BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

EFFECT OF THE ADDITION OF PREGELATINIZED STARCH AND DEXTRIN IN THE FORMULATION OF TILAPIA MECHANICALLY SEPARATED MEAT PATTIES

Flávia Renata Potrich Signor[1]
Gislaine Silveira Simões[2]
Priscila Ferri Coldebella[3]
Arcangelo Augusto Signor[4]
Wilson Rogério Boscolo[1]

[1] Universidade Estadual do Oeste do Paraná – UNIOESTE, Departamento de Engenharia de Pesca, Rua da Faculdade, 645, CEP 85903-160, Toledo, PR, Brasil. E-mail: flavia-potrich@hotmail.com (corresponding author).

[2] Instituto Federal do Paraná – IFPR, Departamento de Gastronomia, Av. Araucária, 780, Vila A, CEP 85860-000, Foz do Iguaçu, PR, Brasil.

[3] Universidade Federal da Integração Latino-Americana – UNILA, Departamento de Engenharia Química, Av. Silvio Américo Sasdelli, 1842, Vila A, CEP 85866-000, Foz do Iguaçu, PR, Brasil.

[4] Instituto Federal do Paraná – IFPR, Departamento de Engenharia de Aquicultura, Av. Araucária, 780, Vila A, CEP 85860-000, Foz do Iguaçu, PR, Brasil.

Received: March 01, 2019
Approved: July 30, 2019

ABSTRACT

Pre-gelatinized starch and dextrin help in the gelatinization of patties without adding heat to improve texture. Aiming to evaluate the effect of the addition of pre-gelatinized starch and dextrin in the preparation of mechanically separated meat patties obtained from Nile tilapia filetage residues. An experimental planning of the rotational central Composite Design (DCCR) 2 ^{2} with 4 axial points with 9 formulations and 4 replications at the central point was applied, totaling 12 assays. A base formulation is developed to be applied in the design with different levels (0, 0.5, 1, 2, 3%) According to the planning (DCCR), pre-gelatinized starch and dextrin. A regression model was developed for the variable Shear Force response (texture). Analyses of chemical composition, Aw, ph, texture and scanning microscopy and sensory analyses were performed. For the development of the patties the best result was for 1.5% of pre-gelatinized starch and 1.0% dextrin. Thus, the use of mechanically separated meat with the addition of pre-gelatinized starch and dextrin to produce restructured products is of great importance for the fish industry, as it improves the texture of the breaded presented a Greater acceptance by consumers.

Key words: nutritional characteristics; pasty texture; acceptability; restructured products.

EFEITO DA ADIÇÃO DE AMIDO PRÉ-GELATINIZADO E DEXTRINA EM EMPANADOS DE CARNE MECANICAMENTE SEPARADAS DE TILÁPIA

RESUMO

Amido pré-gelatinizado e dextrina auxiliam na gelatinização de empanados e melhoram a textura sem uso de calor. O objetivo deste trabalho foi avaliar o efeito da adição de amido pré-gelatinizado e dextrina na preparação de empanados de carne mecanicamente separada obtida a partir de resíduos da filetagem de tilápia do Nilo. Foi aplicado um planejamento experimental do tipo delineamento composto central rotacional (DCCR) 2^2 com 4 pontos axiais, sendo 9 formulações e 4 repetições no ponto central, totalizando 12 ensaios. Sendo desenvolvido uma formulação base para ser aplicado no delineamento com diferentes níveis (0, 0,5, 1, 2, 3%) de acordo com o planejamento (DCCR), de amido pré-gelatinizado e dextrina. Foi desenvolvido modelo de regressão para a variável resposta força de cisalhamento (textura). Foram realizadas análises de composição química, Aw, pH, textura e microscopia de varredura e análises sensorial. Para o desenvolvimento dos empanados o melhor resultado foi adição de 1,5% de amido pré-gelatinizado e 1,0% dextrina. Desta forma, o aproveitamento da carne mecanicamente separada com adição de amido pré-gelatinizado e dextrina para a produção de produtos reestruturados mostrou-se de grande importância para a indústria do pescado, pois melhorou a textura dos empanados apresentado uma maior aceitação por parte dos consumidores.

Palavras-chave: características nutricionais; textura de empanados; aceitabilidade; produtos reestruturados.

INTRODUCTION

Aquaculture and fisheries are important activities in the production of food, employment and income for several people (Santos et al., 2014; Lustosa-Neto et al., 2018). Among consumed fish species, tilapia (*Oreochromis niloticus*) has a great potential in the economic activity (Lago et al., 2016) being marketed as whole fish, fresh cuts, or frozen fillets, however, consumers show a preference in the consumption of fillets (Oliveira Filho et al., 2012). Thus, tilapia processing industries utilize only fillets and discard the backbone, ventral abdominal muscle, deep hypaxial muscle, and fillet final shavings to be used in the further production of fish meal for animal feed (Vidal et al., 2011).

However, the meat adhered to the spinal column has nutritional characteristics that can be used through mechanical separation generating the material called mechanically separated meat – MSM CMS (Kirschnik and Macedo-Viegas, 2009; Palmeira et al., 2016; Magalhães et al., 2019). The nutritional characteristics of MSM show great variation as the result of variations in its production process. Kirschnik and Macedo-Viegas (2009); Freitas et al. (2012); Kirschnik et al. (2013); Fogaça et al. (2015) report varying values in moisture (62.17 to 79.84%), crude protein (9.75 to 15.87%), lipids (2.91 to 18.81%), and mineral matter (1.00 to 2.11%). Nevertheless, the transformation of these residues into products for human consumption is a great alternative for the utilization of tilapia residues (Vidal et al., 2011; Freitas et al., 2012), besides reducing the deposition of organic waste in the environment improving the concept of sustainability (Magalhães et al., 2019), as occurs in other productive chains of chickens, pigs and cattle (Lustosa-Neto et al., 2018).

One of the main challenges of the food industry is to produce convenience foods with additional nutritional value, accessible and sensory cost properties (Monteiro et al., 2018), and easiness of preparation, which has led the fish processing industry to develop alternative products such as hamburgers and breaded patties among others, in order to market pre-prepared products that are called restructured products produced from MSM (Vieira et al., 2015). Therefore, besides minimizing the wasteful use of residues, the industry, guarantees increased added value to these products.

Patties are among these widely consumed alternative products. According to the technical standards of the Brazilian quality and identity (Brasil, 2001b), breaded patties are industrialized meat products obtained from meat and/or MSM from different animal species, processed into pulp with the addition of other ingredients, and subjected to an appropriate heat treatment.

The formulation of patties should contain at least 30% of the designated raw material, except in the case of liver where the threshold may be 20%; optional ingredients may be incorporated such as salt, vegetable proteins, sugars, maltodextrins, starch, seasonings, spices, and aromas among others (Freitas et al., 2012). The fish is a functional and highly nutritious food (Sousa et al., 2019). A maximum of 30% of total carbohydrates and a minimum of 10% of protein, being 4% of non-meat protein, should be in the chemical composition of patties (Brasil, 2001b).

