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YIELD OF MECHANICALLY SEPARATED MEAT IN NATURA AND POST-SMOKING OF *Clarias gariepinus* AT DIFFERENT WEIGHT CATEGORIES

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ABSTRACT

This study aimed at evaluating the yield of mechanically separated meat (MSM) in natura and post-smoking obtained from the African catfish (*Clarias gariepinus*) slaughtered in different weight ranges (A: 0.214 to 0.402 kg; B: 0.538 to 0.634 kg; C: 0.780 to 1.000 kg; D: 1.132 to 1.314 kg; E: 1.396 to 1.706 kg). In a completely randomize design composed by five treatments and 16 replicates, 80 fish were used. The yields of clean trunk and its residues, MSM *in natura*, MSM wastes and smoked MSM were evaluated, as well as the physic-chemical composition of *in natura* and smoked MSM. Additionally, a test of acceptance of the byproduct of smoked MSM was performed. Data were submitted to a variance analysis followed a Tukey's test at a 5% significance level. Weight ranges did not differ ($P < 0.05$) in relation to the yields of clean trunk, MSM production and after the smoking process. From the physic-chemical analysis of the MSM *in natura*, the product was classified as semi-fat fish meat. The smoked MSM displayed an increase in protein, lipids and ash contents in comparison to the MSM *in natura*. The acceptance test did not show significant differences among weight ranges, displaying mean values that correspond to "like it slightly". Thus, it was concluded that *C. gariepinus* can be processed from a weight of 0.600 kg, the MSM *in natura* presented satisfactory organoleptic characteristics, and higher consumption frequency of smoked MSM is achieved when the fish weight 0.900 kg.

Keywords: fish industrialization; African catfish; fish technology.

RENDIMENTO DE CARNE MECANICAMENTE SEPARADA IN NATURA E PÓS-DEFUMAÇÃO DE *Clarias gariepinus* EM DIFERENTES CATEGORIAS DE PESO

RESUMO

O objetivo deste estudo foi avaliar o rendimento da carne mecanicamente separada (CMS) in natura e pós defumação obtida do bagre africano (*Clarias gariepinus*) abatido em diferentes classes de peso (A: 0,214 a 0,402 kg; B: 0,538 a 0,634 kg; C: 0,780 a 1,000 kg; D: 1,132 a 1,314 kg e E: 1,396 a 1,706 kg). Foram utilizados 80 peixes em um delineamento inteiramente casualizado composto por cinco tratamentos e 16 repetições. Avaliou-se os rendimentos de tronco limpo, resíduos do tronco limpo, CMS in natura, resíduos da CMS, CMS defumada, composição físico-química da CMS in natura e CMS defumada, e teste de aceitação do subproduto de CMS defumado. Os dados foram submetidos a ANOVA, e posteriormente ao teste de Tukey a 5% de significância. As classes de peso não diferiram ($P<0,05$) para os rendimentos de tronco limpo, produção da CMS e após o processo de defumação. A partir da análise físico-química a CMS in natura de acordo com o teor lipídico, foi classificada como carne de pescado semi-gorda. A CMS defumada teve um aumento nos teores de proteína, lipídios e cinzas em relação a CMS in natura. O teste de aceitação indicou que não houve diferença significativa entre as classes de peso, obtendo valores médios que correspondem a "gostei ligeiramente". Portanto, o *C. gariepinus* pode ser processado a partir de 0,600 kg, a CMS in natura apresentou características organolépticas satisfatórias e maior frequência de consumo de CMS defumada de peixes com 0,900 kg.

Palavras-chave: industrialização de peixe; bagre africano; tecnologia do pescado.

INTRODUCTION

The increasing demands for animal protein and the constant growth of fish production have made this production sector more organized, in order to guarantee the offer of high quality products and, consequently, higher food security for the world population (FAO, 2018).

According to Basso and Ferreira (2011), the demand for products with high nutritional value and its adequacy to new consumption characteristics such as easy handling and preparation, stimulate the food industry (especially the animal production sectors) and the offer of unique products to the consumer market. The way products are presented and easy/fast preparation methods are among the main demands (Bartolomeu et al., 2011). However, due to the great diversity of produced species, slaughter weight and carcass processing patterns are rare and deserve attention.

