

# EVALUATION OF THE TECHNOLOGICAL QUALITY OF SNACKS EXTRUDED FROM BROKEN GRAINS OF RICE AND MECHANICALLY SEPARATED TILAPIA MEAT FLOUR

Amanda Oliveira Magalhães<sup>1</sup>  
Eliane Teixeira Mársico<sup>2</sup>  
Manoel Soares Soares Júnior<sup>1</sup>  
Maria Lúcia Guerra Monteiro<sup>2</sup>

<sup>1</sup>Universidade Federal de Goiás – UFG, Escola de Agronomia, Departamento de Engenharia de Alimentos, Av. Esperança, s/n, CEP 74690-900, Goiânia, GO, Brasil. E-mail: amanda.magaia@gmail.com (corresponding author).

<sup>2</sup>Universidade Federal Fluminense – UFF, Departamento de Tecnologia de Alimentos, Rua Vital Brazil Filho, 64, CEP 24230-340, Niterói, RJ, Brasil.

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## ABSTRACT

The objective of this study was to evaluate the technological vulnerability of snacks extruded from broken rice grains (BRG) and mechanically separated tilapia meat flour (MSMF) and to characterize the best formulation from a technological point of view. Five snack formulations were elaborated with different levels of MSMF (0%, 10%, 20%, 30% and 40%) replacing the BRG. The snacks were evaluated in relation to expansion index, specific volume, hardness, instrumental color parameters, water activity ( $A_w$ ) and scanning electron microscopy to identify the maximum substitution level of BRG by MSMF that did not compromise the technological quality of the product.  $A_w$  was similar ( $p > 0.05$ ) in all formulations. Replacement of MSMF by BRG influenced ( $p < 0.05$ ) expansion index, specific volume, hardness, and  $L^*$ ,  $a^*$  and  $b^*$  values. However, the replacement of 30% of BRG by MSMF did not compromise the technological quality of the extruded snacks. In addition, this formulation presented high nutritional value, acceptance and purchase intention and could therefore be used as an industrial strategy to meet current consumer demand for nutritious foods and stimulate fish consumption.

**Key words:** by-products; rice derivatives; fish; extrusion; physicochemical properties; acceptability.

## AVALIAÇÃO DA QUALIDADE TECNOLÓGICA DE SNACKS EXTRUSADOS DE GRÃOS QUEBRADOS DE ARROZ E FARINHA DE CARNE DE TILÁPIA MECANICAMENTE SEPARADA

## RESUMO

O objetivo deste estudo foi avaliar a qualidade tecnológica de *snacks* extrusados, produzidos a partir da substituição do grão quebrado de arroz (GQA) pela farinha de carne mecanicamente separada (CMS) de tilápia (FCMS) e caracterizar quimicamente e sensorialmente a melhor formulação sob o ponto de vista tecnológico. Cinco formulações de *snacks* foram elaboradas com diferentes níveis de FCMS (0%, 10%, 20%, 30% e 40%) em substituição ao GQA. Os *snacks* foram avaliados em relação ao índice de expansão, volume específico, dureza, parâmetros instrumentais de cor, atividade de água ( $A_w$ ), e por microscopia eletrônica de varredura para identificação do nível de substituição máximo de GQA por FCMS que não compromettesse a qualidade tecnológica do produto. A  $A_w$  foi similar ( $P > 0,05$ ) em todas as formulações. A substituição de FCMS por GQA influenciou ( $P < 0,05$ ) o índice de expansão, volume específico, dureza, e os valores de  $L^*$ ,  $a^*$  e  $b^*$ . No entanto, a substituição de 30% de GQA por FCMS não comprometeu a qualidade tecnológica dos *snacks* extrusados. Além disso, esta formulação apresentou elevado valor nutritivo, aceitação e intenção de compra podendo, portanto, ser utilizada como uma estratégia industrial para atender a demanda dos consumidores atuais por alimentos nutritivos e estimular o consumo de pescado.

**Palavras-chave:** subprodutos; derivados de arroz; pescado; extrusão; propriedades físico-químicas; aceitabilidade.

## INTRODUCTION

The World Health Organization recommends per capita consumption of 14.5 kg of fish per year. Average world consumption is 19.2 kg per capita per year, but in Latin America it does not reach 9 kg per capita per year (FAO, 2014). The absence of habit,

the high price and a lack of practicality in the elaboration of food prejudice the choice for fish (Galan et al., 2013).

