlet extractor; moisture was determined by drying in an air circulating oven at 105°C until constant weight; and ash content was determined by incineration in a muffle at 550°C for 5 hours. The carbohydrates were calculated by subtracting the moisture, protein, fat, and ash contents from 100. The energy value was determined by multiplying the percentage of protein and carbohydrate by 4 and fat by 9.

Physicochemical analysis

The percentage weight loss was determined in electric grill during an average time of 25.5 ± 4.24 min. until reaching 90°C, and calculated using the following Equation 1.

TABLE 1.
Formulations of fresh marine catfish *Sciades herzbergii* sausages (3,000g) with addition of different smoked pork fat (SPF) concentrations (0, 10, 20 and 30%).

Ingredients	Treatments (g)			
	0	10	20	30
Marine catfish fillet	2,925.0	2,625.0	2,325.0	2,025.0
Smoked pork fat	0.0	300.0	600.0	900.0
Salt (0.8%)	24.0	24.0	24.0	24.0
Curing salt (0.2%)	6.0	6.0	6.0	6.0
Antioxidant (0.25%)	7.5	7.5	7.5	7.5
Stabilizer (0.25%)	7.5	7.5	7.5	7.5
Sausage seasoning (1%)	30.0	30.0	30.0	30.0

A = 0, B = 10, C = 20, and D = 30% SPF.

$$\%Weight\ loss = \frac{(Weight\ of\ raw\ sausage - Weight\ of\ grilled\ sausage)}{Weight\ of\ raw\ sausage} X100 \qquad (1)$$

(1)

The percentage shrinkage after cooking was determined in electric grill and calculated according to the following Equation 2:

$$\%Shrinkage = \frac{(Length\ of\ raw\ sausage - Length\ of\ grilled\ sausage)}{Length\ of\ raw\ sausage} X100 \qquad (2)$$

(2)

For the analysis of water-holding capacity, 5 g pre-homogenized raw sausage were placed on filter papers, housed in Falcon-type tubes, and centrifuged at 3,500 rpm for 10 min. according to Oliveira Filho, Sobral, Balieiro, and Viegas (2017) with some modifications. After, the samples were carefully removed from the filter paper, weighed, and the water holding capacity was calculated by Equation 3:

$$\%WHC = \frac{Sample\ weight\ after\ centrifugation}{Sample\ weight\ before\ centrifugation} X100 \quad (3)$$

(3)

The instrumental texture was analyzed for the attribute hardness, using a CT3-Brookfield® texture analyzer. The sausages were grilled, sliced 20 mm long, and compressed to 50% of their size, using a TA25/1000 probe with pre-test, test, and post-test speed of 2.0 mm s^{-1} at 25°C, according to Bourne (2002).

The instrumental color was determined using a CR 400 (Konica Minolta®) portable colorimeter, previously calibrated with a white standard before each analysis, using a xenon flash lamp, illuminant C (Y = 92.78; x = 0.3139; y = 0.3200), observation angle of 40º, and surface of 8 mm in diameter. Color was expressed using the CIELab color system: L^* (lightness), a^* (redness), and b^* (yellowness) in the internal region of the raw sausages.

The water activity was measured in the raw sausages pre-homogenized in a food processor, using Aqualab CX-2 apparatus, at 25ºC.

Microbiological analysis

For microbiological characterization, the raw sausages of each treatment were collected aseptically, weighed, and diluted in specific buffers, according to Normative Instruction 62 of the Ministry of Livestock and Food Supply - Mapa (Brasil, 2003). The commercial kits Compact Dry TC®, Compact Dry EC®, and Compact Dry XSA® were used for counts of psychrotrophs, total coliforms, thermotolerant coliforms (*E. coli*), and coagulase-positive *Staphylococcus*, respectively, and the Compact Dry SL® kit was used for investigation of *Salmonella*.