Hence, the food industry in this sector has been looking for alternative ingredients, such as tilapia MSM that can improve the nutritional and sensorial quality of its products.

Starch is among the main ingredients in the preparation of patties because it improves the sensory aspects of texture and flavor (Zhang and Barbut, 2005). Starch is a polysaccharide extracted from edible parts of plants (Raphaelides et al., 2012). It is used in the food industry as a thickener facilitating the processing and providing increased texture to the product (Sharma et al., 2008). In addition, because it has good sensory characteristics and water affinity, it is widely used in the meat industry due to its low cost and features that are appropriate for specific technologies that meet industrial requirements and consumer acceptability (Pedroso and Demiate, 2008; Cavenaghi-Altemio et al., 2013).

The pregelatinized starch is a modified product; it is precooked and dried by manufacturers and reconstituted in water to provide viscosity (Pongjaruvat et al., 2014). Therefore, it is an alternative to promote agglutination, improving thickening, texture, stability, and sensation to the palate besides reducing the absorption of oil (Altunakar et al., 2004).

Another alternative ingredient in the formulation of breaded patties is dextrin. Dextrin has a wide variety of applications such as in the production of adhesive, food, textiles, and cosmetics (Mason, 2009), and drugs (Takatori et al., 2011). Dextrins are a class of low molecular weight carbohydrates and represent a mixture of polymers of D-glucose (α-1.4) produced by the partial hydrolysis of starch (Silva et al., 2014). Its structure is similar to that of starch; however, it is smaller and less complex. It is widely used as food additives (Manchun et al., 2014) because it reduces viscosity resulting in the conservation of crunchiness in the product for longer periods after frying (Sanz et al., 2004; Manchun et al., 2014).

Thus, was evaluated in this study the addition of pregelatinized starch and dextrin in the formulation of patties using mechanically separated meat obtained from fillet residues of Nile tilapia.

MATERIAL AND METHODS

Raw material

Tilapia mechanically separated meat (Brazilian Indústria e Comércio de Peixes Ltda, Toledo/PR, Brazil), pregelatinized starch and dextrin (GTfoods, Quatro Pontes/PR, Brazil), hondashi® (Ajinomoto, São Paulo/SP, Brazil), sodium erythorbate (Pryme Foods, Sorocaba/SP, Brazil), tripolyphosphate (Saber Química, Barueri/SP, Brazil), dehydrated onion and garlic, white pepper (Kitano, São Paulo/SP, Brazil), sodium chloride (Cisne, São Paulo/SP, Brazil), and flour for breading (Baptistella, Itatiba/SP, Brazil) were used in the formulation of patties.

Obtaining the raw material

Tilapia carcasses were used for processing MSM after filleting and excluding the head, viscera, trimmings, and fins; the excess of fat was removed through a ventral cut. Subsequently, the MSM was subjected to a washing process in a low-speed centrifuge (Engelmac, Brazil) with 5 ppm of chlorinated water for 5 minutes, cooled down in a cold room, and submitted to a depulper (MT 250, Hich Tech, Brazil) to obtain the MSM, and frozen at -18 °C ± 2 °C.

Pre-treatment of raw material

The MSM was thawed in a refrigerator (6 ± 2°C) for 12 hours and subjected to the pressing process with the aid of a screw press (Etiel Gramado/Rio Grande do Sul, Brazil); batches were standardized as 1.5 kg. An initial manual force was applied for 5 minutes for the initial blood and water loss, followed by another 5 minutes.

Experimental design

In order to evaluate the effect of pregelatinized starch and dextrin in the formulation of tilapia MSM patties, the Rotational Central Compound Design (RCCD) was applied consisting of a complete 2^2 factorial experimental design, 4 axial points, and 4 repetitions at the central point, totaling 12 assays representing 9 different formulations (Table 1). The effect of the concentrations of pregelatinized starch and dextrin on the texture (shear force) of tilapia MSM patties and the ideal percentage of pregelatinized starch and dextrin were verified with this experimental design.

The independent variables (starch and dextrin levels) and levels of variation in the planning were defined according to (Vieira et al., 2015).

The experiments were performed in a random order (Table 2) based on the matrix with the coded, and real values used to perform the tests in this RCCD.

The second-order model used to adjust the response of independent variables is presented in Equation 1:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i=1}^{k=1} \sum_{\substack{j=2 \\ i<j}}^{k} \beta_{ij} X_i X_j + \varepsilon \qquad (1)$$

where: Y is the expected response (shear force in Newton); Xi is the percentage of pregelatinized starch, and Xj is the percentage of dextrin; are input variables x_i (i= 1, 2...k) influence the response Y; k is the number of variables; β_0 is the constant term intersection; β_i is the i^a linear coefficient; β_{ii} is the i^a quadratic coefficient; βij (j= 1, 2...k) interaction coefficient, and ϵ is the model prediction error.

Preparation of tilapia MSM patties

The following ingredients were combined in the formulation of tilapia MSM patties: textured soy protein (2%) and ice (16%) were firstly mixed in an electric processor (RI7620/71, Philips, Brazil) for homogenization, followed by the addition of sodium erythorbate (0.20%), tripolyphosphate (0.15%), dehydrated onion (0.20%), dehydrated garlic (0.15%), dehydrated rosemary (0.03%), dehydrated parsley (0.10%), sodium (1.30%), and hondashi® (1.5%), and white pepper (0.03%). The MSM (approximately 78% of the total formulation), pregelatinized starch, and dextrin were subsequently added according to the RCCD schedule (Table 2). This final mixture was manually homogenized for 5 minutes. The patties were shaped manually with the aid of a rectangular cast with 1.1 cm in height, 2.5 cm in width, and 6 cm in length to maintain product size uniformity. Patties were submitted to a pre-coating process in white flour, immersed in a coating liquid, and coated in bread flour.

To calculate the minimum and maximum percentages of *pick up*, five samples of each formulation were separated, and the patties' weight uniformity were calculated according to (Gonçalves, 2011) using Equation 2:

$$Pick-up(\%) = \frac{P_f - P_i}{P_f} x100 \qquad (2)$$

where: P_f is the final coated weight (g), and P_i is the initial uncoated weight (g).

The patties were pre-fried in vegetable oil soybean (180 °C ± 5 °C) for 30 seconds using a fryer with a screen; the oil temperature was

Table 1. Rotational Central Compound Design (RCCD) to formulation of tilapia MSM patties.

Factors	Code	Level				
		-1.41	-1	0	1	1.41
(X_1) Starch composition (%)	X_1	0.0	0.50	1.0	2.0	3.0
(X_2) Dextrin composition (%)	X_2	0.0	0.50	1.0	2.0	3.0

Table 2. Matrix Rotational Central Compound Design (RCCD) and shear force response.