The fish processing industry requires, besides the continuous production of batches by the producer, transport time, depuration and the final weight of animals, in order to define which processing methods can be used aiming to maximize yields. Additionally, these demands channels the production of fish byproducts, such as the mechanically separated meat (MSM) obtained from fish carcasses (Pires et al., 2014).

The technology used to obtain fish MSM is characterized by the passage of the carcass or wastes obtained during the filleting process in a meat-and-bone separation machine (Vidal et al., 2011). The use of such technique arose from the need to take advantage of wastes discards and non-targeted species as raw materials for the acquisition of fish-based products, thus consequently producing products with high nutritional and market value, such as fish-burgers, sausages, crumbed products, dumplings, among others (Durães et al., 2012; Guimarães et al., 2018; Ribeiro et al., 2018). Yet, smoked MSM is a promising product that can serve as basis for the manufacture of other byproducts.

Franco et al. (2013) reported that the smoking process adds exclusive sensorial characteristics to the fish, thus it also adds value to the product, and may be used as a way of increasing the market value of low-price fish that are not widely appreciated.

Both fish and its byproducts have high nutritional importance in human feeding, as these products are considered protein sources of high biological value with an adequate balance of amino acids (Gonçalves, 2011). It consists of an excellent protein, calcium, unsaturated fatty acids, water-soluble vitamins of the B complex and fat-soluble vitamins A and D source. However, the animals' chemical composition may be influenced by genetic, morphological, physiological or even nutritional factors (Costa et al., 2016).

The African catfish, *Clarias gariepinus* was introduced in national fish farms and its acceptance by the consumer market is due to specific characteristics such as absence of intramuscular spines, pleasant taste of the meat, besides presenting low carbohydrate and saturated fat contents, being considered a fish of lean meat (Ersoy and Ozeren, 2009; Ukwe et al., 2018; Umar et al., 2018).

This study aimed at evaluating the yield, physic-chemical, microbiological and sensorial composition of MSM *in natura* and post-smoking of *C. gariepinus* processed in different weight ranges.

MATERIAL AND METHODS

Raw materials and clean trunk obtention

A total of 80 *C. gariepinus* individuals were distributed in five treatments (16 fish per experimental unit), defined as different weight ranges of the live fish: (A) 0.214 to 0.402 kg; (B) 0.538 to 0.634 kg; (C) 0.780 to 1.000 kg; (D) 1.132 to 1.314 kg; (E) 1.396 to 1.706 kg.

In order to obtain the clean trunk, fish were submitted to a 24h fasting period and subsequently were processed in a fish processing plant with municipal sanitary inspection (SIM) (Brasil, 2017). All fish were initially desensitized with water and ice (Lambooij et al., 2006), followed by the section of the spinal cord with removal of the head and viscera. The skin was removed with the aid of a specific machine (Branco Máquinas - Skin 3000), the extraction of fins was performed manually and finally the fish were completely washed. Then, clean trunks were sorted by weight, labeled, individually frozen in a cold room and stored at -20 °C.

Acquisition of the mechanically separated meat (MSM)

The raw material used in the extraction of MSM was clean trunks of fish. These were cut in small pieces in order to facilitate the passage through the mechanical bone-removal machine (High Tech Ht 250-C). Then, samples were identified and stocked in a freezing chamber. Samples of the obtained MSM were collected for physic-chemical analysis.

Hot Smoking

An industrial vertical smoker (Defumax) was used for the hot smoking process of the MSM. At first, samples were weighted and then added salt at a concentration of 1.5% according to the methodology described by Silva et al. (2012) and Bainy et al. (2015) for products made of fish MSM.

After the salting process, samples were shaped as burgers and weighted, thus obtaining the molds' weight between 0.059 and 0.095 kg, then the molds were placed in grills according to each weight category. Grills were inserted in the smoker and submitted to an initial partial drying (30 minutes at 60 °C). Posteriorly, the mean temperature was increase to 88 °C and kept within the range stablished by Ferreira et al. (2002) for a period of 2 hours and 30 minutes.

Following the smoking process, samples were cooled at room temperature, weighted in a semi-analytical scale, packed and kept under freezing conditions until the microbiological, sensorial and physic-chemical analyses.

