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RESEARCH ARTICLE

BREADED FROM NILE TILAPIA (*OREOCHROMIS NILOTICUS*): EFFECT OF ADDITION FROM DIFFERENT CONCENTRATIONS OF MECHANICALLY SEPARATED MEAT AND COOKING METHODS ON ITS QUALITY

[1, *]Roseane Maria Evangelista Oliveira, [1]Amanda Maria Teixeira Lago, [1]Carlos José Pimenta, [1]Tatiana Abreu Reis, [1]Isabela Emilioreli Nogueira and [2]Heloisa Oliveira dos Santos, [1]Maria Emília de Souza Gomes Pimenta

[1, *]Departamento de Ciência dos Alimentos – DCA, Universidade Federal de Lavras, Caixa Postal 3037 – CEP 37200.000 – Lavras, Minas Gerais, Brazil
[2]Departamento de Agricultura – DAG, Universidade Federal de Lavras, Caixa Postal 3037 – CEP 37200.000 – Lavras, Minas Gerais, Brazil

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ABSTRACT

It had as objective to evaluate, by chemical and physical analyzes, breaded prepared with mechanically separated meat (MSM) increasing inclusion, of waste from Nile tilapia filleting, subjected to two cooking methods. It was observed a decrease in moisture and increase in lipid, protein and ash of baked and fried breaded on both treatments. The MSM increasing inclusion produced greater water loss, increased lipids and calcium. Among the amino acids, lysine was the most abundant. There was a predominance of fatty acids palmitic, oleic and linoleic, giving to the breaded nutritionally healthy characteristics. The color analysis indicated lower L* for fried breaded, increase of b* in baked breaded and increase in a*, with MSM inclusion. The shear force showed higher levels of hardness for roasted samples with low MSM levels. It was found through research that it is feasible to use MSM in the breaded preparation and according to the analyzed variables, baked is the ideal cooking method.

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INTRODUCTION

Changes in consumer demand of processed products, as well as increased global competition are driving the development of new processing techniques and the use of new ingredients in their manufacture (Weiss *et al.,* 2010). The fish has been increasingly valued by consumers, due to the benefits it provides to health, since their nutrients show high physiological, metabolic and nutritional importance. It is considered as protein source for human consumption, containing essential amino acids and provides minerals (calcium, phosphorus and iron) and considerable amounts of essential fatty acids such as omega 3 and 6.Moreover, it is highly digestible, and has good palatability, low cholesterol levels (Godoy *et al.,* 2010; Ogawa and Maia 1999).

Corresponding author: *Roseane Maria Evangelista Oliveira
Departamento de Ciência dos Alimentos – DCA, Universidade Federal de Lavras, Caixa Postal 3037 – CEP 37200.000 – Lavras, Minas Gerais, Brazil

In Brazil the fish industrialization is increasing, however, the procedures for processing fish generate a volume more than 50% of waste that if not properly utilized, become pollutants, may cause damage to the environment. Whereas these wastes contain ahigh protein content and other nutrients, it is necessary their utilization and the incentive of new technologies use for new industrial products development with higher added value and high demand (Gonçalves 2011).The breaded preparation is an interesting alternative, which is well accepted by consumers (Dill *et al.,* 2009) which is defined as industrial meat product derived from different animal species, increased by ingredients, framed or not, and capped with an appropriate cover that features. Can be found as a crude product, semi-boiled, boiled, semi-fried, fried or also pass through other cooking forms (Brasil 2001). In their preparation may be used the mechanically separated meat (MSM) of fish, its obtaining occurs through equipment capable of separating the muscle materials added to spines, also known as minced fish or fish pulp. The MSM can be used in a range of products, due to its mild flavor and no problems associated to the spines presence (Gonçalves 2011; Rebouças *et al.,* 2012). In developing a new product is essential to optimize and standardize parameters, such as shape, color, appearance, odor, flavor, texture and consistency. The interaction among its different components and especially the nutritional parameters should also be optimized and standardized in order to get an integral balance, resulting in an excellent quality and that is good acceptability, producing consumer satisfaction (De Penna 1999; Minim 2006).

By being prepared for consumption, the breaded passes through some kind of heat treatment, it is of fundamental importance for understand the changes undergone by its during the process, because in different heat treatments the forms of heat transfer, temperature, process duration and means of cooking are some of the factors responsible for changes in their chemical composition, causing changes in nutritional value (Ghidurus *et al.,* 2010; Vieira *et al.,* 2007). Given this context, in this work aimed to evaluate, by means of chemical and physical analyzes, breaded prepared with different MSM levels inclusion, of waste from Nile tilapia filleting (*Oreochromis niloticus*), replacing the fillet and submitted to two cooking methods (baked and fried).

MATERIALS AND METHODS

The project was conducted at the Federal University of Lavras (UFLA), in the following laboratories as Food Science, Chemistry, Biochemistry and Food Analysis; Meat and Fish. The Leaf Analysis Laboratory and Chemistry in the Chemistry Department and for Advanced Analyses Laboratory and Biotechnology also in this University were used for specific analysis.

Obtaining raw materials and other ingredients

The raw material used was composed by waste from Nile tilapia filleting (*Oreochromis niloticus*), which were pulped into electrical depulper High Tech Model HT 100C, thus obtaining the MSM, which was washed and frozen (-20 °C±2 °C). The fillets, also of the same origin were ground in an electric meat grinder C.A.F 10I and frozen at a temperature equal to the MSM. The ingredients (starch, isolated soy proteic, salt, hydrogenated vegetable fat, monosodium glutamate and onion cream) used in different breaded formulations were obtained in commercial establishments of Lavras - MG.