On the other hand, fish processing industries generate significant amounts of waste, mainly due to the lack of recognition of this resource as a raw material and source for other products (Castro-Muñoz et al., 2016). Use of these residues in the current concept of sustainability represents an option to reduce food costs, based on the elaboration of new products, and to reduce the deposition of organic residues in the environment.

The total production of Brazilian fish farming was 474,330 tons in 2014. In that same year, the Nile tilapia (*Oreochromis niloticus*) was the most cultivated species, with 198,490 tons, equivalent to 41.9% of the total. However, despite the desirable production and marketing characteristics of tilapia, this species has a low fillet yield (30%); filleting tilapia represents its main form of commercialization, so a significant amount of residue is generated from the process (Monteiro et al., 2014). Therefore, the application of technological processes that consolidate the elaboration of products with added value, improving the efficiency of the process, is fundamental. The ideal would be to use the raw material to its full extent and to recover the by-products, avoiding the formation of residue in the environment (Dapkevicius et al., 2000).

Among the residues generated in the fish filleting process, the mechanically separated meat (MSM) of fish can be easily processed into flour. Tilapia flour produced from meat adhering to the skin and bones yields approximately 8% of the weight of the whole fish and is considered a low-cost source of essential nutrients, constituting an interesting alternative for nutritional supplementation and adding value to some products such as meatballs, burgers, pasta, breads and biscuits (Godoy et al., 2010; Stevanato et al., 2010; Monteiro et al., 2014, 2018).

The relevance of this research is also based on the fact that people increasingly seek a healthy and practical diet, and snacks have been widely accepted by the consumer market (Alves and Grossmann, 2002). The use of tilapia MSM flour (MSMF) as a replacement for broken rice in the preparation of snacks responds to the demand for improvement of the nutritional value of extruded snacks. Therefore, the objective of this work was to evaluate the technological quality of extruded snacks produced with the inclusion of different levels of MSMF in substitution for BRG, as well as to determine the nutritional composition and to verify the sensory acceptance of the best formulation taking into account the technological quality.

## MATERIAL AND METHODS

### Origin of the raw material

Broken rice grains (BRG) were donated by Cristal Alimentos Ltda., in Aparecida de Goiânia, GO. The tilapia (*O. niloticus*) MSM was obtained from the filleting process of the Regional Cooperative of Fish Farmers and Ranchers of Vale do Macacu and Adjacências Ltda. (Coopercrãmma), located in Cachoeiras de Macacu, Rio de Janeiro, RJ.

Approximately 50kg of MSM was obtained, divided into 1-kg portions. MSM was placed in greenhouse drying trays (Tecnal, TE-394/3), with forced-air circulation (65 °C for 12h). The dried material was ground in a knife mill (Marconi, MA630) to obtain flour with standardized granulometry (<0.85 mm).

### Centesimal composition of raw materials

Analysis of the centesimal composition was performed according to the analytical procedures described by the AOAC (2012). Average was determined in an oven at 105 °C until constant weight; ash by incineration in a muffle at 550 °C; lipids by direct extraction in Soxhlet apparatus; proteins by the Kjeldahl method; and total carbohydrates were estimated according to the following equation:  $100 - (\% \text{ protein} + \% \text{ lipids} + \% \text{ moisture} + \% \text{ ash})$ . The fiber content was obtained according to the methodology of the AACC (2001). Analyses were performed in triplicate.

### Processing of extruded snacks

For the dossier formulation, different levels of MSMF (0%, 10%, 20%, 30% and 40%) were used instead of BRG (Table 1).

The BRG and its combinations with MSMF had their humidity adjusted to 14% (Table 2).

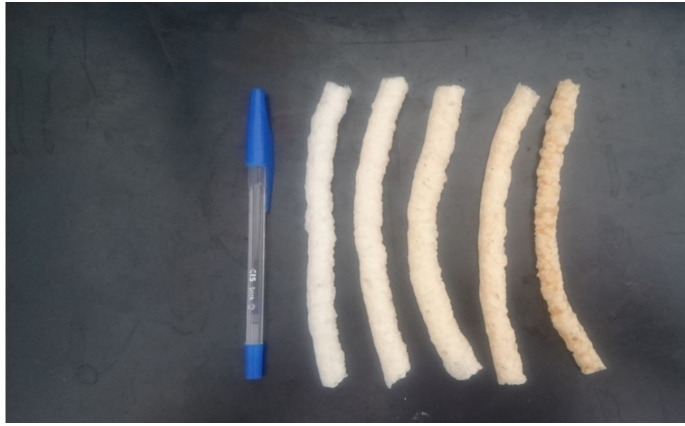
The results obtained in this work are presented in Figures 1 and 2. A single-screw extruder and three heating zones (Imbramaq, Inbra 200) was used, with a corrugated jacket, three-way screw thread, screw rotation speed of 60 Hz and a 3.5-mm diameter die. The feed zone (first) was maintained at 40 °C, the transition

**Table 1.** Snack formulations according to the level of substitution of broken rice grain (BRG) for mechanically separated tilapia meat flour (MSMF).