Sensory analysis

Sensory evaluation was performed in a laboratory equipped with individual booths with white fluorescent light. Affective acceptance tests were performed as described by Meilgaard, Civille, and Carr (2006). The sausages were heated until the internal temperature reached 90°C and cut into slices 2 cm long. Two slices of each treatment (approximately 20 grams of sample) were served monadically in random order. Water and biscuit were offered for palate cleansing between the samples. The sensory test was performed with 70 untrained panelists, who were fish consumers, randomly recruited among students, staff, and professors at campus. All assessors evaluated the four samples for the sensory attributes color, odor, texture, flavor, and overall acceptance, scored according to a hedonic scale of 9 points (1 - disliked very much to 9 - liked very much). In addition, the purchase intention was assessed using a 5-point scale (1 - certainly would not buy to 5 - certainly would buy). The acceptability index was calculated based on the scores associated with the attributes of global acceptance, aroma, texture, and flavor, using the following Equation 4 (Dutcosky, 1996):

$$IA = \frac{Ax100}{B} \quad (4)$$

(4)

where:

A is the average score obtained for the product, and *B* is the maximum score given to the product.

The study was approved by the Research Ethics Committee of the University of Pernambuco/Propege, Process # 637.490 (CAAE: 24094213.9.0000.5207).

Statistical analysis

The experimental design was completely randomized with four treatments (0, 10, 20, and 30%) and three replicates (each sausage considered as a replicate) for the physicochemical and microbiological determinations.

The results of the nutritional, physicochemical, microbiological, and sensory determinations were evaluated for normality using the Shapiro-Wilk test and for homoscedasticity with the Bartlett test. When the assumptions were met, first and second order regression analysis was used. As the two models have different dimensions, the comparisons were based on the adjusted coefficient of determination (R^2). Non-parametric Kruskal-Wallis test was adopted when the assumptions of normality and homoscedasticity were not met. In case of significant differences between treatments, non-parametric tests for multiple comparisons were applied to evaluate which concentrations of smoked pork fat (SPF) were associated with the different hedonic values. The analyses were performed with the aid of the free open-source statistical software R.

Results and discussion

The moisture content of the sausages made with *Sciades herzbergii* marine catfish decreased from 75.1 to 64.7% due to the higher amount of smoked pork fat (SPF) in the formulation (Table 2). The regression analysis presented slope and coefficient of determination significantly different from zero ($p = 1.21e^{-7}$), which indicates that the second order model was appropriate to express the relationship between moisture and SPF in fish sausages. The negative relationship between these variables may be due to the replacement of free water by fat. In sausages made with tambaqui meat (*Colossoma macropomum*), the addition between 4.5 and 9% pork fat also led to a decrease in moisture content from 71.1 to 68.8% (Sleder et al., 2015). Sausages made with African catfish (*Clarias gariepinus*) without fat addition presented 74% moisture (Oksuz, Evrendilek, Calis, & Ozeren, 2008), which is close to that found in marine catfish sausages without SPF addition of the present study. This great similarity in moisture contents may be due to the similar physicochemical composition of fish meat. The maximum moisture content allowed by Brazilian legislation in fresh sausages is 70% (Brasil, 2000). Therefore, according to the adjusted second-order model (Table 2), it is observed that the minimum addition of SPF may be 17% in the *Sciades herzbergii* sausages to obtain moisture content close to that allowed by Brazilian legislation.

The fat content of marine catfish sausages increased with the increase in SPF in the formulations (Table 2), from 2.1 (without SPF addition) to 12.2% (30% SPF), which was also observed in other studies. Sausages made with tambaqui meat (*C. macropomum*) with addition of 4.5 to 9% fat presented from 5.45 to 8.33% lipids (Sleder et al., 2015), while salmon meat sausages with addition of salmon oil presented 5.89% lipids (Oliveira et al., 2014). In general, these values are well below the maximum percentage permitted by Brazilian legislation, which is 30% (Brasil, 2000).

No significant differences were detected for the protein content of marine catfish (P = 0.070) (Table 2) with the increase in SPF level, with an average value of 19.2 ± 0.5%. This behavior was also observed in sausages made with tambaqui meat (*C. macropomum*), in which the addition of pork fat did not interfere with the protein values (mean of 18.8%) (Sleder et al., 2015). The protein content of the marine catfish sausages was close to that observed in African catfish sausages (*C. gariepinus*) (20.71%) (Oksuz et al., 2008), thus showing a similarity in protein composition of sausages made with *S. herzbergii* and *C. gariepinus* catfishes. The minimum protein content required by Brazilian law for fresh sausages is 12% (Brasil, 2000). In this study, the protein contents of marine catfish sausages were above the required level, suggesting that it is a high-protein food.