MSM washing

The MSM obtained was added ice water (10 °C) and 0.5% NaCl at a ratio of 5L of water for 2kg of MSM. The mixture was stirred to obtain a homogeneous solution, which was then drained and pressed manually on organza cloth until to remove the water excess and obtain a mass.

Breaded preparation from tilapia

For breaded preparation were used different formulations, according to Table 1.

Table 1. Breaded formulations prepared using MSM and Nile tilapia fillet (*Oreochromis niloticus*) at different inclusion levels

Ingredient	Quantity (%)				
	F1	F2	F3	F4	F5
MSM	81.0	60.7	40.5	20.7	0.0
Fillet	0.0	20.7	40.5	60.7	81.0
Starch	3.5	3.5	3.5	3.5	3.5
Isolated Soy Protein	3.5	3.5	3.5	3.5	3.5
Cold water	7.0	7.0	7.0	7.0	7.0
Salt	2.5	2.5	2.5	2.5	2.5
Hydrogenated vegetable fat	1.2	1.2	1.2	1.2	1.2
Monosodium glutamate	0.6	0.6	0.6	0.6	0.6
Onion cream	0.7	0.7	0.7	0.7	0.7

*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Source: Adapted Pimenta (2011).

All ingredients were weighed, and the MSM and the fillet proportionately according to each formulation. Then, they were manually homogenized, modeled on a circular stainless steel mold and breaded. In the breaded process for obtaining the batter (solid suspension in liquid that acts as a bonding layer between the substrate and the end cover), it was used a blender (Arno brand) where all the ingredients (Table 2) were homogenized at the same time. For the breading (end cap) breadcrumbs and corn flour (fine crushed) were used.

Table 2. Formulation of liquid from breaded used in all breaded formulations prepared with MSM and Nile tilapia fillet (*Oreochromis niloticus*) at different levels

Ingredients	Quantities
Wheat flour	125 grams
Corn starch	75 grams
Milk powder	50 grams
Salt	10 grams
Water	500 mL

The breaded were dipped in batter and then in breading and vice-versa. Finally, they were subjected at two different heat treatments (baked and fried). For the baked breaded preparation, it was used the electric oven (Electrolux brand) at a temperature of 200 °C. The samples were baked per 50 minutes, being 25 minutes on each side. The frying was performed in a conventional gas stove, and the samples were dipped in soy oil under high temperatures average 190 °C per 2 minutes. Samples of baked and fried breaded were frozen at -18 °C until the realization of the chemical and physical analyzes. The breaded treated heat were compared with the product *in natura* (breaded crude).

Chemical and physical breaded characterization

The physical and chemical breaded determinations were performed in three replicates, each replicate analyzed in triplicate.

Centesimal composition

Analyzes to obtain the breaded centesimal composition (moisture, ether extract, crude protein and ash), were performed according to the methods proposed by the Association of Official Agricultural Chemists - AOAC (2000).

Calcium and Phosphorus

Calcium and phosphorus were quantified in flame photometer from extracts of samples obtained by digestion nitric perchloric (DNP) and determined according Malavolta *et al.* (1989).

Amino acid profile

The amino acid profile was obtained, according to the methodology proposed by Prates (2002), with adaptations. For the quantitative determination of amino acids was used liquid chromatography (HPLC) on Shimadzu, model Prominence, operating with fluorescence detection, using Shim-pack Amino-Na (Shimadzu brand). For the quantification and separation of amino acids were used mobile phases A, B and C in gradient with injection volume of 10 µL and a wavelength of 350 nm for excitation and 450 nm for emission. The amino acid content was determined by comparing the peak area of the samples with standard calibration curve.

Fatty acids profile

To determine the breaded fatty acids profile of methyl esters were analyzed by gas chromatography (GC) in Shimadzu model GC - 17 A with detector of flame ionization (FID) using a capillary column Carbowax (30 mx 0.25 mm). Nitrogen was used as carrier gas, with a programmed linear velocity of 37.8 cm/s at a flow of 1.0 $mL.min^{-1}$. The injector and detector temperatures were controlled in isotherm form at 220 °C and 240 °C, respectively. For the column, initial temperature of 100 °C was maintained per 2 minutes increasing at a rate of 4 $°C.min^{-1}$ until it reaches 240 °C. For recording and analysis of chromatograms, the chromatograph was coupled to a microcomputer, using the GC Solution program. The compounds identification was performed by retention time of the corresponding pattern and the percentage in function of compounds area.

Instrumental color

Color determination was performed according to James and Berry (1997), in colorimeter CM-5 Konica Minolta (reflectance, 30mm SCI - brightness included), operating in the CIE (Comission Internationate L'Eclairage), to measure the parameters L* (lightness), a* (intensity of red to green colors) and b* (intensity of yellow to blue colors).

Shear Force

The instrumental analysis of texture was performed on texturometer TA.XT Plus/50 (Stable Micro Systems) equipped with a Warner-Bratzler of rectangular blade for distance of 40mm and speed of 2mm/s. Three breaded were used in each formulation and type of cooking. Shear force was measured according Abularach *et al.,* (1998).

Experimental design

The experimental design was completely randomized in a 5x2 factorial (5 breaded formulations and 2 types of cooking). The data were analyzed by the Scott-Knott test at 5% probability level using SISVAR Program (Ferreira 2000).