Ingredients	Levels of substitution of BRG by MSMF (%)				
	0	10	20	30	40
BRG	100	90	80	70	60
MSMF	0	10	20	30	40

**Table 2.** Centesimal composition (mean ± standard deviation) of the raw materials used in the formulation of experimental extruded snacks.

Variable (%)	Mechanically separated tilapia meat	Broken rice grain
Moisture	75.43±0.32	10.51±0.19
Ashes	1.16±0.13	0.57 ±0.04
Lipids	2.48±0.02	2.24±0.26
Proteins	20.73±0.04	6.29±0.11
Carbohydrates	0.20±0.03	80.39±0.57
Fibers	0.06±0.00	0.20±0.24



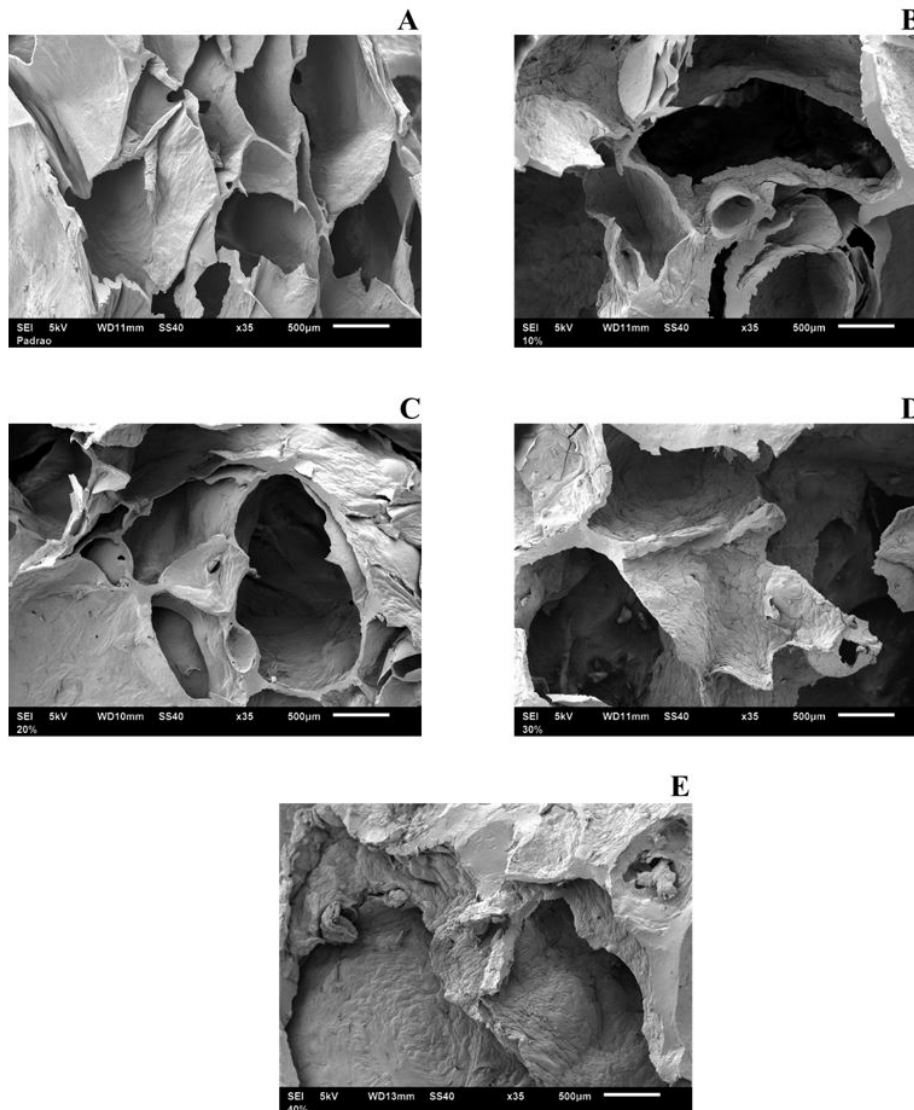
**Figure 1.** Image of the snacks with 0%, 10%, 20%, 30% and 40% levels of broken rice grains (BRG) for mechanically separated tilapia meat flour (MSMF) from left to right. (Source: Personal archive).

zone (second) was maintained at 60 °C, and the high-pressure zone (third) and outlet orifice at 90 °C.