The ash contents (total minerals) of marine catfish sausages increased ($P = 6.79e^{-5}$) with addition of pork fat in the formulation, from 3.3% to 4.2%, according to the second order model (Table 2), probably due to the composition of the raw material, once pork fat contains higher ash levels when compared to catfish fillets. A study with addition of salmon oil in sausages made with salmon meat reported ash levels similar to the present study (Oliveira et al., 2014).

The carbohydrate content of the sausages was very low (approximately 0.1%) which was expected, once vegetable ingredient was not added to the sausage formulations. In contrast, sausages made with tambaqui (*C. macropomum*) containing up to 9% pork fat presented higher carbohydrate values, ranging from 1.2 to 1.3% (Sleder et al., 2015), probably due to the addition of carrageenan in that formulation.

Fish meat naturally has low energy value, and higher energy values in processed products may have a negative impact on human health. Therefore, the energy value of sea catfish sausages was also investigated. According to the adjusted second order model ($P = 9.1e^{-9}$), the addition of SPF increased the energy value of sausages, from 97.3 to 188.2 kcal 100 g^{-1} (Table 2). This increase may be due to the higher caloric contribution of pork fat in relation to catfish fillets. Sausage made with tambaqui meat (*C. macropomum*) with different pork fat concentrations (0 to 9%) also showed an increase in energy value, from 106.69 to 155.47 kcal 100 g^{-1} (Sleder et al., 2015).

The addition of SPF did not affect ($p > 0.05$) (Table 3) the water-holding capacity (WHC) of catfish sausages, with an average value of 79.54 ± 4.32%. Similar behavior was also verified in sausages made with tambaqui meat (*C. macropomum*) with addition of up to 9% pork fat, with no significant differences in WHC (Sleder et al., 2015). According to Huda, Alistair, Lim, and Nopianti (2012), the level of protein denaturation is one of the main factors affecting WHC in meat products. In addition, salt and some additives such as phosphates can also affect the WHC of meat emulsions. The similar amounts of these ingredients used in all treatments may have contributed to the lower changes in WHC of the present study.

A significant increase ($p = 0.0215$) in percentage shrinkage was observed with the increase in SPF levels, which ranged from 11.91 (without SPF) to 17.58% (30% SPF) (Table 3), probably due to the fat disintegration at higher cooking temperatures.

The higher SPF content in fresh sausages made with catfish fillets led to an increase ($p = 1.86e^{-5}$) in cooking loss (28.16 to 44.26%) (Table 3). When subjected to heating, fat tends to dissolve and drain from the product, which may have led to the decrease in weight after cooking. In contrast, Sleder et al. (2015) found no changes in weight loss with the addition of up to 9% pork fat, with values ranging from 24.21 to 26.59%. This may be due to the chemical composition of the muscle of fish species and the differences in pork fat of the sausages under study.

TABLE 2.
Adjusted model, coefficient of determination (adjusted R^2) and P-value of the first and second order regressions of the dependent variables (moisture, protein, fat, ash, and energy value) of fresh sausages made with fillets of the marine catfish *Sciades herzbergii* containing different percentages of smoked pork fat (SPF) (0, 10, 20, and 30%).

Variable	Adjusted model	R^2	p
Moisture (%)	Moisture = 75.588 – 0.345SPF	0.9516	$4.12e^{-8}$*
	Moisture = 75.106 – 0.201SPF – 0.00482 SPF^2	0.9645	$1.21e^{-7}$*
Fat (%)	Fat = 2.026 + 0.336SPF	0.8748	$4.94e^{-6}$*
	Fat = 2.113 + 0.310SPF + 0.000867SPF^2	0.8673	4.58^{-5}*
Protein (%)	Protein = 19.179 + 0.00518SPF	0.075	0.6439
	Protein = 19,426 – 0.0691SPF + 0.00248SPF^2	0.3222	0.070
Ash (%)	Ash = 3.251 + 0.0280SPF	0.8415	$1.62e^{-5}$*
	Ash = 3.305 + 0.0118SPF + 0.000541SPF^2	0.8552	$6.79e^{-5}$*
Energy value (kcal 100 g^{-1})	Energy value = 95.368 + 3.030SPF	0.9666	$6.4e^{-9}$*
	Energy value = 97.277 + 2.458SPF + 0.0191SPF^2	0.9667	$9.1e^{-9}$*

*Significant regressions ($p < 0.05$).