Yield calculations

Yields were calculated during the processing stages, obtaining the following variables:

i) Clean trunk: ratio between the fish's living weight and the clean trunk, using the equation: $YCT = \frac{CT * 100}{LW}$; where YCT (yield of clean trunk), CT (weight of clean trunk) and LW (live weight);

ii) MSMCT: yield of the clean trunk weight in relation to the weight after the process of MSM acquisition, based on the equation: $YMSMCT = \frac{MSM * 100}{CT}$; where YMSMCT (yield of the mechanically separated meat in relation to the clean trunk), MSM (weight of the mechanically separated meat), and CT (clean trunk);

iii) MSMLV: yield of the MSM in relation to the live weight of fish, based on the equation: $YMSMLV = \frac{MSM * 100}{LV}$; where YMSMLV (yield of the MSM in relation to live weight), CMS (weight of the mechanically separated meat), and LV (live weight of fish);

iv) Smoking: ratio between MSM weight prior and after the smoking process, with every MSM mold being individually weighted, based on the equation: $YSMSM = \frac{SMSM * 100}{MSM}$; where YSMSM (yield of the smoked mechanically separated meat), SMSM (weight of the smoked MSM), and MSM (weight of the used MSM);

v) Clean trunk wastes: expressed by the equation: $ResCT = 100 - YCT$; wastes of the MSM: in relation to live weight, expressed by the equation: $ResMSMLW = 100 - YMSMLW$; in relation to clean trunk, equation: $ResMSMLW = 100 - YMSMCT$.

Physic-chemical analyses

The physic-chemical analyses were performed in all different weight categories in both regular and smoked MSM of the fish, according to the methodology described in AOAC (2016).

Microbiological analyses

In samples of both smoked and *in natura* MSM microbiological quantifications were performed, regarding the gender *Clostridium* (sulphite reducers), molds and yeasts, according to Anvisa - Resolution RDC n° 12 of January 2, 2001 (Brasil, 2001).

Sensorial analysis

Before each sensorial test, judges were advised on the methodology of evaluation and on the procedures of the analysis to be performed. Thirty-eight non-trained (but that were used to consume fish-derived protein) contributors participated in the trials.

The acceptance trial was performed according to ABNT (1998) standards, using the hedonic scale of nine points with extremes of 1 - extremely disliked; and 9 - extremely liked, by which the participants expressed their acceptance for the products. Both the purchase intention and frequency of consumption were evaluated in relation to the disclosed samples.

Statistical analyses

All data were assessed regarding the normality (Shapiro-Wilk test) of errors and homoscedasticity (Levene's test) of variances. Then, a variance analysis (ANOVA) was performed and when significant differences were found, a Tukey's test was applied at a 5% significance level. All statistical analyses were performed with the aid of the software STATISTICA 7.0®.

RESULTS

The clean trunk yield displayed statistical differences among weight categories ($P < 0.05$) (Table 1). Weight classes A and B presented similar yields, while C, D and E were different. Regarding YCT (%), it was higher in classes B, C, D, and E, while Res.CT (%) was higher in class A, which did not differ from class B.

The yield of MSM in relation to trunk (PTL), weight of MSM (PCMS) and percentage of MSM in relation to clean trunk, as well as the wastes generated in the processing of clean trunk to obtain the MSM (Res.CMS) did not present statistical differences ($P > 0.05$) among weight categories (Table 2).

The residues of the MSM extraction process (Res.MSM) were similar and did not present any significant differences ($P > 0.05$) in the evaluated weight classes (Table 3).

The values of the centesimal composition of the smoked MSM (Table 4) displayed significant differences regarding the moisture content ($P < 0.05$), which was lower in the fish belonging to the heaviest fish (class E), whilst the lower protein contents were observed in class B ($P < 0.05$). The lowest concentration of lipids was found in class A ($P < 0.05$). A significant difference ($P < 0.05$) was verified in the ash content, which was higher in class E in comparison to others.

The MSM yield after the smoking process did not present statistical difference ($P > 0.05$) within weight categories, as shown in Table 5.

Table 1. Mean values of individual live weight (LV), clean trunk (WCT) and percentage of clean trunk in relation to live weight (YCT), as well as waste of clean trunk in relation to live weight (Res.TL) from the processing of *C. gariepinus* in different weight categories.