### Physical and instrumental analysis of extruded snacks

The snacks produced had a cylindrical shape, and their diameter and height were measured in 30 random units with a caliper (Messen, Digital Caliper). These values were used to calculate the volume of the snacks (VS) according to the following formula:  $VS = \pi r^2 h$ , where  $\pi = 3.14$ ,  $r^2 =$  square radius and  $h =$  height (Capriles et al., 2009). The snacks were weighed on an analytical balance; the density was calculated by the mass per volume ratio ( $\text{mg mm}^{-3}$ ), and specific volume (VE) by the volume per mass ratio ( $\text{mm}^3 \text{mg}^{-1}$ ).

Expansion index (EI) was determined as the ratio of the diameter of the snacks to the extruder outlet orifice diameter (3.5 mm) (Faubion and Hosney, 1982). Water activity ( $A_w$ ) was determined



**Figure 2.** Micrographies of the snacks with levels of 0% (A), 10% (B), 20% (C), 30% (D) and 40% (E). (Source: Personal archive).



at room temperature using an automatic meter (Bras. Eq. AquaLab CX-2-T). All analyses were performed in triplicate.

Hardness was determined according to the AACC 16-50 method (AACC, 2000), using the torus (TA.HD *Plus* texture analyzer). This parameter was evaluated as the maximum breaking force applied under the platform (HDP/90 heavy-duty platform) with a Probe Knife Edge with a slotted insert (HDP/BS) at a cutting speed of 2 mm/s. Fifteen random determinations were performed for each formulation with 10-cm long snacks. Each snack formulation was ground and put on a smooth surface. Ten measurements of instrumental color parameters were performed for each formulation using a Hunter Lab Color Quest XE and the CIE-Lab system, with a 10° viewing angle and standard D65 illuminant.

The values of L\* (brightness, black 0/white 100), a\* (intensity of red, green -/red +) and b\* (intensity of yellow, blue -/yellow +) were obtained. In addition, we calculated the hue or hue angle (H°), where  $H^\circ = \text{tangent arc}(b^*/a^*)$ , and chroma or saturation (C\*), where  $C^* = [(a^*^2 + b^*^2)^{1/2}]$ , as proposed by McGuire (1992).

### Scanning electron microscopy

Scanning electron microscopy images of the snacks were captured and magnified on a scanning electron microscope (Sputter Coater, SCD 050), with increases between 700×, 900× and 3000×. After the samples were dried in an air-circulating oven at 60 °C for 24 h, they remained in the dissector until the moment of analysis. The samples were then fixed in aluminum foams using double-sided tape and bathed in 15-nm thick gold film.

### Selection, centesimal composition and acceptance of the best snack formulation

Based on the results of the technological quality analyses (physical, instrumental and scanning electron microscopy), the best formulation was selected and characterized in relation to nutritional value and sensorial aspects. Determination of the selected sample's centesimal composition was carried out according to the same methods used for the evaluation of raw materials.

The experimental protocol was approved by the Research Ethics Committee of the Institution (protocol 5083/2017); to meet the protection and privacy requirements of the volunteers, the terms of free and informed consent were used. Sensory analysis was performed with 100 untrained tasters who evaluated the attributes of appearance, aroma, texture and flavor, on a structured hedonic seven-point scale: 7 – I liked it extremely; 4 – neither liked nor disliked; 1 – extremely dissonant (Stone and Sidel, 2004).

The intention of the testers to purchase the selected snack was also evaluated, through a five-point scale (5 – would certainly buy; 4 – would probably buy; 3 – I doubt if I would buy; 2 – probably would not buy; 1 – certainly would not buy). Testers tasted 3g of the product accompanied by a glass of water.

### Design and analysis of results

The design was completely randomized, with five treatments based on different levels of BRG substitution by MSMF (control (0%), 10, 20, 30 and 40%), and four replicates for each treatment. Results were evaluated by means of analysis of variance (ANOVA) and Tukey test at the 5% probability level.