TABLE 3.
Adjusted model, coefficient of determination (adjusted R^2), and P-value of the first and second order regressions of the dependent variables (water-holding capacity, percentage shrinkage, percentage weight loss, hardness, lightness-*L**, redness-*a**, yellowness-*b**, and water activity) of sausages made with fillets of the marine catfish *Sciades herzbergii* containing different percentages of smoked pork fat (SPF) (0, 10, 20, and 30%).

Variable	Adjusted model	R^2	p
Water-holding capacity (WHC) (%)	WHC = 81.637 – 0.0585SPF	0.0448	0.2127
	WHC = 81.816 – 0.112SPF + 0.00179SPF^2	0.0460	0.652
Shrinkage (S) (%)	S = 11.913 + 0.189SPF	0.3679	0.0215*
	S = 12.184 + 0.108SPF + 0.0027SPF^2	0.3062	0.0782
Weight loss (WL) (%)	WL = 28.525 + 0.532SPF	0.8387	$1.86e^{-5}$*
	WL = 28.230 + 0.621SPF – 0.00295SPF^2	0.8218	0.0001*
Hardness (g)	Hardness = 4742.767+40.318SPF	0.046	0.490
	Hardness = 3728.225 + 344.681SPF-10.145 SPF^2	0.1399	0.2057
Lightness (*L**)	*L** = 43.806 + 0.537SPF	0.9216	$4.66e^{-7}$*
	*L** = 42.463 + 0.940SPF – 0.00134SPF^2	0.9696	$6.08e^{-8}$*
Redness (*a**)	*a** = 7.060 + 0.0301SPF	0.2131	0.0740
	*a** = 6.738 + 0.127SPF – 0.00321SPF^2	0.4544	0.0265*
Yellowness (*b**)	*b** = 7.315 + 0.140SPF	0.703	0.0003*
	*b** = 6.608 + 0.352SPF – 0.00708SPF^2	0.8616	$5.35e^{-5}$*
Water activity (*aw*)	*aw* = 0.975 – 0.000482SPF	0.8409	$1.66e^{-5}$*
	aw = 0.974 – 0.000234SPF – 0.00000825 SPF^2	0.8477	$8.50e^{-5}$*

*Significant regressions ($p < 0.05$).

With respect to the attribute hardness, no significant differences were observed in sausages made with marine catfish meat with the increase in SPF ($p > 0.05$) (Table 3), with a mean value of 5347.54 ± 2130.14 g. Hardness of food corresponds to the strength required to produce a certain deformation, and the myofibrillar proteins, myosin and actin, are the main responsible for hardness of meat sausages (Bourne, 2002). Therefore, it can be assumed that the results for hardness of catfish sausages were due to similar protein levels among all treatments. The hardness of the sausages of the present study was close to that observed in several studies, including sausages made with minced fish from Nile tilapia filleting waste (Oliveira Filho, Netto, Ramos, Trindade, & Viegas, 2010), fish sausages commercialized in Malaysia (Huda et al., 2012), and surimi sausage (Santana, Huda, & Yang, 2015).

The L^* value (lightness) of the sausages increased ($p = 6.08e^{-8}$) from 42.46 (without SPF addition) to 58.60 (30% SPF) (Table 3), possibly due to the lightness of the pork back fat. The commercial fish sausages from Malaysia ($L^* = 58.73$) (Huda et al., 2012) were also within the range found in the present study.

The increase in pork fat proportion in catfish sausage formulations significantly changed a^* values (redness) ($p = 0.0265$) from 6.74 (without SPF addition) to 7.66 (30% SPF), according to the adjusted second-order model (Table 3). This increase may be due to the smoked pork fat which made the meat reddish. Therefore, the greater the addition of smoked fat, the redder the sausages were. The a^* values of pasteurized and smoked sausages made with mechanically separated meat (MSM) from Nile tilapia filleting residues ($a^* = 6.16$) (Dallabona et al., 2013) were close to those observed in the present study.