RESULTS AND DISCUSSION

Centesimal composition

The results for centesimal composition are shown in Table 3.Table 3. Mean values of centesimal composition, in percent of breaded prepared with different MSM levels of Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried).

Table 3. Mean values of centesimal composition, in percent of breaded prepared with different MSM levels of Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)

Composition (%)	Cooking methods	Formulations				
		F1	F2	F3	F4	F5
Moisture *	*In natura*	57.87 cA	60.93 bA	62.21 aA	62.55 aA	63.63 aA
	Baked	38.96 eC	44.41 dC	48.88 cC	52.56 bC	54.84 aB
	Fried	51.61 bB	52.99 bB	54.37 aB	54.91 aB	54.56 aB
Ether Extract *	*In natura*	8.73 aC	6.70 bC	5.65 cC	5.14 cC	4.40 dC
	Baked	12.76 aB	9.27 bB	7.63 cB	6.57 dB	5.12 eA
	Fried	15.36 aA	14.05 bA	11.48 cA	10.86 cA	5.50 dA
Crude protein *	*In natura*	14.59 bC	14.96 bC	15.66 bB	16.75 aB	17.43 aC
	Baked	21.37 aA	21.47 bA	21.52 bA	21.75 bA	21.95 bA
	Fried	19.02 bB	20.74 aA	20.16 aB	20.52 aA	20.88 aB
Ashes *	*In natura*	3.05 aB	2.82 bB	2.77 cB	2.60 cC	2.38 dC
	Baked	4.85 aA	4.34 bA	3.93 cA	3.54 cA	3.12 dA
	Fried	3.13 aB	3.00 aB	2.84 bB	2.79 bB	2.58 cB

*Means followed by the same lower case in line and uppercase in column do not differ to each other by the *Scott-Knott* test (P<0.05).
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

With reference to the breaded moisture percentage "*in natura*", it was found that the formulations added with larger MSM percentages showed lower mean values for this variable (P<0.05). Thus, it can affirm that the F1 formulation had lower moisture value, then the formulation F2. The F3, F4 and F5 formulations did not differ statistically (P>0.05) among themselves and showed higher mean values that other formulations. Moura (2012) also found that as increased the fish MSM percentage in instead to meat of the meat products reviews, decreased moisture content. In obtaining washed MSM process occurs a breach of the muscle organizational structure, due to the rigorous grinding and salt addition, and part of the water is lost. In ground fillet, although some loss of water can occur, this is very small, almost negligible, which contributes to the higher values found. Assessing the effect of moisture heat treatments, it is possible to observe that the baked breaded presented lower mean value when compared to fried breaded. According to Dill *et al.* (2009), during the frying process, the breaded cover is sealed more easily not permitting the exit of water from the surface, that is, occurs the formation of a film between the cover and the flesh resulting from the hydration of proteins and starch gelatinization derived from wheat flour used in the roofing system (batter). For F5, however, there was no significant difference in the percentage of breaded moisture - baked and fried (P>0.05), both lower than that found for the breaded "*in natura*".

The breaded moisture values *in natura* range from 57.87 to 63.63%, which is above the results (52.5%, 52.9% and 54.75%) obtained by Hosda *et al.* (2013), that evaluated nuggets from fillet and MSM of tilapia with added sage and rosemary. Higher result (67.47%) was found by Cortez Netto *et al.* (2010) in breaded from tilapia (*Oreochromis nicoloticus*). These variations are normal and are due to the different raw materials used to obtain the MSM and the filet. For the baked breaded this behavior was even more pronounced, since the mean moisture values observed in the formulations containing higher percentages of MSM (F1, F2 and F3), were much lower (P<0.05) than those presented by the formulations F4 and F5. During the cooking to the oven occurs a substantial water loss, which contributes to the observed values, particularly in the breaded products containing more MSM, since in them some water is still weakly bound. In fried breaded, F1 and F2 did not differ from each other (P>0.05) and showed lower moisture values than those presented by the F3, F4 and F5 which were statistically equal, indicating that the MSM presence in higher levels contributes for water loss during heat processing. According Ordonez (2005), the moisture has an inverse correlation with the lipid content. This statement is consistent with the results found in this study, since when observed a high percentage of lipids, the moisture was low. For the breaded *in natura* F1 and F5 were obtained moisture values 57.87% and 63.63% and lipid 8.73% and 4.40%, respectively. The same behavior was verified by Cortez Netto *et al.* (2010) for the breaded preparation of jundiá (*Rhamdia quelen*), pacu (*Piaractus mesopotamicus*) and tilapia (*Oreochromis niloticus*) with moisture percentage 63.68%, 65.84% and 67.46%, and lipids with 10.18%, 8.23% and 4.08%, respectively. The ether extract content of breaded F1 (formulated with 100% MSM) was higher than the other treatments, following a decreasing order among them.

The high content of ether extract present in samples added of higher MSM concentrations also can be explained due MSM to be extracted from the abdominal muscle, which is near to carcass of tilapia, where contains considerable adiposity (Bordigon *et al.,* 2010). While increasing the ether extract percentage, according Vidotti and Martins (2010) the fat present in the clipping and ventral abdominal cavity of the fish is composed for monounsaturated fatty acids, total polyunsaturated, saturated and omega-3, which brings nutritional benefits to the product. The baked breaded should have higher percentages of ether extract, due to the low moisture content when compared to fried breaded. However, it was verified higher levels in these last. This probably occurred due to fast moisture output of the product, which led to the creation of pores leading to formation of capillary pathways for the entry of the oil during the frying process (Ngadi *et al.,* 2006). Breaded products with added of final cover (breading) can reach 20% of oil or fat absorption in relation to the final weight of the product (Lemos, 2003).