In addition, orthogonal regression and contrast analysis were performed to verify significant differences between the control snack and snacks with different levels of BRG substitution by MSMF (Statistica 7.0). Graphs were constructed using Microsoft Excel software. Pearson correlation between the physical and instrumental variables was also performed.

## RESULTS

### Centesimal composition of the raw materials used

The low value found for moisture in the BRG was adequate. In relation to the ash of the BRG, a value of 0.57% was verified; it is variable among the studies available in the literature due to a wide variety of rice cultivars and different processing methods. The mean value for lipids in BRG and MSMF was low (2.24% and 2.48%). Regarding the protein and fiber content of the by-products, a high protein content was observed for MSMF (20.73%) when compared to BRG (6.29%), and there was a higher amount of fiber in BRG (0.20%) than in MSMF (0.06%). As for carbohydrate content, MSMF (0.20%) presented a low value when compared to BRG (80.39%), indicating that in addition to serving as a protein source, the snacks elaborated in this study can serve as an energy source (Table 2).

### Physical and instrumental characteristics of extruded snacks

The physical characteristics of the extruded snacks were significantly influenced ( $p < 0.05$ ) by the substitution of BRG with MSMF, with the exception of Aw (Table 3).

The variable SV presented significant regression with a quadratic effect (Table 4), and the level of 30% presented a higher value for this parameter. On the level of 40% the value of SV decreased.

The expansion index presented a significant regression with a quadratic effect (Table 4), indicating an increase and subsequent decline in expansion. The level of 30% presented the highest EI value (0.91) and the level of 40% the lowest (0.57), a lower value than that for the control group (0.70). There was no significant difference ( $p > 0.05$ ) between the levels of 10, 20 and 30%. There was an orthogonal contrast for the variable IE, which means that the snacks with substitution of BRG by MSMF differed from the control group.

The hardness of the snacks presented significant regression with an increasing linear effect (Table 4), indicating an increase of this variable with an increase in replacement of BRG by MSMF. The level of 40% presented the highest value, and the control formulation showed the lowest hardness value. Contrast was observed for the hardness of the snacks, that is, snacks with BRG

**Table 3.** Physical and instrumental analyzes (mean  $\pm$  standard deviation) of extruded snacks with different levels of substitution of broken rice grains (BRG) for mechanically separated tilapia meat flour (MSMF).

Variable	Levels of substitution of BRG by MSMF (%)				
	0	10	20	30	40
SV ( $\text{mm}^3 \text{mg}^{-1}$ )	6.96 $\pm$ 0.49b	7.06 $\pm$ 0.49b	7.83 $\pm$ 0.40ab	8.53 $\pm$ 0.59a	5.06 $\pm$ 0.51c
EI ( $\text{mm}^3 \text{mg}^{-1}$ )	0.70 $\pm$ 0.02b*	0.86 $\pm$ 0.04a	0.87 $\pm$ 0.06a	0.91 $\pm$ 0.08a	0.57 $\pm$ 0.07c
Aw	0.38 $\pm$ 0.01a	0.39 $\pm$ 0.02a	0.39 $\pm$ 0.03a	0.40 $\pm$ 0.02a	0.38 $\pm$ 0.01a
Hardness (N)	37.27 $\pm$ 0.16d*	47.93 $\pm$ 0.74c	46.84 $\pm$ 0.69c	50.86 $\pm$ 0.68b	54.54 $\pm$ 0.71a
Luminosity	83.65 $\pm$ 0.98a*	84.10 $\pm$ 0.28a	79.63 $\pm$ 0.59b	80.05 $\pm$ 0.60b	74.98 $\pm$ 0.81c
<i>a</i> *	0.73 $\pm$ 0.17d*	1.70 $\pm$ 0.08c	4.65 $\pm$ 0.34a	4.15 $\pm$ 0.10b	4.43 $\pm$ 0.19 <sup>a</sup> b
<i>b</i> *	13.03 $\pm$ 0.38d*	17.23 $\pm$ 0.53c	23.45 $\pm$ 0.31b	22.70 $\pm$ 0.34b	24.48 $\pm$ 0.38a
Angle Hue	13.05 $\pm$ 0.38d*	17.31 $\pm$ 0.53c	23.91 $\pm$ 0.32b	23.08 $\pm$ 0.33b	24.87 $\pm$ 0.30a
Chroma	86.82 $\pm$ 0.72a*	84.36 $\pm$ 0.24b	78.79 $\pm$ 0.80c	79.64 $\pm$ 0.31c	79.75 $\pm$ 0.50c

<sup>a,b</sup>Means followed by different letters in the same line differ among themselves by the Tukey test at the 5% level; EI = Expansion index; SV = specific volume; Aw = Water activity; N= Newtons; \*Orthogonal Contrast=control vs levels of substitution of BRG by MSMF.