According to the adjusted second-order model (Table 3), the color coordinate b^* (yellowness) increased ($p = 5.35e^{-5}$) with the addition of SPF in marine catfish sausages from 6.61 (without SPF addition) to 10.80 (30% SPF). This response may be due to the use of smoked fat, which causes the Maillard reaction (or caramelization), making the products more yellowish. Meagre sausages (*Argyrosomus regius*) and surimi sausages presented b^* values of 7.39 to 8.89 and 10.68, respectively, (Ribeiro et al., 2013; Santana et al., 2015), which was close to those of the present study.

The water activity (*aw*) corresponds to the amount of free water in meat tissues, and most of the bacteria develop in water activity > 0.88 (Hoffmann, 2001). The water activity (*aw*) of sausages made with *S. herzbergii* catfish fillets decreased ($p = 8.50e^{-5}$) from 0.974 (without SPF addition) to 0.960 (30% SPF), with better description by the second order model (Table 3). This reduction in *aw* with the addition of SPF in sausages may be due to the substitution of free water by the fat present in SPF. The aw values of the sausages of the present study were close to those observed in mortadella made with MSM from Nile tilapia (*aw* = 0.982) (Bartolomeu et al., 2014) and Nile tilapia fillet sausages (*aw* = 0.980) (Dallabona et al., 2013). The high water activity of these products demonstrate they are quite susceptible to the proliferation of microorganisms such as bacteria and fungi, and thus should be stored under refrigeration.

The bacterial counts of catfish sausages are listed in Table 4. Total coliforms and coagulase-positive *Staphylococcus* were found in the sausages, with no significant differences ($p > 0.05$) between treatments. No *Salmonella* counts were detected in the samples studied, while the enumeration of *E. coli* and psychrotrophic bacteria was less than 1 log CFU g^{-1} in all samples.

No significant pathogenic bacteria counts were detected in sausages made with tambaqui meat (*C. macropomum*) containing pork fat (Sleder et al., 2015). In addition, sausages made with tilapia meat (*Oreochromis niloticus*) with or without addition of SPF (7%) also presented low microbial counts (Marques et al., 2012).

According to Resolution RDC 12, of January 2, 2001, of the National Agency of Sanitary Surveillance - Anvisa, fish-based products should contain maximum microbial counts of 3 log CFU g^{-1} of *E. coli*, 3 log CFU g^{-1} coagulase-positive *Staphylococcus*, and no *Salmonella* spp. in 25 g sample. However, there are no limits for total coliforms and psychrotrophic bacteria counts. Therefore, according to the Brazilian legislation, all marine catfish sausages of this study were within the legal standards established for consumption.

No significant differences were observed for the color acceptance of marine catfish sausages ($p > 0.05$), with the addition of SPF (0 to 30%), ranging from 7.3 to 7.7 (corresponding to 'liked moderately') (Table 5). Similar results were also observed for tambaqui sausage (*C. macropomum*), with no changes with the addition of up to 9% SPF in the formulations (Sleder et al., 2015). The color results of this study were close to those found in mortadella (Bartolomeu et al., 2014) and pasteurized sausages (Dallabona et al., 2013) made with MSM from Nile tilapia filleting waste. For the attribute color, the acceptability index of marine catfish sausages was above 80%, thus indicating good acceptance. According to Dutcosky (1996), acceptance scores above 70% represent that most of the consumers approved the product. The vongole sausage presented acceptability index of 80% for the color attribute (Bispo, Santana, & Carvalho, 2004), while sausages made with tambaqui meat had acceptability index ranging from 80 to 83% (Sleder et al., 2015).

The odor of marine catfish sausages improved ($p < 0.05$) with increasing SPF levels, from 7.1 to 7.9 ('liked moderately') (Table 5). Probably the better acceptance was due to the substitution of fish odor by smoke odor. In agreement with the present study, the odor of trout sausages made with fresh or frozen fillets also presented better acceptance scores (Dincer & Cakli, 2010), which was also observed in mortadella made with MSM from Nile tilapia (Bartolomeu et al., 2014). For the attribute odor, the acceptability index of the sausages ranged from 78.6% in those formulated without addition of pork fat to 87.3% with addition of 30% pork fat.