Assay	Starch (%)	Dextrin (%)	Shear Force (N)	
			Average	Standard deviation
1	0.5 (-1)	0.5 (-1)	13.53	0.81
2	0.5 (1)	2.0 (+1)	16.56	1.06
3	2.0 (1)	0.5 (-1)	13.84	0.59
4	2.0 (1)	2.0 (1)	14.92	0.82
5	0.0 (-1.41)	1.0 (0)	11.13	1.27
6	3.0 (1.41)	1.0 (0)	9.30	0.80
7	1.0 (0)	0.0 (-1,41)	13.83	0.95
8	1.0 (0)	3.0 (1,41)	14.85	1.28
9	1.0 (0)	1.0 (0)	14.44	2.80
10	1.0 (0)	1.0 (0)	15.70	1.01
11	1.0 (0)	1.0 (0)	15.56	3.29
12	1.0 (0)	1.0 (0)	15.09	1.08

monitored with a digital thermometer (TP 3001, China). These pre-fried samples were packed in polyethylene bags and stored in a household freezer (-10 to -8°C) until analysis.

Baked patties were prepared using frozen patties placed in a gas oven (FLG 700, G. PANIZ, Brazil) at 200 °C ± 5 °C for 15 minutes on each side. A skewer thermometer (TP 3001, digital thermometer, China) was used to ensure that the cooking temperature in the geometric center of patties reached a minimum and maximum temperature of 72 °C and 75 °C, respectively.

The yield was determined by the average weight of 5 samples of each formulation. The yield of each formulation was calculated according to Equation 3 (Berry, 1992).

$$Yield(\%) = \frac{P_f}{P_i} x100 \quad (3)$$

where: P_f is the final baked weight (g), and P_i is the initial weight before baking (g).

Texture analysis

The patties texture is directly related to the shear force. A texturometer (TAHD pluse, TATX-2i, Brazil) with a Warner Bratzler probe and a 5 kg load cell was used to evaluate the patties shear force. The patties were baked in an electric oven (FLG 700, G. PANIZ, Brazil) at 200 °C for 15 minutes on each side and cooled to room temperature. The cutting speed was 2.0 mm/s with a 35.00 mm thickness; the results were expressed in Newton (N).

Chemical characterization of tilapia MSM patties

Proximal composition, pH, and water activity were analyzed in tilapia MSM *in natura* and pressed in patties.

The methodologies adopted by the AOAC (2000) were used for the analysis of proximal composition (dry matter, mineral matter, lipids, and crude protein). The nitrogen conversion factor used for the crude protein analysis was 6.25.

The pH was verified in 10 g of sample homogenized in 50 mL of distilled water using a pH meter (mPA 210, Tecnopon, Brazil).

The water activity (Aw) was measured using a water activity analyzer (Labswift, Novasina, Brazil).

Microbiological analysis

The microbiological quality of tilapia MSM and patties obtained under optimized conditions was analyzed. Counts of coagulase positive *Staphylococci*, *Salmonella* sp., and coliforms were performed at 45 °C according to Brasil (2001a).

Analyzes using scanning electron microscopy

Microscopic analysis was conducted in an emulsion of Tilapia MSM patties obtained under optimized conditions of pregelatinized starch and dextrin concentrations and in control samples (Tilapia MSM patties without pregelatinized starch and dextrin), both before the breading process.

These samples were previously lyophilized (Lyophilizer L101, Liobras, Brazil) for 48 hours and analyzed by scanning electron microscopy (Philips/FEI, Quanta 200, USA). A metallizer (Sputtering BAL-TEC, SCD 050 sputter coater, USA) was used for the coating process with gold powder when the sample was deposited on a double carbon tape over an aluminum plate and placed in a vacuum chamber containing argon. The gold bombardment was carried out at 40 V for 98 s of deposition to obtain approximately 15 mm of layer thickness.

Sensory analysis

This study was approved by the Research Ethics Committee with Human Beings of the West Paraná State University under certificate nº 61654016.9.0000.0107.

The sensory analysis was performed in tilapia MSM patties and determined by the results from the statistical model and a control sample (1 with and 2 without pregelatinized starch and dextrin).

The Hedonic Scale Test of 1 to 9 points (I highly disliked it to I greatly liked it) was applied to evaluate the attributes of appearance, aroma, taste, texture, and overall impression. The purchase intention test of 1 to 5 points (I would certainly not buy the product to I would certainly buy the product) was applied to 76 untrained testers according to Dutcosky (2015). All samples received a coded number and tasters were given water to clean taste buds between tests.

Statistical analysis

The data were submitted to the analysis of normality and homoscedasticity and, considering these assumptions, were submitted to analysis of variance (ANOVA) at the significance level of 5% was performed to evaluate the difference in chemical characteristics between tilapia MSM in natura and pressed in patties and the effects of the addition of starch and dextrin. The RCCD experimental model was analyzed by the correlation coefficient (R) of the polynomial equation generated in the model, and the statistical significance was verified by the Fischer's F-test at the significance level of 5%. The significance of correlation coefficients was tested by the Student's t-Test. The response surface and the contour response of the predicted model were used to evaluate the interactive relationships between significant variables. The Derringer desirability function was used to estimate the best starch and dextrin concentrations in the tilapia MSM patties formulation. The desirability function allowed estimating the operating conditions that guarantee to fulfill the criteria for all involved responses, and at the same time provided the best joint response of the studied factors (Candioti et al., 2014).

All the statistical analyses in this study were carried out using the software STATISTICA version 8.0 (StatSoft, 2007).

RESULTS

Characterization of MSM

Table 3 shows the results of the proximal composition of *in natura* and pressed MSM. Significant changes occurred in the MSM composition after the pressing process reducing moisture content and pH and concentrating protein and lipids contents.

Table 3. Centesimal composition of *in natura* and pressed MSM.

Parameters	pressed MSM	*in natura* MSM	Concentric Nutrients (%)*	p-value
Moisture (%)	59.20±0.80	67.38±2.89	-12.14	0.018**
Crude Protein (%)	17.10±0.45	11.89±1.22	43.82	0.005**
Lipids (%)	23.63±0.40	17.77±1.49	32.98	0.006**
Mineral Matter (%)	1.68±0.02	1.62±0.05	3.70	0.089[ns]
Water Activity	0.99±0.00	0.99±0.00	-	0.725[ns]
pH	7.02±0.00	7.13±0.01	-1.54	0.001**

*The nutrients concentration was calculated considering natural matter 100%; (p-value <0.05); **Significant at the 95% confidence level; the treatments differ statistically; [ns]Not significant at the 95% confidence level; the treatments are statistically similar; MSM = mechanically separated meat.

Table 4. Variables effects and variance analysis (ANOVA) of RCCD experimental.