**Table 4.** Regression equations for predicting the physical and instrumental characteristics of extruded snacks with different levels of substitution of broken rice grains for mechanically separated tilapia meat flour.

Variable	Regression Equations	R <sup>2</sup>	P Value
SV ( $\text{mm}^3 \text{mg}^{-1}$ )	$y = 6.5192(\pm 0.42) + 0.1830(\pm 0.05)x - 0.0051(\pm 0.001)x^2$	0.98	<0.0001
EI ( $\text{mm}^3 \text{mg}^{-1}$ )	$y = 0.6889(\pm 0.03) + 0.0250(\pm 0.004)x - 0.00068(\pm 0.0001)x^2$	0.87	<0.0001
Hardness (N)	$y = 39.9955(\pm 0.95) + 0.3746(\pm 0.039)x$	0.85	<0.0001
Luminosity	$y = 83.8814(\pm 0.63) - 0.0382(\pm 0.07)x - 0.0043(\pm 0.002)x^2$	0.89	<0.0001
<i>a</i> *	$y = 0.4671(\pm 0.29) + 0.2370(\pm 0.03)x - 0.0034(\pm 0.001)x^2$	0.89	0.0006
<i>b</i> *	$y = 12.8107(\pm 0.54) + 0.6216(0.06)x - 0.0084(\pm 0.002)x^2$	0.95	<0.0001
Angle Hue	$y = 12.7907(\pm 0.57) + 0.6475(\pm 0.07)x - 0.0088(\pm 0.002)x^2$	0.98	<0.0001
Chroma	$y = 87.2965(\pm 0.55) - 0.5191(\pm 0.06)x + 0.0082(\pm 0.002)x^2$	0.91	<0.0001

EI = Expansion index; SV = specific volume; N=Newton.

substituted by MSMF differed from the control group. According to the results of the present study (Table 3), an increase in hardness (maximum strength peak) was observed with increasing addition of MSMF, statistically different between the formulations tested. In this research, the higher amount of MSMF protein may have retained greater moisture in the extrudate, making it harder.

The raw materials studied presented very different color patterns, BRG being white, showing high luminosity (*L*\*), and MSMF darker with reddish and yellowish tones. When mixed in different proportions, the interference from an increase in the MSMF level caused differences in the tonalities of the snacks (Figure 1).

The control and level 10% formulations had the highest values of *L*\*, while the level of 40% showed the lowest value for this variable (Table 3). The variable *L*\* presented a quadratic regression effect, indicating darkening of the snacks on substitution of the ingredients (Table 4), and the orthogonal contrast was significant. The values of the chromaticity coordinates *a*\* and *b*\* differed statistically ( $p < 0.05$ ) (Table 3), and both were lower for the control group. The highest value of *a*\* was observed in the level of 20% and the highest value of *b*\* in the level of 40%; the higher the values of *a*\* and *b*\*, the more red and yellow the snack, respectively

(Bender et al., 2016). These color variables presented a quadratic regression effect (Table 4), and the snacks with BRG substitution by MSMF differed from the control group.

The variables chroma (*C*\*) and hue (*H*<sup>o</sup>) showed significant difference ( $p < 0.05$ ) and orthogonal contrast. There was a significant quadratic effect for both variables, and the control formulation had the highest value of *C*\* and the lowest *H*<sup>o</sup>. The value of *C*\* decreased while that of *H*<sup>o</sup> increased on inclusion of MSMF in substitution for BRG, a reduction of color intensity and an increase in orange color of the snacks. Correlations of the physical and instrumental variables of the extruded snacks are presented in Table 5. It was observed that SV and EI presented a high direct correlation.

### Scanning electron microscopy

By analyzing the micrographs of the extruded snacks, it was verified that the microstructure of the product was altered by the inclusion of MSMF instead of BRG (Figure 2); 500x approximation of the images allowed verification of the internal structure. Comparing the micrographs, it is observed that the snacks with

0%, 10%, 20% and 30% substitution of BRG by MSMF presented cells with better-defined and larger structures, while snacks with a substitution level of 40% presented more compact and rigid structures, which was also observed with the naked eye, suggesting less expansion and, consequently, a harder product, corroborating analysis of the results obtained for EI, SV and hardness.