The texture of the marine catfish sausages containing different SPF levels corresponded to the score 'liked moderately' (7.3 to 7.6), with no significant differences ($p > 0.05$) between treatments (Table 5). The acceptability index ranged from 81.6 to 84.8%, that is, above 70%, thus showing good acceptance for the attribute texture. This result agrees with those obtained in the instrumental hardness, showing that SPF had little impact on the texture of marine catfish sausages within the range studied (0 to 30%). Other studies on fish sausages presented texture acceptance close to that observed for sea catfish sausages (Prabpree & Pongsawatmanit, 2011; Dallabona et al., 2013; Bartolomeu et al., 2014).

The flavor of the sausages improved ($p < 0.05$) with increasing SPF levels, which ranged from 6.8 ('liked slightly', without SPF addition) to 7.9 ('liked moderately', with 30 % SPF) (Table 5). The acceptability index (AI) for the attribute flavor varied from 75.9 to 87.5%, increasing with the addition of SPF. When subjected to heating, SPF tends to mix with the other ingredients, enhancing the product's flavor. However, excessive fat intake can cause health problems. Therefore, the food industry should produce a meat product formulation with minimal fat levels to maintain the technological and sensory aspects, without affecting the nutritional quality. Similar flavor acceptance scores were found in sausages made with vongole shellfish (Bispo et al., 2004) and mortadella made with MSM from tilapia filleting residues (Bartolomeu et al., 2014).

TABLE 4.

Microbiological characterization of sausages made with fillets of the marine catfish *Sciades herzbergii* containing different percentages (0, 10, 20, and 30%) of smoked pork fat (SPF)1.

Microbiological characterization	SPF (%)			
	0	10	20	30
Total coliforms (log CFU g^{-1})	1.1 ± 0.8^a	2.2 ± 0.4^a	2.7 ± 0.5^a	3.3 ± 0.1^a
E. coli (log CFU g^{-1})	$< 1^a$	$< 1^a$	$< 1^a$	$< 1^a$
Salmonella (25 g sample)	Absence	Absence	Absence	Absence
Coagulase-positive *Staphylococcus* (log CFU g^{-1})	2.1 ± 0.8^a	2.1 ± 1.1^a	2.8 ± 0.2^a	3.0 ± 0.8^a
Psychrotrophs (log CFU g^{-1})	$< 1^a$	$< 1^a$	$< 1^a$	$< 1^a$

[1]Different letters in the same row indicate a significant difference ($p < 0.05$).

TABLE 5.
Sensory evaluation (mean ± standard deviation), acceptability index (AI -%), and purchase intention - PI (mean ± standard deviation) of sausages made with fillets of the marine catfish *Sciades herzbergii* containing different percentages (0, 10, 20, and 30%) of smoked pork fat (SPF)[1].

Sensory attributes[2]	SPF (%)			
	0	10	20	30
Color	7.4±1.4[a]	7.7±1.2[a]	7.5±1.2[a]	7.3±1.7[a]
AI (%)	82.5	85.1	83.0	80.6
Odor	7.1±1.7[b]	7.6±1.4[ab]	7.8±1.0[ab]	7.9±1.2[a]
AI (%)	78.6	84.0	86.5	87.3
Texture	7.3±1.6[a]	7.5±1.3[a]	7.6±1.4[a]	7.5±1.5[a]
AI (%)	81.6	82.9	84.8	83.8
Flavor	6.8±1.8[c]	7.3±1.5[bc]	7.8±1.1[ab]	7.9±1.4[a]
AI (%)	75.9	80.6	86.2	87.5
Overall acceptance	7.0±1.5[b]	7.3±1.3[ab]	7.7±1.0[ab]	7.7±1.3[a]
AI (%)	78.1	81.3	85.2	85.6
PI[3]	3.6±1.2[b]	3.8±1.1[ab]	4.1±0.9[a]	4.1±1.0[a]

[1]Different letters in the same row indicate a significant difference by Tukey's test ($p < 0.05$). [2]Nine-point hedonic scale (9 - liked extremely, 8- liked very much, 7- liked moderately, 6 - liked slightly, 5 - neither liked nor disliked, 4 - disliked slightly, 3 - disliked moderately, 2 - disliked very much, 1- disliked extremely). [3]Five-point hedonic scale (5 - certainly would buy, 4 - probably would buy, 3 - doubt if would buy, 2 - probably would not buy, 1 - certainly would not buy).