Variable	Effect					ANOVA[1]	
	Effect	SE	QS	fd	QM	F	p-value
(1) Starch (%) (L)	15.9486	0.4538	0.1177	1	0.11772	0.05058	0.823579
starch (%) (Q)	0.13278	0.5903	90.5908	1	90.59084	38.92569	0.000001*
(2) Dextrin (%) (L)	-2.5454	0.4079	11.1260	1	11.12601	4.78070	0.036715*
Dextrin (%) (Q)	1.2908	0.5903	9.4118	1	9.41183	4,.4414	0.053386
1L by 2L	-0.8204	0.4079	2.6355	1	2.63548	1.13243	0.295748
Error	-0.8829	0.8297	69.8183	30	2,2728		
Total			193.3468	35			

*The parameters are parameters are significant (p-value <0.05) for 95% confidence level. [1]SE = experimental standard error; QS = quadratic sum; fd = freedom degrees; QM = quadratic mean, 1L by 2L = starch and dextrin interaction; F = F calculated.

Effect of the addition of pregelatinized starch and dextrin on the formulation of tilapia MSM patties

Table 2 shows the results of the effect of the addition of starch and dextrin on the shear force (N) of patties according to the RCCD experimental design.

This variation is presented in Table 4, which demonstrated that the pregelatinized starch composition presents a significant effect (p-value <0.05) on the shear force of tilapia MSM patties while dextrin did not significantly influence this parameter. The variation observed in the shear force values was between 9.30 N and 16.56 N suggesting that the planning was important for improving the texture of tilapia MSM patties.

An objective response function, given for shear force, was generated through the planning that represents the statistical model demonstrated in Equation 4:

$$SF(N) = 15.946 + 0.066.X_1 - 1.273.X_1^2 + 0.6451.X_2 - 0.41._2^2 - 0.441.X_1.X_2 \quad (4)$$

where: X_1 is the pregelatinized starch content (%), and X_2 is the dextrin content (%).

Thus, the surface response graph was generated from the objective function for shear force (Figure 1). The surface response graph shows that there is a favorable or optimal region (dark red region) to obtain tilapia MSM patties with shear force close to 15 N.

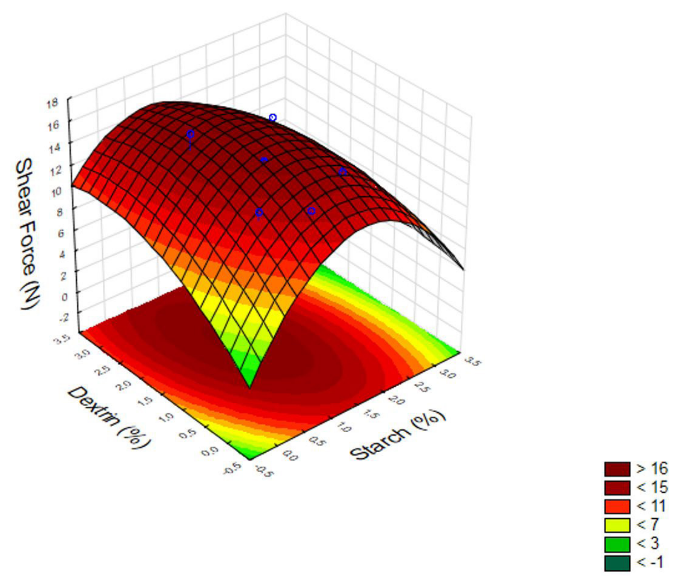

Figure 1. Response surface for shear force.

The Derringer's desirability function allowed the estimation of the desirable levels of pregelatinized starch and dextrin in the formulation of tilapia MSM patties (Figure 2). The optimum shear force value of 15.95 N was observed when using 1.5% of starch and 1.5% of dextrin.

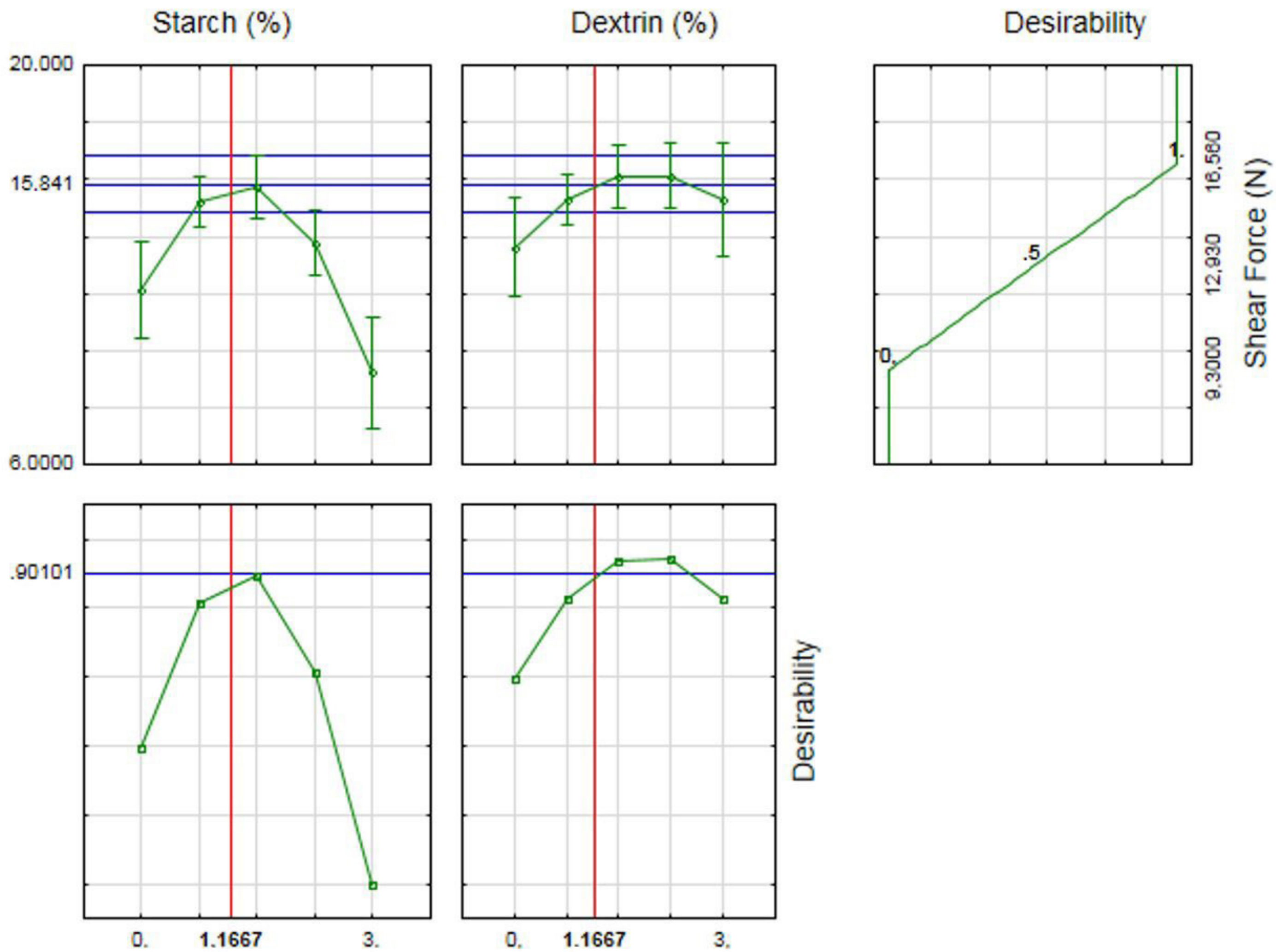

Figure 2. Estimated desirability parameters for the % starch and % dextrin variables for the shear force.