Regarding to crude protein, for breaded "*in natura*" it was observed mean values significantly lower (P<0.05) for the formulations F1, F2 and F3 and F4 and F5 had significantly higher mean values (P<0.05), so the greater amount of MSM in the formulation, the lower protein percentage. In the MSM washing process and salt addition parts of the proteins are lost, which makes its proteic value lower to the fillet. However, the normative Instruction n° 6, 15 February 2001, establishing measures that regulate the industrialization of animal products, ensuring equal conditions between producers and ensuring transparency in production, processing and marketing, establishes that the breaded may show in its centesimal composition the minimum 10% of this attribute (Brasil, 2001). The results presented in Table 3 show that even with the increased MSM inclusion, the crude protein remained in accordance with the law, since the mean values ranged from 14.59% to 21.95%. The breaded showed higher proteins values in relation to the MSM "meatballs" from Nile tilapia produced by Oliveira *et al.* (2011), which were between 11.60% and 13.00%. However, were similar to fish breaded developed by Veit *et al.* (2011) and Cortez Netto *et al.* (2010), who found values of 14.67% and 19.05%, respectively. In both heat treatments there was increase in protein content, being the highest percentage in the baked breaded. Farfán and Sammán (2003) also found high values of protein in meat that have been subjected to some type of heat treatment compared to meats *in natura*. The authors explained the increase in the nutrients concentration due to water loss during cooking. The obtained values for ash showed significant variations among the formulations of breaded added MSM (F1, F2, F3 and F4) and formulation elaborated only with tilapia fillet (F5). Note that the ash content decreased as it increased the percentage of ground fillet in relation to the MSM percentage used in the breaded preparation. According to Oliveira Filho (2009), this is probably because the obtaining MSM incorporating by the mass small bone fragments and, therefore, responsible for causing changes in the composition of the mineral residue. Cortez Netto *et al.* (2010), elaborated breaded with 100% of tilapia fillet ground and got ash content of 2.70%, corroborating with the results found in this study, when compared to formulations F5 (100% fillet) that were 2.58%. Bordigon *et al.* (2010) elaborate pre-fried croquettes of MSM and obtained a mean value 3.36% of ash, similar to results found for the F1 formulation (100% MSM) fried in treatment, which showed a rate 3.13%. Regarding the cooking type, it was found that the baked breaded showed a higher ash percentage, followed of fried breaded. A similar result was observed by Souza (2013) on chicken nuggets subjected to different heat processing. The author justifies the result due to the dehydration of the products by the heat action, causing a decrease in weight of food, and consequently concentration in mineral content, which increases the percentage values.

Calcium and Phosphorus

The mean values found in assessing of the calcium and phosphorus amount are shown in Table 4.

Table 4. Mean values of calcium and phosphorus in percentage, of breaded prepared with different levels of MSM and tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)

Formulations / Breaded	Calcium %*		Phosphorus %*	
	Baked	Fried	Baked	Fried
F1	0.38 dA	0.21 dB	0.68 bA	0.68 aB
F2	0.16 cA	0.15 cB	0.67 bA	0.66 aB
F3	0.16 cA	0.07 bB	0.67 bA	0.66 aB
F4	0.07 bA	0.03 aB	0.67 bA	0.66 aB
F5	0.04 aA	0.02 aB	0.66 aA	0.66 aB

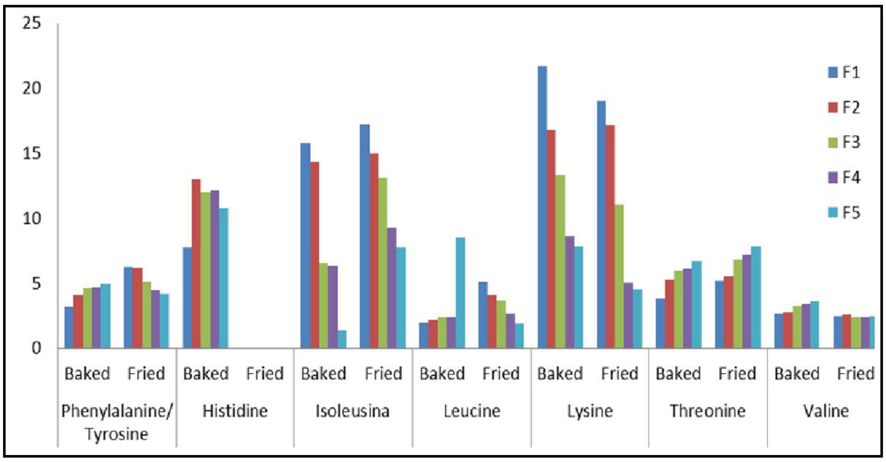
*Means followed by the same lower case in the column and uppercase the line do not differ to each other by the *Scott-Knott* test (P<0.05).