Better overall acceptance ($p < 0.05$) was found with an increase of up to 30% SPF in the sausages, which ranged from 7.0 to 7.7 ('liked moderately'), and acceptability index ranging from 78.1 to 85.6% (Table 5). However, since there was no significant difference from 10% SPF inclusion, and the descriptive score remained as 'liked moderately', it is possible to reduce the SPF levels without compromising the overall acceptance of marine catfish sausages. Other studies on fish sausages also presented a classification of 'liked moderately' for the overall acceptance (Prabpree & Pongsawatmanit, 2011; Marques et al., 2012; Dallabona et al., 2013; Bartolomeu et al., 2014).

The purchase intention of *Sciades herzbergii* marine catfish sausages was higher ($p < 0.05$) with the increase in SPF levels, with no significant difference from 10 % inclusion (Table 5).

Conclusion

Fresh sausages made with fillets of the marine catfish *Sciades herzbergii* exhibited good nutritional, physicochemical, microbiological, and sensory characteristics. However, although the overall acceptance scores have improved with the increase in smoked pork fat (SPF) levels, a significant difference was not found from the inclusion of 10% SPF. Therefore, it is possible to produce fresh sausages containing 10% SPF, with satisfactory technological and sensory characteristics and healthy appeal.

Acknowledgements

The authors thank the National Council for Scientific and Technological Development (CNPq) for the financial support of the project through the Universal Call MCTI/CNPq 14/2013, process 470655/2013-5.

References

Association of Official Analytical Chemists [AOAC]. (2012). Official methods of analysis of the AOAC (19th ed.). Gaithersburg, MD: AOAC.

Bartolomeu, D. A. F. S., Waszczynskyj, N., Kirschnik, P. G., Dallabona, B. R., Costa, F. J. O. G., & Leivas, C. L. (2014). Storage of vacuum-packaged smoked bologna sausage prepared from Nile tilapia. Acta Scientiarum. Technology, 36(3), 561-567. doi: 10.4025/actascitechnol.v36i3.18263

Bispo, E. S., Santana, L. R. R., & Carvalho, R. D. S. (2004). Aproveitamento industrial de marisco na produção de linguiça. Ciência e Tecnologia de Alimentos, 24(4), 664-668. doi: 10.1590/S0101-20612004000400031

Bourne, M. C. (2002). Food texture and viscosity: concept and measurement (2nd ed.). London, GB: Academic Press.

Brasil. (2000). Instrução normativa n. 4, de 31 de março de 2000. Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal (RIISPOA). Brasília, DF: Diário Oficial da União.

Brasil. (2003). Instrução normativa n. 62 de 26 de agosto de 2003. Oficializa os métodos analíticos oficiais para análises microbiológicas para controle de produtos de origem animal e água. Brasília, DF: Diário Oficial da União.

Brasil. (2011). Boletim estatístico da pesca e aquicultura 2011. Brasília, DF: Diário Oficial da União.

Cortez-Vega, W. R., Fonseca, G. G., Feisther, V. A., Silva, T. F., & Prentice, C. (2013). Evaluation of frankfurters obtained from croaker (Micropogonias furnieri) surimi and mechanically deboned chicken meat surimi-like material. CyTA - Journal of Food, 11(1), 27-36. doi: 10.1080/19476337.2012.680199

Dallabona, B. R., Karam, L. B., Wagner, R., Bartolomeu, D. A. F. S., Mikos, J. D., Francisco, J. G. P., ... Kirschnik, P. G. (2013). Effect of heat treatment and packaging systems on the stability of fish sausage. Revista Brasileira de Zootecnia, 42(12), 835-843. doi: 10.1590/S1516-35982013001200001

Dincer, T., & Cakli, S. (2010). Textural and sensory properties of fish sausage from rainbow trout. Journal of Aquatic Food Product Technology, 19(3-4), 238-248. doi: 10.1080/10498850.2010.509539

Dutcosky, S. D. (1996). Análise sensorial de alimentos. Curitiba, PR: Champagnat.

Food and Agriculture Organization [FAO]. (2018). The state of world fisheries and aquaculture 2018. Meeting the sustainable development goals. Rome, IT: FAO.

Hoffmann, F. L. (2001). Fatores limitantes à proliferação de microorganismos em alimentos. Brasil Alimentos, 9(1), 23-30.