	LV	WCT	YCT (%)	Res.CT (%)	P value
Class A	0.214 to 0.402	0.137 ± 0.03	44.11 ± 4.25b	55.89 ± 4.25a	> 0.05
Class B	0.538 to 0.634	0.279 ± 0.03	47.24 ± 3.49ab	52.76 ± 3.49ab	> 0.05
Class C	0.780 to 1.000	0.431 ±0.05	47.44 ± 2.59a	52.56 ± 2.59b	> 0.05
Class D	1.132 to 1.314	0.587 ± 0.05	49.07 ± 3.86a	50.93 ± 3.86b	> 0.05
Class E	1.396 to 1.706	0.763 ± 0.07	49.54 ± 3.12a	50.46 ± 3.12b	> 0.05

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg. Means ± standard deviation indicate significant difference by the Tukey's test ($P < 0.05$).

The values of the centesimal composition of the MSM (Table 6) displayed significant differences regarding the moisture content ($P < 0.05$), which was higher in class A, whilst lower moisture contents ($P < 0.05$) were obtained in classes B and E. A significant difference ($P < 0.05$) in the crude protein content was also observed, being higher in class E, which was similar to class A.

No molds or yeasts were detected regarding the total quantification parameter in the smoked MSM of *C. gariepinus*, as well as the accounting of sulphite reducers *Clostridium*, which may compromise the quality of the samples (Table 7).

The results obtained in the acceptance test have demonstrated that the final smoked product (MSM), regardless of weight category, were well accepted by the participants. The distribution of attributed grades were found to be higher than 5, which corresponds to the concept "did not like and did not dislike", showing acceptance of the product. In relation to the smoked

Table 2. Mean values of clean trunk weight (WCT), weight of MSM (WMSM) and MSM yield in relation to clean trunk (YMSM), and the percentage of wastes from the MSM in relation to clean trunk (Res.MSM).

	WCT (kg)	WMSM (kg)	YMSM (%)	Res.MSM (%)	P value
Class A	2.541	2.386	93.88 ± 1.58	6.12	NS
Class B	4.987	4.862	97.48 ± 0.05	2.52	NS
Class C	3.092	2.981	96.41 ± 1.24	3.29	NS
Class D	5.616	5.349	95.24 ± 2.74	4.76	NS
Class E	6.558	6.404	97.65 ± 0.95	2.35	NS

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg.

Table 3. Values of total live weight of *C. gariepinus* used for the extraction of MSM (LWT), weight of MSM after the extraction process (WMSM), yield of the MSM in relation to live weight (YMSM) and residue of the MSM extraction process in relation to the fish's live weight (Res.MSM).

	LWT (kg)	WMSM (kg)	YMSM (%)	Res.MSM (%)	P value
Class A	5.591	2.386	42.67	57.33	NS
Class B	10.557	4.862	46.05	53.95	NS
Class C	6.518	2.981	45.73	54.27	NS
Class D	11.445	5.349	46.74	53.26	NS
Class E	13.23	6.404	48.36	51.64	NS

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg.

Table 4. Mean values of the physic-chemical composition of smoked MSM of *C. gariepinus* in each weight category.

	Moisture (%)	Crude Protein (%)	Lipids (%)	Ash (%)	P value
Class A	58.36 ± 2.17a	28.53 ± 0.91ab	9.35 ± 0.28c	5.03 ± 0.52b	>0.05
Class B	57.02 ± 1.37a	26.60 ± 0.67b	11.51 ± 0.26a	5.45 ± 0.20b	>0.05
Class C	57.59 ± 1.79a	27.66 ± 0.82ab	10.46 ± 0.06b	5.41 ± 0.52b	>0.05
Class D	57.48 ± 0.58a	29.04 ± 2.03a	10.51 ± 0.19b	5.03 ± 0.33b	>0.05
Class E	51.40 ± 2.91b	29.12 ± 0.09a	11.80 ± 0.16a	6.65 ± 0.67a	>0.05

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg. Means ± standard deviation indicate significant difference by the Tukey's test ($P < 0.05$).

Table 5. Mean values of the yield obtained from *C. gariepinus* processing after smoking in relation to different weight categories.