*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

As for calcium, breaded had higher mean values (P<0.05) as it increased the percentage of MSM addition, replacing ground tilapia fillet. Thus, the formulations added 100% MSM (F1) had higher mean values (0.38% and 0.21%), followed the formulations F2 (75% MSM), F3 (50% MSM) F4 (25% MSM) and finally the formulation added of 100% ground fillet (F5), with lower mean (0.04% and 0.06%) for baked and fried samples, respectively. A similar result was observed by Oliveira Filho (2009), frankfurter-type saus ages with mechanically separated meat of waste from Nile tilapia filleting, where the calcium content of the samples increased with the addition of 60% to 100% of MSM replacing tilapia fillet. For the phosphorus, it was noticeable that there were no major differences among the breaded s, although the formulation added 100% MSM (F1) had a greater mean (0.68%) of this mineral. These results can be explained due to the fish contain three types of hard tissues: enamel, dentin and bone, which consist of elongated hydroxyapatite crystals formed by crystalline calcium phosphate (Costa *et al.,* 2008; Hildebrand, 1995), which explains the higher percentage of these minerals found in breaded added with a higher MSM percentage, since, according to Gonçalves (2011), to obtain the pulp use a mechanized process scraping the spines separating the meat (MSM).Regarding the type of heat treatment used there was no significant difference (P<0.05) for the mineral calcium, which formulations of breaded submitted to cooking in an electric oven showed higher levels when compared to fried breaded. According to Gall *et al.* (1983) the loss of moisture due to cooking may result in the concentration of the mineral content, so it can explain the higher percentage of calcium in baked breaded, because as seen earlier these samples showed lower moisture content compared to breaded that were fried in conventional gas stove. There is controversy about the phosphorus, because even the cooking method had been significant, there was a minimal variation among the processing types. According to Vieira *et al.* (2007), the literature still not explains satisfactorily the relation among the mineral, the cooking method and other food constituents.

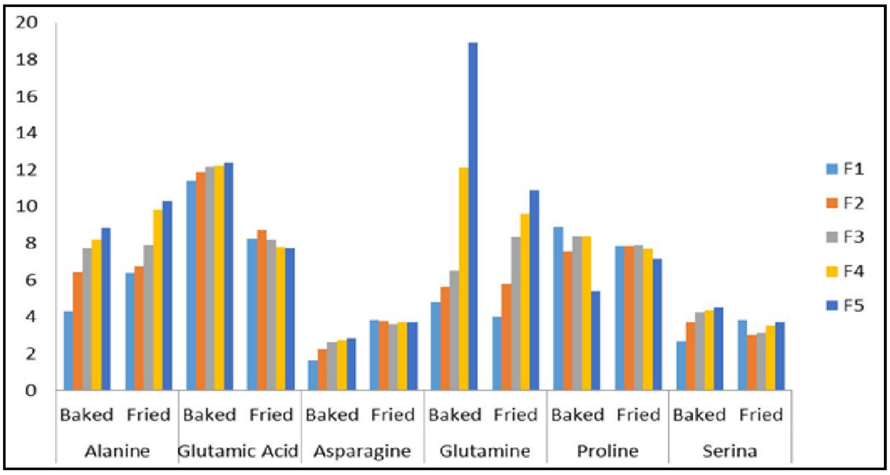
Amino acid profile

The essential and nonessential amino acids contents of the analyzed breaded in this study were expressed in g/100g (Fig. 1 and 2).Among the essential amino acids, lysine appears in larger quantity, ranging from 7.86 to 21.70 g/100g for baked breaded and 4.54 to 18.99 g/100g for fried breaded (Fig. 1). The variation showed increasing with the MSM inclusion, therefore, with the greatest values corresponding to samples added 100% MSM Oliveira Filho (2009).



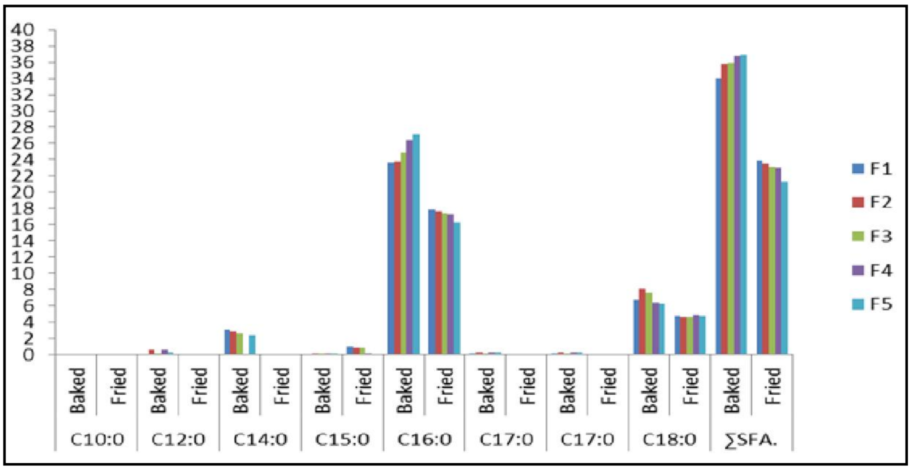
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Fig. 1. Essential amino acid profile (g/100g) of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)