Characterization of patties

After the model validation, the proximal composition of tilapia MSM patties obtained within the optimum concentration of pregelatinized starch and dextrin was determined. The results showed that the patties presented values of moisture (50.54%), crude protein (12.00%), carbohydrates (15.74%), lipids (18.41%), mineral matter (3.45%), water activity (0.96), and pH (6.69) within the required values by the current legislation (Brasil, 2001b).

Scanning electron microscopy

The electron micrographs (Figure 3) obtained by scanning electron microscopy (SEM) correspond to the control formulations (tilapia MSM patties without starch and dextrin) and the center point (tilapia MSM patties with the addition of 1.5% starch and 1.0% dextrin).

Sensory analysis

The microbiological quality of the patties was evaluated before the application of the sensory analysis. The results were within the values advocated in the current legislation for processed foods (Brasil, 2017), and therefore, the processing of the tilapia MSM patties was conducted under good hygienic-sanitary conditions.

The patties prepared with the optimized formulation (1.5% starch and 1.0% dextrin) and the control patties (no addition of starch and dextrin) presented scores above 7 (I liked regularly) and close to 8 (I liked it a lot) in the hedonic scale considering all analyzed attributes (appearance, flavor, aroma, texture, and overall impression), the results of the purchase intention analysis showed a score above 4 (I would possibly buy it) and 5 (I would certainly buy it) (Figure 4).

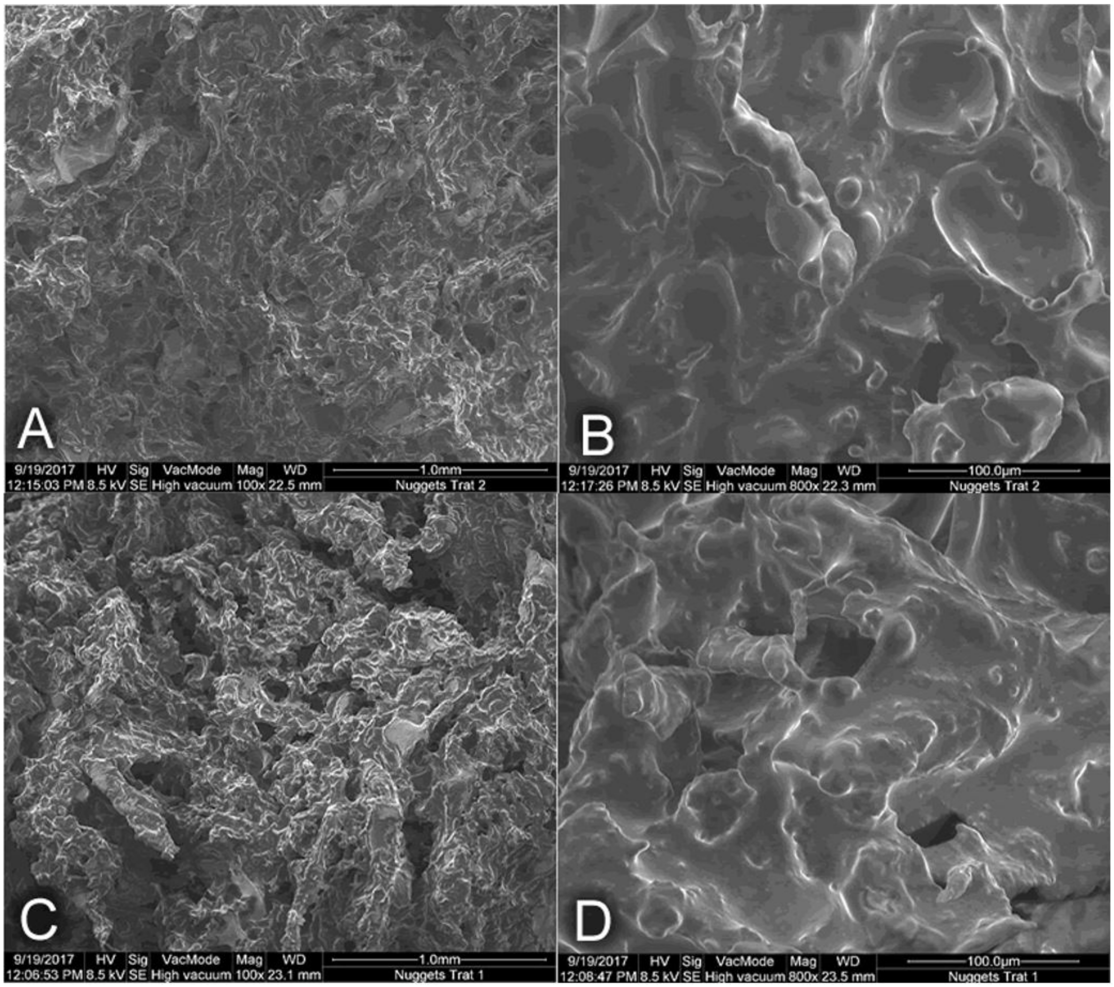

Figure 3. Scanning electron microscopy of tilapia MSM patties. (A) and (B) Control without starch and dextrin; (C) and (D) contents of 1.5% starch and 1.0% dextrin.

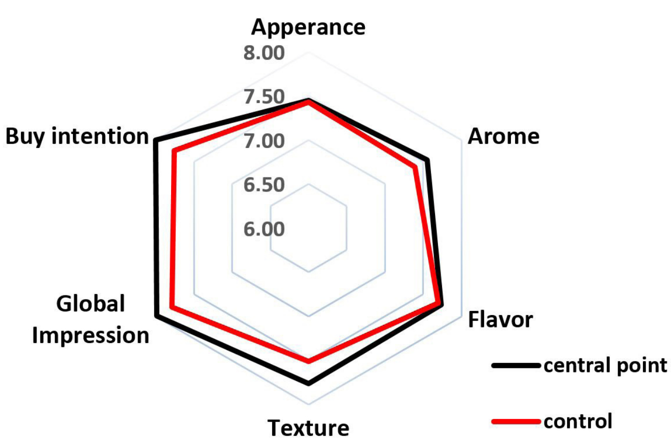

Figure 4. Hedonic scale notes of acceptance of optimized formulation (central point - with 1.5% pregelatinized starch and 1.0% dextrin) and control sample patties (control - without addition of pregelatinized starch and dextrin). For purchase intention the scale was adjusted to be inserted in the graph.