	WMSM (kg)	WMSMA (kg)	YSMSM (%)	P value
Class A	81.05 ± 7.46	50.75 ± 7.81	62.65 ± 9.29	NS
Class B	75.30 ± 5.26	45.22 ± 8.45	61.76 ± 9.76	NS
Class C	78.25 ± 4.86	51.00 ± 9.09	62.95 ± 10.54	NS
Class D	79.45 ± 4.27	51.35 ± 7.88	63.75 ± 9.98	NS
Class E	76.45 ± 6.10	48.95 ± 10.01	60.77 ± 11.52	NS

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg. Means ± standard deviation indicate significant difference by the Tukey's test ($P < 0.05$). Values of smoking yield refer to the yield of smoked MSM in relation to the MSM prior to smoking. WMSM: weight of MSM prior to smoking; WMSMA: weight of MSM after smoking; YSMSM: yield of the smoked MSM in relation to MSM *in natura*.

Table 6. Mean values of the physic-chemical characteristics of the MSM of *C. gariepinus* in each weight category evaluated in the experiment.

	Moisture (%)	Crude Protein (%)	Lipids (%)	Ash (%)	P value
Class A	73.07 ± 0.07a	17.28 ± 0.38ab	6.18 ± 0.05b	3.09 ± 0.17	< 0.05
Class B	71.68 ± 0.20c	16.63 ± 0.17b	7.47 ± 0.60a	3.16 ± 0.30	< 0.05
Class C	72.48 ± 0.13b	16.89 ± 0.32b	6.57 ± 0.51ab	3.26 ± 0.20	< 0.05
Class D	72.25 ± 0.15b	17.11 ± 0.24b	6.65 ± 0.30ab	3.39 ± 0.12	< 0.05
Class E	71.87 ± 0.020c	18.19 ± 0.94a	6.89 ± 0.54ab	3.34 ± 0.16	< 0.05

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg. Means ± standard deviation indicate significant difference by the Tukey's test (P < 0.05).

Table 7. Microbiological evaluation of the smoked MSM of *C. gariepinus* in each weight category.

	Total Count of Molds and Yeasts at 25 ± 1 °C	Total count of sulphite reducers *Clostridium*	P value
Class A	1.0×10^1	$< 1.0 \times 10^1$	NS
Class B	3.0×10^1	$< 1.0 \times 10^1$	NS
Class C	2.5×10^1	$< 1.0 \times 10^1$	NS
Class D	5.0×10^1	$< 1.0 \times 10^1$	NS
Class E	9.0×10^1	$< 1.0 \times 10^1$	NS

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg.

Table 8. Mean values of the participants' grades of the smoked MSM of *C. gariepinus*.

	Class A	Class B	Class C	Class D	Class E	P value
Aspect	7.18 ± 1.36	7.13 ± 1.24	7.18 ± 1.47	7.23 ± 1.33	6.78 ± 1.46	NS
Smell	7.00 ± 1.47	7.08 ± 1.14	7.13 ± 1.34	7.05 ± 1.57	7.03 ± 1.33	NS
Flavor	7.03 ± 1.27	7.10 ± 1.17	7.18 ± 1.65	7.18 ± 1.53	6.60 ± 1.75	NS
Texture	6.90 ± 1.43	6.93 ± 1.42	7.33 ± 1.27	6.95 ± 1.63	6.35 ± 1.69	NS
Overall Impression	7.13 ± 1.20	6.98 ± 1.42	7.15 ± 1.49	7.10 ± 1.53	6.63 ± 1.48	NS
General Mean	7.04 ± 1.34	7.04 ± 1.28	7.91 ± 1.44	7.10 ± 1.51	6.67 ± 1.55	
Buy Intention	3.76 ± 0.88	3.58 ± 0.89	3.95 ± 0.96	4.05 ± 1.09	3.42 ± 1.37	NS
Cons.Freq.	4.61 ± 1.57ab	4.42 ± 1.35ab	5.34 ± 1.32a	4.76 ± 1.72ab	4.24 ± 1.87b	< 0.05

Weight categories: Class A - 0.300 kg; Class B - 0.600 kg; Class C - 0.900 kg; Class D - 1.200 kg; and Class E - 1.500 kg. Means ± standard deviation indicate significant difference by the Tukey's test (P < 0.05).

MSM, no statistical difference (P > 0.05) was found for product aspect, smell, flavor, texture, and overall impression (Table 8). The value of the grades attributed for consumption frequency (Cons.Freq) were significantly different (P < 0.05). The grades varied from 1 to 7, being 1 "would never eat it" and 7 "would always eat it". It was verified that the grade attributed to class C differed among others in each weight category.