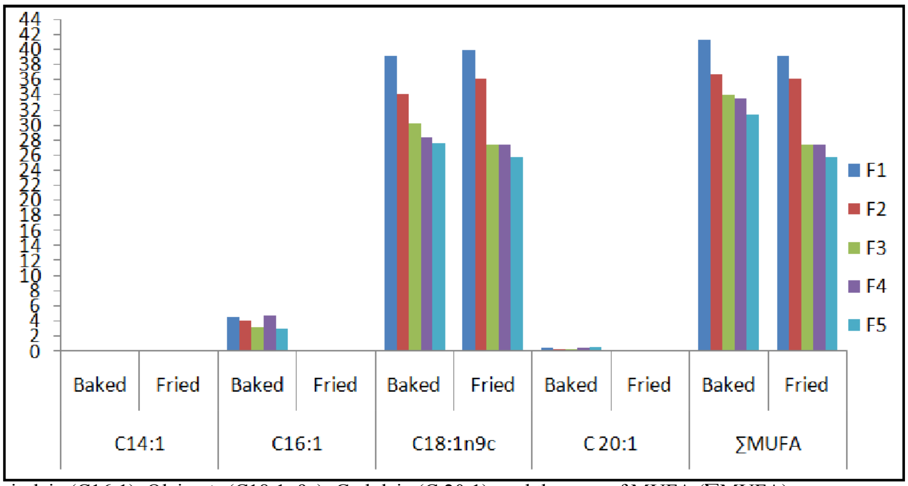
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Fig. 2. Profile nonessential amino acids (g/100g) of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)



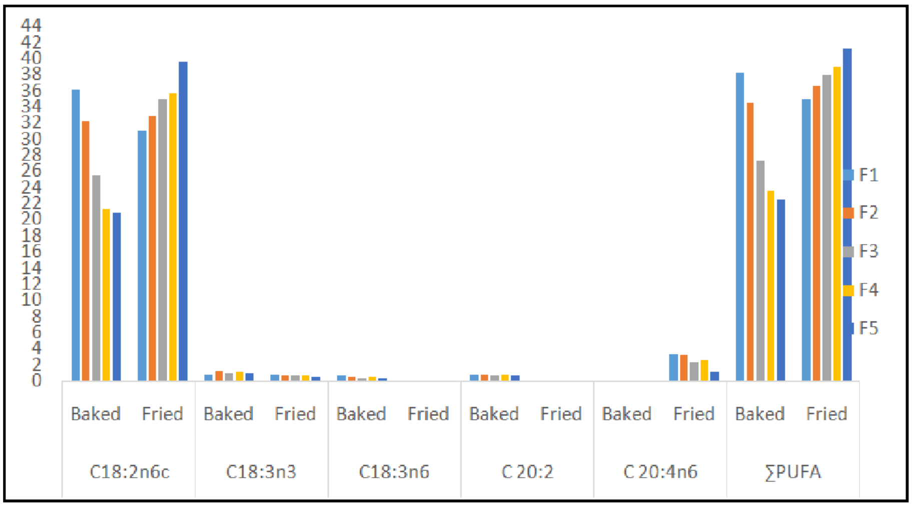
*Capric - C10:0, Lauric - C12:0, Myristic - C14:0, Pentadecylic - C15:0, Palmitic - C16:0, Stearic - C18:0, Margaric C17:0, Eicosanoic C 20:0 and the sum of saturated fatty acids - ∑SFA.
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Fig. 3. Profile of saturated fatty acids (SFA) (g/100g) of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)



* Myristoleic (C14:1), Palmitoleic (C16:1), Oleic *cis* (C18:1n9c), Gadoleic (C 20:1), and the sum of MUFA (∑MUFA).
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Fig. 4. Profile of monounsaturated fatty acids (MUFA) (g/100g) of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)



*Linoleic cis (C18:2n6c), α-Linolenic (C18:3n3), ϒ-Linolenic (C18:3n6), Eicosadienoic (C 20:2), Arachidonic (C 20:4n6) and the sum of PUFA (∑PUFA).
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Fig. 5. Profile of polyunsaturated fatty acids (g/100g) of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)

Analyzing sausages with added MSM of Nile tilapia observed lower levels of lysine in samples with higher MSM percentages. The amino acid proline increased from 5.39 to 8.88 g/100g in baked samples and 7.18 to 7.86 g/100g in fried samples, with the MSM addition factor responsible for the increase in the amino acid amount, probably because the raw material had enough collagen (Fig. 2). According to Sikorski (1990), the insoluble protein of fish is mainly composed for proline, hydroxyproline and glycine. In general, the fried and baked breaded show relevant contents of essential and nonessential amino acids. The essential amino acids levels of breaded were also compared to recommended levels (g/100g) by FAO (1991) for children 3-8 years old. In general, one can say that the baked and fried breaded is appropriate to reference levels and is considered as an excellent protein source, for its balanced amino acid content and for present concentrations considerably higher to the established. It should be emphasized that the fries sample showed deficient only in histidine.

Fatty acids profile

The fatty acids levels (FA), saturated (SFA) and unsaturated (UFA), of the breaded analyzed in this study were expressed in percentages (Figs. 3, 4, 5 and 6). In general, both breaded of tilapia with MSM inclusion (25% to 100%) and as the control (100% fillet) showed considerable amounts of fatty acids.The palmitic acid (C16:0) was major among the saturated fatty acids with a contribution from 66.263 to 73.642% of the SFA total in the baked samples, and from 75.150 to 76.255% in the fried samples.The monounsaturated fatty acids showed a varied from 31.315 to 41.263 g/100g for baked samples in a conventional oven and 25.689 to 39.099 g/100g for the fried samples, being the oleic acid *cis* (C18:1n9c) the most responsible for the monounsaturated fatty acids fraction (MUFA) (Fig. 4). Similar results were observed by Mizzoto (2010), in fish pâtés and by Souza (2013) who worked with chicken breaded, subjected to different heat processing.