DISCUSSION

Characterization of MSM

The MSM presented a high pH value when compared to the Brazilian legislation value, for fresh fish which is 6.8 (Brasil, 2002). The pH value can be explained due to the presence of large amounts of water in the meat, being considered as a highly perishable product. For the contents of water activity shows that are highly perishable foods and should be stored under refrigeration.

According to Kurade and Baranowski (1987), the ruptures and damages of muscle tissue during the process of MSM extraction lead to the exposure to the activity of intramuscular enzymes, blood, pigments, and oxygen. Thus, the MSM must be processed as quickly as possible and kept frozen until its use because reactions that induce oxidative changes continue to occur even at low temperatures (Rebouças et al., 2012).

Therefore, the pressing process improved the MSM composition due to the elimination of water, blood, and the concentration of protein and fat content, improving the nutritional and sensorial characteristics of the product.

Before proceeding to the preparation of patties, it was verified that the MSM presented adequate microbiological quality, complying with the current legislation for foods (Brasil, 2017).

Effect of the addition of pregelatinized starch and dextrin on the formulation of tilapia MSM patties

The pregelatinized starch quadratically influenced the shear force indicating the existence of a maximum point for the parameter texture. Thus, a relationship between pregelatinized starch and water was observed.

According to WHO (1998) reports, starch granules swell slightly (10 to 20%) when in contact with cold water because as the result of water absorption.

Altunakar et al. (2004) worked with fried chicken nuggets, analyzed different types of starch (amylomaize, waxy corn, and pregelatinized tapioca), and verified that the water retention percentage of pregelatinized starch was significantly higher than that of the other analyzed starches because of its water holding capacity. The starch influences the parameters involved in the technological processes used in the food industry, such as texture and water retention, which characterize most processed products (Denardin and Silva, 2008).

The coefficient of determination was 0.824, which indicated that 82,4% of the experimental data were explained by the statistical design and the objective function was adjusted appropriately to the experimental data. Therefore, the model can be used to predict the shear force data in tilapia MSM patties. Demonstrated by the analysis of variance that the predicted model (Equation 4) is valid in the 95% confidence interval.

The desirability parameters indicated that values above 1.5% of pregelatinized starch decreased the value of shear force. Because there was no significant dextrin effect, the use of 1.5% pregelatinized starch and 1.0% dextrin are suggested in this study for the formulation of tilapia MSM patties.

The comparison between the experimental means and those estimated by the model did not present significant difference by the Student's t-test ($p < 0.05$) confirming the validity of the model used in this study.

Silva et al. (2006) worked with several native starches and starches modified for use in the food industry and found that the solubility of dextrins and pregelatinized starches was 100% at 50, 60, 70, 80, and 90 ºC. In this study, the use of pregelatinized starch improved the patties texture because of its a high viscosity and water solubility; therefore, it is indicated for applications in which high water absorption is desired such as in meaty emulsions.

Characterization of patties

A reduction in crude protein and moisture contents was observed on the patties compared to the raw material (pressed tilapia MSM); this reduction is related to the inclusion of ingredients in the formulation of patties.

The minimum and maximum percentage of pick-up added were 21.21 and 25.62, pre-defined to maintain uniformity in the patties' weight (Gonçalves, 2011); these values did not exceed the limit of 30% of carbohydrates in patties.

The breading process increases the shelf life of products by delaying oxidation and consequently, rancidity, protecting the meat against cold burning during the process of freezing (Dill et al., 2009).

The value of 18.41% lipids observed in the patties was justified by the high content of lipids in the used raw material (23.63%). The lipid content in fish for human diet is considered an important component when compared to other foods of plant or animal origin (Palmeira et al., 2016).

The observed mineral matter contents showed an increase when compared to the used raw material. This increase is related to the addition of salt and the hondashi food enhancer.

Vieira et al. (2015) evaluated popcorn-type Nile tilapia added with 0.1% and 2% of cornstarch; these authors verified an increase of over 90% in yield and an improvement in sensory parameters. The yield of 98.86% observed in this study indicates that the pregelatinized starch promotes water absorption and improves the quality of the final product due to its capacity of gelatinization and its action as a thickening agent.

The values of pH and water activity are used to determine storage temperatures for meat products; values of pH <5.0 or Aw 0.91 do not recommend freezing for storage (Terra et al., 2007). The values determined in this study recommended freezing at -18 °C for the conservation of tilapia MSM patties.

Scanning electron microscopy

The starch and dextrin added in the emulsion preparation were well incorporated in the protein matrix; a large amount of homogeneous and well-structured protein matrix was observed in images from both treatments (A and C) and (B and D).

Starch granule points were not observed in the C and D images (Figure 4), corresponding to the central point, demonstrating a uniformity in the emulsification of pregelatinized starch, which shows high viscosity and water absorption.

Air holes were observed distributed between the protein matrix in both treatments, demonstrating no influence from the addition of starch (Figure 4A and C).

Sensory analysis

The results show that the tilapia MSM patties, both optimized and control formulations, showed good acceptance by consumers. All analyzes of attributes presented means above acceptability of 5, which refers to the indifferent concept according to Dutcosky (2015). Angelini et al. (2013); Fogaça et al. (2015); Vieira et al. (2015); Kimura et al. (2017) worked with restructured products using tilapia MSM and also obtained good product acceptance.

However, considering the values of texture and aroma, the tilapia MSM patties with pregelatinized starch and dextrin had better acceptance than the control sample. Therefore, the inclusion of pregelatinized starch in the formulation improves the product's texture, aroma, and yield. Vieira et al. (2015) worked with cornstarch for popcorn-type patties and found better product acceptance and yield than that of controls.

CONCLUSION

The incorporation of pregelatinized starch and dextrin in the formulation of MSM improved the texture, without occur alteration of the product homogeneity, favoring the sensorial quality, improving the aroma, purchase intention and overall impression and with product good acceptance by consumers.

Thus, the use of pregelatinized starch and dextrin in patties is a great technological alternative to be used for the fish industry in restructured products production.

REFERENCES

Altunakar, B.; Sahin, S.; Sumnu, G. 2004. Functionality of batters containing different starch types for deep-fat frying of chicken nuggets. European Food Research and Technology, 218(4): 318-322. **http://dx.doi.org/10.1007/s00217-003-0854-5**.

Angelini, M.F.C.; Galvão, J.A.; Vieira, A.F.; Savay-da-Silva, L.K.; Shirahigue, L.D.; Cabral, I.S.R.; Modesta, R.C.D.; Gallo, C.R.; Oetterer, M. 2013. Shelf life and sensory assessment of tilapia quenelle during frozen storage. Pesquisa Agropecuária Brasileira, 48(8): 1080-1087. **http://dx.doi.org/10.1590/S0100-204X2013000800038**.

AOAC – Association of Official Analytical Chemists. 2000. Official methods of analysis of the Association of Official Analytical Chemists. Washington: AOAC.