DISCUSSION

The way of slaughtering fish and its availability for consumption have great importance both in the product's economic value and on the efficiency of the adopted procedure, as processing yields are higher when the size of fish is standardized.

Adames et al. (2014) evaluated the processing of *Pinirampus pirinampu* and observed that the highest yields of clean trunk were obtained in fish above 620 grams, while the lowest yields were found to have higher percentage of wastes. When *C. gariepinus* was classified by weight, Souza et al. (1999) observed that the clean trunk yield was varied between 51.70%, 56.67% and 54.54% regarding fish of 1 kg, 1-2 kg and above 2 kg, respectively, values that were higher in comparison to the present study. Conversely, Durães et al. (2012) obtained a 57.98% clean trunk yield in the same species (in relation to live weight), considering the fins.

The values of Res.CT demonstrated that the samples belonging to the weight categories with higher quantities of wastes were A and B - 55.89% and 52.75%, respectively. Durães et al. (2012) found 47.12% of wastes (heads, skin and viscera) deriving from the processing of *C. gariepinus* aiming to obtain a clean trunk as final product.

The yield of *in natura* MSM in relation to a clean fish presented values between 93.88% and 97.65%, although Durães et al. (2012) found a percentage of 85.85% in the same species. This may have occurred due to the fact that the MSM was extracted from the clean trunk including the fins, and these present a higher amount of fine, pointed bones.

The form of processing (e.g. equipment use and adjustment) might be among the most strongly influencing factors in final yield, and consequently in the wastes deriving from MSM extraction. The yield of MSM in natura varied from 42.67% to 48.36% in relation to LW, with the lowest yield being observed in class A, while the highest yield was found in class E. According to Kirschnik and Macedo-Viegas (2009), MSM extraction yield of *Oreochromis niloticus* was 46.90% in relation to whole fish, which is similar to the values found in classes B, C and D in our study. Therefore, yield values of the MSM in relation to live fish are directly related to the size of the organisms.

The moisture content of MSM in natura were found within the range of 71.68% and 73.07%, being lower to the values reported by Souza et al. (1999) for the filet MSM of *C. gariepinus*, whom obtained moisture contents of 77.78% for fish smaller than 1kg, 77.49% for fish between 1-2kg and 76.39% for fish above 2kg. According to Lajolo and Mercadante (2017), smaller fish present higher moisture and lower fat contents. However, in the study developed by Durães et al. (2012), this parameter was shown to be of 78.42% in the MSM of *C. gariepinus*, higher than the one found in our study.

The protein content of MSM in natura was 15.82%, similar to the values found by Durães et al. (2012) (15.86%), while Souza et al. (1999) verified that in *C. gariepinus* filets of fish smaller than 1kg, between 1-2kg and above 2kg, crude protein values were 18.03%, 18.58% and 18.41%, respectively. Gonçalves and Cezarini (2008) when evaluating *Rhamdia quelen* meat in natura, found a crude protein content of 14.67%, whilst Avelar (2013) found 15.46% of crude protein in *Brycon cephalus* in natura and Bordignon et al. (2010) found 15.11% of crude protein in MSM made of “V” cuts of *O. niloticus* filets. These were all similar to the results found in this study.

Lipid contents and the technological aspect of foods are of great importance, seen that higher lipid concentrations result in an increase of oxidative processes, producing aldehydes, ketones and free short-chain fatty acids, substances that are all responsible for unpleasant smell in fish meat (Oliveira and Lira, 2009), which consequently results in lower shelf life. The highest lipid content found in MSM in natura was of class B (7.47%), not differing from classes C, D and E (6.89%, 6.65% and 6.57%, respectively). Contrarily, the lowest content was found in class A, which did not differ from classes C, D and E. It was verified that an inverse relation between protein and lipid contents was found for class B.

The values found in this study are above the ones observed for *R. quelen* in natura (1.89-2.41%), *C. gariepinus* (3.17-3.26%), *R. quelen* in natura (2.38%) and *C. gariepinus* (1.51-3.03%). All lipid contents found in this study are well above the ones found by other authors for *C. gariepinus* and for other species (Gonçalves and Cezarini, 2008; Marengoni et al., 2009; Manske et al., 2011). According to Lajolo and Mercadante (2017), *C. gariepinus* meat can be classified as a semi-fat fish meat, seen that by the centesimal indicative, lipid contents in fish meat above 10% are considered fat, whilst between 2.5-10% it can be considered as semi-fat and below 2.5%, lean meat.