Among the polyunsaturated fatty acids (PUFA), the most abundant was the linoleic acid *cis* (C18:2n6c), belongs to the omega-6 family. This FA represented from 90.536 to 94.537% and from 88.596 to 96.200% of PUFA total for baked and fried breaded, respectively (Fig. 5). The fried breaded also showed good concentration, 2.619 to 9.328% of PUFA total, arachidonic acid (C20:4n6). Druziani *et al.,* (2007) mentioned that the how greater the polyunsaturated value, better the nutritional quality of the product. The ratios values of PUFA/SFA ranged from 0.889 to 1.641 for baked breaded and from 1.463 to 1.924 for fried breaded (Fig. 5). According to the Department of Health and Social Security (DHSS 1984) *apud* Furuya *et al.,* (2013), the diets that present ratio of PUFA/SFA greater than 0.45 are considered healthy from the nutrition point of view for humans.In studies with chicken nuggets sold commercially (Gibbs *et al.,* 2013), and with burgers of catfish (Hassaballa *et al.,* 2009), were detected palmitic acid dominance (C16:0) oleic acid (C18:1n9c) and linoleic acid (C18:2n6c) in the products subjected to different heat processing, thus corroborating the results found in this work. It should be emphasized that the fatty acids C18:1n9t and C18:2n6t are the forms *trans* obtained from oleic and linoleic acid, respectively. The fried breaded in soybean oil, showed a predominance of linolelaidic TFA (Fig. 6). The same result was observed by Souza (2013), in chicken breaded. The author asserts that the formation of *trans* was expected, due to the vegetable oil present until 59% linoleic acid and other fractions of FA, as oleic acid itself. Therefore, the TFA content of the frying oil itself may have been absorbed by the product. Thus, the FA presence shows that the food has FA *trans* in its composition after undergoing certain type of heat treatment. The sum of fatty acids *trans* (∑TFA) ranged from 1.753 to 2.367 g/100g (Fig. 6). However, as Echarte (2004), this amount may be considered low, given that a mean portion of fried potato contains 5 to 6 g TFA/100 g.

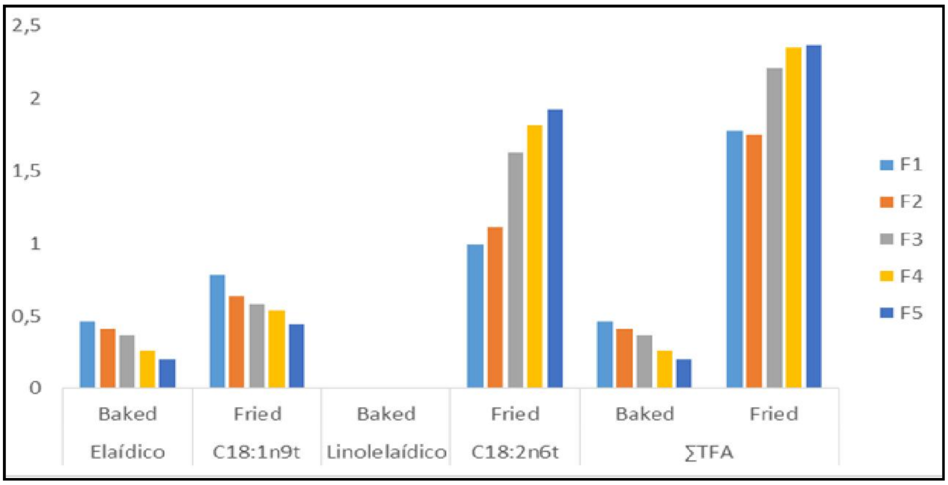
Instrumental color

The color evaluation of the breaded samples were performed to check the color intensity among the different formulations and heat treatments types in breaded *in natura*, baked and fried (Table 5).The L* breaded value was not influenced by changes of MSM levels, since no significant difference (P>0.05) in this parameter among the formulations. Minozzo (2010), on the other hand, found that the smaller the amount of MSM greater brightness of pate made with the fish *tilapia*, *armado* and *flaminguinha*.

Among cooking methods, the samples differed significantly (P<0.05), lower L* values for the fried samples, followed by baked samples, ie, the heat treatment gave a darker tone to the breaded. According Ngadi *et al.* (2009), the golden brown color is a direct consequence of the Maillard reaction, a chemical reaction that occurs mainly on the surface of fried products, generating darkening of them. As for the parameter a* there was a significant difference among the formulations and it was possible to observe a decrease in the red intensity with the inclusion of 0% to 100% of MSM from tilapia. This fact may be due to the MSM washing process, where occurs the partial or total blood removal, pigments and heme compounds, conferring a bit more reddish and grayish to the raw material (Oliveira Filho, 2009; Tenuta Filho and Jesus, 2003). A similar result was found by Trindade *et al.* (2005) in bologna with increasing MSM addition of chickens. It was also observed, higher a* values in fried breaded, showing results between 9.313 to 9.950, followed by baked breaded with means from 4.940 to 4.993 and finally of the breaded *in natura* with values ranging from 1.700 to 2.053.For the b* parameter, it was observed that for different breaded formulations, there was no significant difference (P>0.05). Moura (2012), analyzing sausage prepared with waste from filleting of *jundiá* (*Rhamdia quelen*), found no difference among the MSM samples added and control sample. However, Oliveira Filho (2009) working with sausages from tilapia, noted that the b* value decreased with the MSM addition. The heat processing type on this attribute was significant (P<0.05) for the breaded that were baked in a conventional gas stove. These showed higher values when compared to fried breaded and *in natura*, which gave to the product a higher yellow intensity.