The control formulation had thinner internal walls when compared to the other formulations, and thickening occurred with the gradual inclusion of MSMF instead of BRG. Thus, for the same conditions of humidity and processing temperature, it was verified that the substitution of BRG by MSMF favors expansion of the internal structure of the snacks up to the level of 30%.

In order to choose a snack that does not compromise market acceptability, the snack with 30% MSMF in substitution of BRG was chosen as it had the best technological characteristics (maximum EI, SV, hardness and values of  $a^*$  and  $b^*$ ), that is, similar to snacks produced with commercial corn grits, the raw material most used and most consumed by the population. Thus, this snack was selected to be evaluated in relation to centesimal composition and sensorial acceptance. The moisture content of the level of 30% (Table 6) was within the limit.

### Sensory evaluation

Considering the snack with 30% MSMF replacing BRG, the testers “liked extremely” or “liked regularly” the attributes appearance (90%), aroma (67%), texture (63%) and taste (72%).

In addition, consumers showed a high intention to buy the product, with 57% saying they would buy the product, 48%

“probably buying” and 9% “certainly buying”. Only 15% said they would not buy the product, 13% “probably would not buy” and 2% “certainly would not buy”.

## DISCUSSION

### Centesimal composition of the raw materials used

The humidity below 14% prevents microbial development, increases chemical and enzymatic stability and increases commercial validity (Barbosa-Cánovas et al., 2007). The low lipid value which is a property characterized as positive, since a high lipid content may hinder the expansion of extrusions, while lipid values of up to 5% facilitate extrusion and improve texture. Depending on the amount, lipids can cause food spoilage during storage, producing odor and rancid taste (Kubow, 1993). On the other hand, the enzymatic activity of lipase is decreased in the extrusion process, guaranteeing greater stability in relation to the crude product (Lacerda et al., 2010). It is important to note that the fiber values found in MSMF may be derived from scales that occasionally survive the mechanical separation of meat adhered to the skin of the fish. Mattos and Martins (2000) proposed a classification for the fiber content of foods: very high (greater than 7%), high (4.5% to 6.9%), moderate (2.4% to 4.4%) and low (less than 2.4%). According to this classification, the by-products used in the present study have a low fiber content.

The presence of high levels of protein in MSMF shows that this by-product can enrich products made from it and can offer benefits related to nutrition and health of consumers. Thus, the

**Table 5.** Correlation of the physical and instrumental characteristics of the extruded snacks with different levels of substitution of broken rice grains (BRG) for mechanically separated tilapia meat flour (MSMF).

Variable	Specific Volume <sup>1</sup>	Expansion Index <sup>2</sup>	Hardness <sup>3</sup>	Luminosity	$a^*$	$b^*$
Specific Volume <sup>1</sup>	-	0.80*	-0.24	0.45*	0.03	-0.06
Expansion Index <sup>2</sup>	-	-	-0.06	0.50*	0.05	0.01
Hardness <sup>3</sup>	-	-	-	0.73**	0.76**	0.85**
Luminosity	-	-	-	-	-0.80**	0.83**
$a^*$	-	-	-	-	-	0.98**
$b^*$	-	-	-	-	-	-

\*significant at 5% probability and \*\* significant at 1% probability; <sup>1</sup>mm; <sup>2</sup>mg<sup>-1</sup>; <sup>3</sup>Newtons.

**Table 6.** Centesimal composition (mean ± standard deviation) of the snack with 30% inclusion of mechanically separated tilapia meat flour (MSMF) in substitution for the broken rice grain (BRG).

Componente (%)	30% of inclusion of MSMF	Snack of corn and linseed <sup>1</sup>
Carbohydrates	58.76±0.66	66.50±5.59
Protein	28.84±1.11	14.69±0.60
Lipids	4.34±0.24	0.22±0.09
Fibers	0.33 ±0.00	14.38±0.97
Ashes	1.53±0.43	1.70±0.04
Moisture	6.53±0.37	6.41±0.10

<sup>1</sup>Source: Trevisan and Arêas (2012).

by-products of tilapia and rice have proved to be an alternative source of nutrients, since they can help reduce the deficiencies of traditional and best-selling snacks, which are made with corn grits, oil, salt and flavorings.

### Physical and instrumental characteristics of extruded snacks

The greater the proportion of non-starch material added, the lower the degree of gelatinization of the starch of the product, due to a decrease in the proportion of amide and increase in interactions between starch and protein (Guerreiro, 2007). This impairs the maintenance of the expanded structure of the snack immediately after extrusion, increasing the degree of collapse of the structure and decreasing VS.