Huda, N., Alistair, T. L. J., Lim, H. W., & Nopianti, R. (2012). Some quality characteristics of Malaysian commercial fish sausage. Pakistan Journal of Nutrition, 11(8), 798-803. doi: 10.3923/pjn.2012.798.803

Marques, L. F., Nunes, J. S., Castro, D. S., Araujo, L. K., & Sales, M. L. S. (2012). Avaliação da qualidade de linguiça de tilápia do Nilo (Oreochromis niloticus). Revista Semiárido de Visu, 2(1), 3-10.

Meilgaard, M., Civille, G. V., & Carr, T. B. (2006). Sensory evaluation techniques (4th ed.). Boca Raton, FL: CRC Press.

Nassu, R. T., Gonçalves, L. A. G., & Beserra, F. J. (2002). Efeito do teor de gordura nas características químicas e sensoriais de embutido fermentado de carne de caprinos. Pesquisa Agropecuária Brasileira, 37(8), 1169-1173. doi: 10.1590/S0100-204X2002000800015

Oksuz, A., Evrendilek, G. A., Calis, M. S., & Ozeren, A. (2008). Production of a dry sausage from African catfish (Clarias gariepinus, Burchell, 1822): microbial, chemical and sensory evaluations. International Journal of Food Science and Technology, 43(1), 166-172. doi: 10.1111/j.1365-2621.2006.01418.x

Oliveira Filho, P. R. C., Netto, F. M., Ramos, K. K., Trindade, M. A., & Viegas, E. M. M. (2010). Elaboration of sausage using minced fish of Nile tilapia filleting waste. Brazilian Archives of Biology and Technology, 53(6), 1383-1391. doi: 10.1590/S1516-89132010000600015

Oliveira Filho, P. R. C., Sobral, P. J. A., Balieiro, J. C. C., & Viegas, E. M. M. (2017). Comparison of stunning methods on the physicochemical properties of frozen Nile tilapia (Oreochromis niloticus) fillets. Journal of Aquatic Food Product Technology, 26(3), 325-334. doi: 10.1080/10498850.2016.1184205

Oliveira, A. C. M., Himelbloom, B. H., Montazeri, N., Davenport, M., Biceroglu, H., Brenner, K. A., ... Crapo, C. A. (2014). Development and characterization of fish sausages supplemented with salmon oil. Journal of Food Processing and Preservation, 38(4), 1641-1652. doi: 10.1111/jfpp.12126

Prabpree, R., & Pongsawatmanit, R. (2011). Effect of tapioca starch concentration on quality and freeze-thaw stability of fish sausage. Kasetsart Journal (Natural Science), 45(2), 314-324.

Ribeiro, B., Cardoso, C., Silva, H. A., Serrano, C., Ramos, C., Santos, P. C., & Mendes, R. (2013). Effect of grape dietary fibre on the storage stability of innovative functional seafood products made from farmed meagre

(Argyrosomus regius). International Journal of Food Science and Technology, 48(1), 10-21. doi: 10.1111/j.1365-2621.2012.03151.x

Ribeiro, E. B., Almeida, Z. S., & Carvalho-Neta, R. N. F. (2012). Hábito alimentar do bagre Sciades herzbergii (Siluriformes, Ariidae) da Ilha dos Caranguejos, Maranhão, Brasil. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 64(6), 1761-1765. doi: 10.1590/S0102-09352012000600048

Santana, P., Huda, N., & Yang, T. A. (2015). Physicochemical properties and sensory characteristics of sausage formulated with surimi powder. Journal of Food Science and Technology, 52(3), 1507-1515. doi: 10.1007/s13197-013-1145-1

Sleder, F., Cardoso, D. A., Silva, L. S. S., Abreu, J. S., Oliveira, A. C. S., & Almeida Filho, E. S. (2015). Development and characterization of a tambaqui sausage. Ciência e Agrotecnologia, 39(6), 604-612. doi: 10.1590/S1413-70542015000600007

Vasconcelos-Filho, M. B., Oliveira, C. R. R., Melo, C. C., Silva, M. A. P., Andrade, H. A., & Oliveira Filho, P. R. C. (2017). Rendimento corporal do bagre marinho, Sciades herzbergii. Arquivos de Ciências do Mar, 50(1), 72-80. doi: 10.32360/acmar.v50i1.18823