Shear force

The MSM inclusion of waste from Nile *tilapia* filleting in replacing to the fillet caused a decrease (P<0.05) in the mean values of shear force (Table 6).



* Elaidic (C18:1n9t), Linolelaidic (C18:2n6t) and the sum of TFA (∑TFA).
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Fig. 6. Profile of unsaturated fatty acids *trans* (TFA) (g/100g) of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)

Table 5. Parameters mean values L*, a* and b* of breaded prepared with different MSM levels and Nile tilapia fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)

Composition (%)	Cooking methods	Formulations				
		F1	F2	F3	F4	F5
Moisture *	In natura	57.87 cA	60.93 bA	62.21 aA	62.55 aA	63.63 aA
	Baked	38.96 eC	44.41 dC	48.88 cC	52.56 bC	54.84 aB
	Fried	51.61 bB	52.99 bB	54.37 aB	54.91 aB	54.56 aB
Ether Extract *	In natura	8.73 aC	6.70 bC	5.65 cC	5.14 cC	4.40 dC
	Baked	12.76 aB	9.27 bB	7.63 cB	6.57 dB	5.12 eA
	Fried	15.36 aA	14.05 bA	11.48 cA	10.86 cA	5.50 dA
Crude protein *	In natura	14.59 bC	14.96 bC	15.66 bB	16.75 aB	17.43 aC
	Baked	21.37 aA	21.47 bA	21.52 bA	21.75 bA	21.95 bA
	Fried	19.02 bB	20.74 aA	20.16 aB	20.52 aA	20.88 aB
Ashes *	In natura	3.05 aB	2.82 bB	2.77 cB	2.60 cC	2.38 dC
	Baked	4.85 aA	4.34 bA	3.93 cA	3.54 cA	3.12 dA
	Fried	3.13 aB	3.00 aB	2.84 bB	2.79 bB	2.58 cB

*Means followed by the same lower case in the line and uppercase the column do not differ to each other by the *Scott-Knott* test (P<0.05).
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

Table 6. Mean values observed in the shear force analysis (kg-f) of breaded prepared with different MSM levels of Nile *tilapia* fillet (*Oreochromis niloticus*) and subjected to two cooking methods (baked and fried)

Parameters	Cooking methods	Formulations				
		F1	F2	F3	F4	F5
L*	In natura	69.753 aA	70.210 aA	70.080 aA	69.756 aA	70.023 aA
	Baked	63.170 aB	63.543 aB	63.296 aB	64.316 aB	64.713 aB
	Fried	51.266 aC	50.893 aC	51.290 aC	51.363 aC	50.806 aC
a*	In natura	1.664 cC	1.700 cC	1.973 bC	2.153 aC	2.223 aC
	Baked	4.940 cB	4.993 cB	6.433 bB	5.933 bB	6.433 aB
	Fried	9.213 cA	9.480 bA	9.533 bA	9.833 aA	9.950 aA
b*	In natura	19.226 aB	19.256 aB	19.413 aB	19.100 aB	18.806 aB
	Baked	23.576 aA	24.390 aA	23.916 aA	23.643 aA	24.623 aA
	Fried	19.200 aB	19.313 aB	19.773 aB	19.373 aB	19.056 aB

*Means followed by in the same letter lowercase in line and uppercase in column do not differ by the Scott-Knott test (P<0.05).
*F1= 100% MSM and 0% fillet / F2= 75% MSM and 25% fillet / F3= 50% MSM and 50% fillet / F4= 25% MSM and 75% fillet / F5= 0% MSM and 100% fillet.

The breaded shear force decreased to 0.843 kg-f (0% MSM) to 0.326 kg-f (100% MSM), 2.800 kg-f (0% MSM) to 2.250 kg-f (100% MSM) and 1.960 kg-f (0% MSM) to 1.710 kg-f (100% MSM) for samples *in natura*, baked and fried, respectively. These findings confirm the levels influence of the protein and lipid in breaded composition, so those with higher MSM concentrations showed lower mean values for protein attribute, and higher lipid values (Table 3). Hedrick *et al.* (1994) characterize the meat proteins, as the main components responsible for the hardness of the products. Further, according to Troy *et al.* (1999), the decrease of fat concentration in meat products usually imply in the quality attributes reduction such as tenderness and juiciness. The MSM inclusion, of waste from

Nile tilapia filleting (0-100%) and chicken(0-100%) in sausages also resulted in hardness decreases of 13196 g to 881 g in fish sausages (Oliveira Filho, 2009), and 195.7 kPa to 67.0 kPa in chicken sausages (Daros *et al.,* 2005). The baked samples showed more hardness when compared to fried and *in natura*, because they have higher mean values of shear force. According to Souza (2013), the cooking reduces the amount of free moisture available in all products, making them less tender and juicy. As seen above, the centesimal composition analysis of the baked breaded showed lower moisture content, followed fried and finally *in natura*.

Conclusions

The mechanically separated meat of waste from Nile tilapia filleting can be used as raw material in the breaded preparation. Breaded prepared with increasing levels of the same MSM showed good nutritional quality due to the excellent balance of amino acids, important fatty acids and the presence of good levels of minerals and protein, and increased the levels of lipids and minerals. Each cooking method will act in very specific way, and can increase the fat content, modify the moisture percentage, degrade proteins, among other reactions that can alter the nutritional value of the final product. Therefore, it is suggested that the best way to prepare, among the two cooking methods evaluated, is the baked.

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