Maximum expansion is desired for extruded snacks, since a high EI is correlated with greater crispness, as the internal structure presents larger cells with thinner walls (Mercier et al., 1998). Therefore, an expanded structure is expected in snacks (Christofides et al., 2004). All the snack formulations presented low  $A_w$  (less than 0.5) and were considered microbiologically stable (Delgado et al., 2016).

Hardness is an important characteristic for snacks, since it affects the acceptability of the final product, making the product harder or crisper (Krüger et al., 2003), but there is no definition of acceptable values for snacks (Alves and Grossmann, 2002).

The percentage added the MSMF affects in hardness. This trend was also observed by Altan et al. (2008), who evaluated the addition of tomato bagasse to extruded products, and by Bender et al. (2016) for the inclusion of grape hull flour in extruded corn products. According to Ding et al. (2005), the moisture level of the raw material is the major factor for the hardness of expanded rice-based extrudates, and an increase in moisture content results in increased hardness. Lourenço et al. (2016) observed increasing hardness in the extrusion of BRG with elevated inclusion of shrimp flour.

The color of snacks is an important characteristic for their commercialization, being influenced by the raw materials that make up the formulation (Paucar-Menacho et al., 2008; Akillioglu and Yalcin, 2010). Therefore, in terms of color, the control snack showed a lower tendency for red and yellow compared to snacks incorporating MSMF. Similar results were observed by Bender et al. (2016), in corn snacks with the addition of grapefruit flour. It should be noted that the inclusion of darker ingredients in food products has been associated by consumers with whole and therefore healthier ingredients (Walker et al., 2014).

The increase of yellow ( $b^*$ ) intensity in extruded products is justified by a low moisture content during processing, which favors the appearance of non-enzymatic browning reactions (Borba et al., 2005). Therefore, an increase in moisture exerts a contrary effect on the color of food which is its most important visual attribute.

The variable SV and EI since they are measures of volumetric and radial expansion, respectively (Aquino et al., 2016). The variable  $L^*$  presented a negative correlation with  $a^*$ , that is, as the red level increased, the brightness decreased. In addition, the values

of  $a^*$  showed a positive correlation with the  $b^*$  values, that is, as the red tint increased in the snacks, the yellow tint also increased.

### Scanning electron microscopy

The extruded material has an irregular surface, with smooth parts, fluted parts and many holes, formed due to expansion of the product at the extruder outlet and water vapor released by the product during the decompression occurring in the material (Becker et al., 2014).

The moisture content established for flour by national legislation (Brasil, 2005) that allows a maximum of 15% moisture. Formulation T3 showed a significant amount of protein when compared to snacks made from linseed millet (approximately double) as mentioned by Trevisan and Arêas (2012), indicating that the product developed in the present study is a source of protein, according to ANVISA (Brasil, 2012).

According to Costa et al. (2016), the incorporation of MSMF promotes an increase in protein, minerals (magnesium, potassium, phosphorus, iron and calcium) and lipids which have a high content of essential fatty acids, mainly omega 3 and omega 6 series that are beneficial to human health. Therefore, it is notable that snacks based on rice and tilapia products are more nutritionally interesting than the traditionally marketed corn snacks.

### Sensory evaluation

Sensorial characteristics are the first criteria observed by the consumer at the time of purchase, being decisive in the choice of the product; acceptance of the texture is the most important attribute in these products (Capriles and Arêas, 2012). The inclusion of fishmeal at high levels usually causes unpleasant sensory alterations in the odor and taste of the products, generated mainly by free fatty acids and volatile sulfur compounds (Ganesan et al., 2014). However, some authors reported high acceptance and intention to buy products such as pasta and bread with 20% of fish meal added (Bastos et al., 2014; Goes et al., 2016), corroborating the results of the present study.

According to Surasani (2016), the addition of fish by-products for the nutritional enrichment of commercial products may be sensorily satisfactory depending in particular on the processing of the product, the type of fish and the proportion used in the formulation.

## CONCLUSION

Substitution of 30% of BRG for meat meal mechanically separated from tilapia resulted in a product with better technological qualities, such as higher rate of expansion, VE, hardness and color, similar to those of traditional extruded corn snacks. In addition, this formulation presented high nutritional value as well as high acceptance and purchase intention. Therefore, this snack represents an attractive alternative for the industrial sector and for the nutritional enrichment of widely consumed conventional products, thus meeting the demand of current consumers and stimulating the consumption of fish.



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