Berry, B. 1992. Low fat level effects on sensory, shear, cooking, and chemical properties of ground beef patties. Journal of Food Science, 57(3): 537. **http://dx.doi.org/10.1111/j.1365-2621.1992.tb08037.x**.

Brasil. 2001a. Agência Nacional de Vigilância Sanitária. Resolução RDC nº 12, de 2 de janeiro de 2001. Regulamento técnico sobre padrões microbiológicos para alimentos. Diário Oficial da União, Brasília, 10 de janeiro de 2001.

Brasil. 2001b. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa nº 6, de 15 de fevereiro de 2001. Aprovar os regulamentos técnicos de identidade e qualidade de paleta cozida, de produtos cárneos salgados, de empanados, de presunto tipo serrano e de prato elaborado pronto ou semipronto contendo produtos de origem animal. Diário Oficial da União, Brasília, 19 de fevereiro de 2001.

Brasil, 2002. Ministério da Agricultura, Pecuária e Abastecimento. Departamento de Inspeção de Produtos de Origem Animal. Instrução normativa n° 51, de 18 de setembro de 2002. Aprova os Regulamentos Técnicos de Produção, Identidade e Qualidade do Leite tipo A, do Leite tipo B, do Leite tipo C, do Leite Pasteurizado e do Leite Cru Refrigerado e o Regulamento Técnico da Coleta de Leite Cru Refrigerado e seu Transporte a Granel. Diário Oficial da União, Brasília, 20 de setembro de 2002, Seção 1.

Brasil, Ministério da Agricultura, Pecuária e Abastecimento. 2017. Decreto nº 9.013, de 29 de março de 2017. Dispõem sobre o regulamento da inspeção industrial e sanitária de produtos de origem animal. Diário Oficial da União, Brasília, Brasilia, 30 de março de 2017.

Candioti, L.V.; De Zan, M.M.; Camara, M.S.; Goicoechea, H.C. 2014. Experimental design and multiple response optimization: using the desirability function in analytical methods development. Talanta, 124: 123-138. **http://dx.doi.org/10.1016/j.talanta.2014.01.034**. PMid:24767454.

Cavenaghi-Altemio, A.D.; Alcade, L.B.; Fonseca, G.G. 2013. Low-fat frankfurters from protein concentrates of tilapia viscera and mechanically separated tilapia meat. Food Science & Nutrition, 1(6): 445-451. **http://dx.doi.org/10.1002/fsn3.42**. PMid:24804055.

Denardin, C.C.; Silva, L.P.D. 2008. Estrutura dos grânulos de amido e sua relação com propriedades físico-químicas. Ciência Rural, 39(3): 1-10. http://dx.doi.org/**10.1590/S0103-84782009005000003**.

Dill, D.D.; Silva, A.P.; Luvielmo, M. 2009. Processamento de empanados: sistemas de cobertura. Estudos Tecnológicos, 5(1): 33-49.**http://dx.doi.org/10.4013/ete.2009.51.03**.

Dutcosky, S.D. 2015. Análise sensorial de alimentos. Curitiba: Champagnat.

Fogaça, F.H.S.; Otani, F.S.; Portella, C.D.G.; Santos-Filho, L.G.A.; Sant'Ana, L.S. 2015. Caracterização de surimi obtido a partir da carne mecanicamente separada de tilápia do Nilo e elaboração de fishburger. Semina: Ciências Agrárias, 36(2): 765-776. **http://dx.doi.org/10.5433/1679-0359.2015v36n2p765**.

Freitas, D.D.G.C.; Resende, A.L.S.S.; Furtado, A.A.L.; Tashima, L.; Bechara, H.M. 2012. The sensory acceptability of a tilapia (*Oreochromis niloticus*) mechanically separated meat-based spread. Brazilian Journal of Food Technology, 15(2): 166-173. **http://dx.doi.org/10.1590/S1981-67232012005000010**.

Gonçalves, A.A. 2011. Tecnologia do pescado: ciência, tecnologia, inovação e legislação. São Paulo: Atheneu.

Kimura, K.S.; Souza, M.L.R.; Gasparino, E.; Mikcha, J.M.G.; Chambó, A.P.S.; Verdi, R.; Coradini, M.F.; Marques, D.R.; Feihrmann, A.; Goes, E.S.R. 2017. Preparation of lasagnas with dried mix of tuna and tilapia. Food Science and Technology, 37(3): 507-514. **http://dx.doi.org/10.1590/1678-457x.24816**.

Kirschnik, P.G.; Macedo-Viegas, E.M. 2009. Efeito da lavagem e da adição de aditivos sobre a estabilidade de carne mecanicamente separada de tilápia do Nilo (*Oreochromis niloticus*) durante estocagem a -18 °C. Food Science and Technology, 29(1): 200-206. **http://dx.doi.org/10.1590/S0101-20612009000100031**.

Kirschnik, P.G.; Trindade, M.A.; Gomide, C.A.; Moro, M.E.G.; Viegas, E.M.M. 2013. Estabilidade em armazenamento da carne de tilápia-do-nilo mecanicamente separada, lavada, adicionada de conservantes e congelada. Pesquisa Agropecuária Brasileira, 48(8): 935-942. **http://dx.doi.org/10.1590/S0100-204X2013000800018**.

Kurade, S.A.; Baranowski, J.D. 1987. Prediction of shelf-life of frozen minced fish in terms of oxidative rancidity as measured by TBARS number. Journal of Food Science, 52(2): 300-302. **http://dx.doi.org/10.1111/j.1365-2621.1987.tb06598.x**.

Lago, A.M.T.; Pimenta, C.J.; Nogueira, I.E.; Vidal, A.C.C.; Pimenta, M.E.D.S.G. 2016. Residuos de Tilapia como materia prima para producción de salchichas: rendimiento y costo. Revista de Ciencia y Tecnología, (26): 34-39.

Lustosa-Neto, A.D.; Nunes, M.L.; Maia, L.P.; Barbosa, J.M.; Lira, P.P.; Furtado-Neto, M.A.A. 2018. Almôndegas de pirarucu e tilápia nilótica: caracterização e aplicação na merenda escolar. ActaFish, 6: 1-12.

Magalhães, A.O.; Mársico, E.T.; Soares Júnior, M.S.; Monteiro, M.L.G. 2019. Evaluation of the technological quality of snacks extruded from broken grains of rice and mechanically separated tilapia meat flour. Boletim do Instituto de Pesca, 45(2): 429. **http://dx.doi.org/10.20950/1678-2305.2019.45.2.429**.

Manchun, S.; Cheewatanakornkool, K.; Dass, C.R.; Sriamornsak, P. 2014. Novel pH-responsive dextrin nanogels for doxorubicin delivery to cancer cells with reduced cytotoxicity to cardiomyocytes and stem cells. Carbohydrate Polymers, 114: 78-86. **http://dx.doi.org/10.1016/j.carbpol.2014.08.002**. PMid:25263867.