Ash contents of MSM in natura were similar among classes and differed from the results found by Souza et al. (1999). The authors found lower contents for the filet of *C. gariepinus*: 1.14% for fish below 1kg, 1.09% for fish weighting between 1-2kg, and 1.13% for fish above 2kg. When evaluating *C. gariepinus* MSM, Durães et al. (2012) found an ash content of 1.51%. This fact may be explained by the use of a MSM made of clean trunk, where the wastes are composed by bones, which may have been incorporated into the MSM.

The values of the centesimal composition of the smoked MSMs revealed that the moisture content were not different among samples of classes A, B, C and E, whilst for class E a significant difference was found (51.40%). Gonçalves and Cezarini (2008) found for traditionally smoked *R. quelen* and using liquid smoke, values of 57.35% and 58.94%, respectively, being similar to the ones found in this study. Manske et al. (2011) verified a moisture content of 64.85% in *R. quelen* filet, above the ones found in our investigation.

Crude protein contents for the smoked MSM remained similar, being higher only in classes D and E. Comparable results were reported by Gonçalves and Cezarini (2008) for traditionally smoked *R. quelen* (28.91%), for skinless smoked filet of *O. niloticus*, verified by Souza et al. (2005) (29.67%) and for smoked *R. quelen* filet (28.10%), found by Manske et al. (2011).

The lipid contents of smoked MSM displayed differences among classes, with classes B and E the ones with the highest levels. Manske et al. (2011) observed in smoked filet of *R. quelen* that the lipid content was found to be of 7.09%, while Souza et al. (2005) found for *O. niloticus* smoked filet a 3.55% content, being lower than the ones found in this study.

Concerning the ash content of smoked MSM, class E was higher in comparison to others; however, classes A, B, C and E were similar. Gonçalves and Cezarini (2008) observed an ash content of 3.62% when evaluating the composition of smoked *R. quelen* and according to Souza et al. (2004), the ash content of the smoked filet of *O. niloticus* was 5.13%, whilst for whole fish it was 7.30%, demonstrating that different products directly influence this variable.

When evaluating the yield and wastes in both filleting and smoking processes of *O. niloticus*, Souza et al. (2005) observed that during the smoking process, losses of 15.59-15.79% occur, being lower in comparison to the losses found by catfish (36.25-39.23%). The authors reported that such weight loss was due to the natural dehydration that occurs during the smoking process, although variations may occur among species, due to its varying organoleptic characteristics.

According to Santos et al. (2007), the surface-volume ratio of the product may lead to higher losses during smoking processes. In this sense, it can be observed that the hamburger molds that were used to shape the MSM before the process increased the surface of the product in relation to its volume. This fact may explain the highest loss of moisture of *C. gariepinus* when compared to the utilization of the filet in the process.

Minozzo (2011) reported that the kind of processing adopted in fish influences in the yield of the smoked product, a fact that was observed in this and in the study developed by Gonçalves and Cezarini (2008), in which the authors found a yield of 40.99% in *R. quelen* filet. According to Sigurgisladottir et al. (2000), weight losses during the smoking process are dependent of the origin and type of raw material, as well as of the final product's characteristics and the procedures adopted in the smoking process, concerning time and temperature.

As for the evaluation of the acceptance of smoked MSM in regard of the texture, appearance and flavor, the results found in this study were similar to the ones reported by Abolagba et al. (2015) and Sotolu and Abdullateef (2018). The authors reported mean values of acceptance for reared *C. gariepinus* that demonstrated that the smoked MSM of the fish was well accepted by the participants due to its flavor, juiciness and tenderness.

CONCLUSION

The African catfish (*Clarias gariepinus*) can be explored for the obtention of mechanically separated meat (MSM) of the animal's clean trunk, especially when fish are within the range of 0.600 and 1.500 kg. The acceptance by the final consumer is high, especially in regard of the smoked MSM of fish weighting 0.900 kg. Finally, the smoking process keeps the fish's organoleptic characteristics.

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