Mason, W.R. 2009. Starch use in foods. In: BeMiller, J.; Whistler, R. (Eds.). Starch: chemistry and technology. New York: Academic Press. p. 745-795.

Monteiro, M.L.G.; Mársico, E.T.; Soares Junior, M.S.; Deliza, R.; Oliveira, D.C.R.; Conte-Junior, C. 2018. Tilapia-waste flour as a natural nutritional replacer for bread: a consumer perspective. PLoS One, 13(5): e0196665. **http://dx.doi.org/10.1371/journal.pone.0196665**. PMid:29723283.

Oliveira Filho, P.R.C.; Viegas, E.M.M.; Kamimura, E.S.; Trindade, M.A. 2012. Evaluation of physicochemical and sensory properties of sausages made with washed and unwashed mince from Nile tilapia by-products. Journal of Aquatic Food Product Technology, 21(3): 222-237. **http://dx.doi.org/10.1080/10498850.2011.590270**.

Palmeira, K.R.; Mársico, E.T.; Monteiro, M.L.G.; Lemos, M.; Conte Junior, C.A. 2016. Ready-to-eat products elaborated with mechanically separated fish meat from waste processing: challenges and chemical quality. CYTA: Journal of Food, 14(2): 227-238. **http://dx.doi.org/10.1080/19476337.2015.1087050**.

Pedroso, R.A.; Demiate, I.M. 2008. Evaluation of the influence of starch and carrageenan on the physicochemical and sensory characteristics of cooked turkey ham. Food Science and Technology, 28(1): 24-31. **http://dx.doi.org/10.1590/S0101-20612008000100005**.

Pongjaruvat, W.; Methacanon, P.; Seetapan, N.; Fuongfuchat, A.; Gamonpilas, C. 2014. Influence of pregelatinised tapioca starch and transglutaminase on dough rheology and quality of gluten-free jasmine rice breads. Food Hydrocolloids, 36: 143-150. **http://dx.doi.org/10.1016/j.foodhyd.2013.09.004**.

Raphaelides, S.; Dimitreli, G.; Exarhopoulos, S.; Mintzas, D.; Lykidou, A. 2012. Effect of processing conditions on the physicochemical and structural characteristics of pregelatinised starch–fatty acid–glycerol extrudates. Carbohydrate Polymers, 88(1): 282-289. **http://dx.doi.org/10.1016/j.carbpol.2011.12.003**. PMid:24750635.

Rebouças, M.C.; Rodrigues, M.C.P.; Castro, R.J.S.; Vieira, J.M.M. 2012. Caracterização do concentrado protéico de peixe obtido a partir dos resíduos da filetagem de tilápia do Nilo. Semina: Ciências Agrárias, 33(2): 1-8. **http://dx.doi.org/10.5433/1679-0359.2012v33n2p697**.

Santos, D.B.; Barbieri, E.; Bondioli, A.C.; Melo, C.B. 2014. Effects of Lead in white shrimp (*Litopenaeus schmitti*) metabolism regarding salinity. O Mundo da Saúde, 38(1): 16-23. **http://dx.doi.org/10.15343/0104-7809.20143801016023**.

Sanz, T.; Salvador, A.; Fiszman, S. 2004. Effect of concentration and temperature on properties of methylcellulose-added batters application to battered, fried seafood. Food Hydrocolloids, 18(1): 127-131. **http://dx.doi.org/10.1016/S0268-005X(03)00050-X**.

Sharma, A.; Yadav, B.S.; Ritika. 2008. Resistant starch: physiological roles and food applications. Food Reviews International, 24(2): 193-234. **http://dx.doi.org/10.1080/87559120801926237**.

Silva, D.M.; Nunes, C.; Pereira, I.; Moreira, A.S.; Domingues, M.R.M.; Coimbra, M.A.; Gama, F.M. 2014. Structural analysis of dextrins and characterization of dextrin-based biomedical hydrogels. Carbohydrate Polymers, 114: 458-466. **http://dx.doi.org/10.1016/j.carbpol.2014.08.009**. PMid:25263914.

Silva, G.O.; Takizawa, F.F.; Pedroso, R.A.; Franco, C.M.L.; Leonel, M.; Sarmento, S.B.S.; Demiate, I.M. 2006. Características físico-químicas de amidos modificados de grau alimentício comercializados no Brasil. Food Science and Technology, 26(1): 188-197. **http://dx.doi.org/10.1590/S0101-20612006000100030**.

Sousa, G.S.; Gomes da Silva, M.T.; Cunha, D.A.S.; Santos, E.C.B. 2019. Elaboração e caracterização de alimento funcional enriquecido com proteína de camarão. Revista Brasileira de Engenharia de Pesca, 11(2): 1-9. **http://dx.doi.org/10.18817/repesca.v11i2.1622**.

StatSoft. 2007. Statistica: data analysis software system, version 8.0. Tulsa.

Takatori, Y.; Akagi, S.; Sugiyama, H.; Inoue, J.; Kojo, S.; Morinaga, H.; Nakao, K.; Wada, J.; Makino, H. 2011. Icodextrin increases technique survival rate in peritoneal dialysis patients with diabetic nephropathy by improving body fluid management: a randomized controlled trial. Clinical Journal of the American Society of Nephrology, 6(6): 1337-1344. **http://dx.doi.org/10.2215/CJN.10041110**. PMid:21493740.

Terra, N.N.; Freitas, R.J.S.; Cichoski, A.J. 2007. Atividade de água, pH, umidade e desenvolvimento de *Staphylococcus xylosus* durante o processamento e armazenamento da paleta suína curada, maturada e fermentada. Food Science and Technology, 27(4): 1-5. **http://dx.doi.org/10.1590/S0101-20612007000400014**.

Vidal, J.M.A.; Rodrigues, M.C.P.; Zapata, J.F.F.; Vieira, J.M.M. 2011. Concentrado protéico de resíduos da filetagem de tilápia-do-nilo (*Oreochromis niloticus*): caracterização físico-química e aceitação sensorial. Ciência Agronômica, 42(1): 7. **http://dx.doi.org/10.1590/S1806-66902011000100012**.

Vieira, P.H.S.; Melo, C.C.; Medeiros, R.F.; Vasconcelos-Filho, M.B.; Moura, J.V.S.; Albuquerque, C.A.; Oliveira-Filho, P.R.C. 2015. Value added products of Nile tilapia (*Oreochromis niloticus*) using different concentrations of starch. Acta of Fisheries and Aquatic Resources, 3(1): 41-53. http://dx.doi.org/**10.2312/ActaFish.2015.3.1.41-53**.

WHO – World Health Organization, Food and Agriculture Organization of the United Nations. 1998. Carbohydrates in human nutrition. Rome: FAO.

Zhang, L.; Barbut, S. 2005. Effects of regular and modified starches on cooked pale, soft, and exudative; normal; and dry, firm, and dark breast meat batters. Poultry Science, 84(5): 789-796. **http://dx.doi.org/10.1093/ps/84.5.789**. PMid:15913192.