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

NUGGETS PREPARED USING MECHANICALLY SEPARATED MEAT (MSM) OBTAINED FROM TILAPIA CARCASSES AND CASSAVA DOUGH*

Rafael Gomes Abreu BACELAR[1]*
Marília da Silva SOUSA[1]
José Humberto SANTOS FILHO[1]
Nathálya de Oliveira MOURA[1]
Maria Christina Sanches MURATORI[1]

[1] Universidade Federal do Piauí – UFPI, Campus Universitário Ministro Petrônio Portella, Bairro Ininga, 64.049-550, Teresina, PI, Brazil. rafael.bacelar@hotmail.com (*corresponding author)

*This study was financed in part by the National Council for Technological and Scientific Development (CNPq) (grant #443319/2016-2) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) – scholarship awarded to the first author. This study is part of Rafael G. A. Bacelar PhD thesis.

Received: September 20, 2020
Approved: May 27, 2021

ABSTRACT

The aim of this study was to develop Mechanically Separated Meat (MSM) nuggets produced using tilapia fillet residues (obtained from the filleting process performed at the Fish Market in Teresina, Piauí, Brazil) and cassava dough. Five nugget formulations were developed, and the following microbiological analyses were performed: *Escherichia coli* counts, coagulase-positive *Staphylococcus* counts, and *Salmonella* sp. detection. Physicochemical analyses were also carried out concerning moisture content, ash, protein, lipids, carbohydrates, calories, water activity and pH. A sensory analysis was performed by untrained tasters concerning color, aroma, flavor, texture, global acceptance, and purchase intention. The microbiological analyses results indicate that both the tilapia MSM and the prepared nuggets exhibited suitable hygienic-sanitary standard for human consumption. The physicochemical assessments indicated a nutrient-rich product. Regarding the sensory analysis, good nugget acceptance was observed. In conclusion, the use of tilapia MSM to produce nuggets is a good way to use carcasses that would otherwise be discarded, and cassava dough up to 21.5% may be used for nugget production.

Keywords: *Oreochromis niloticus*; *Manihot esculenta*; waste; fish.

NUGGETS PREPARADOS COM CARNE MECANICAMENTE SEPARADA (CMS) OBTIDA DE CARCAÇAS DE TILÁPIA E MASSA DE MANDIOCA

RESUMO

O objetivo desse trabalho foi desenvolver *nuggets* de Carne Mecanicamente Separada (CMS) produzida com resíduos de filetagem de tilápia (obtido a partir do processo de filetagem realizado no Mercado de Peixe em Teresina, Piauí, Brasil) com acréscimo de massa de mandioca. Para isso, foram desenvolvidas cinco formulações e realizadas análises microbiológicas de: contagem de *Escherichia coli*, contagem de *Staphylococcus* coagulase positiva e detecção de *Salmonella* sp. Foram realizadas também análises físico-químicas: teor de umidade, cinzas, proteína, lipídios, carboidratos, calorias, atividade de água e pH. A análise sensorial foi feita com a participação de provadores não treinados, avaliando os atributos de: cor, aroma, sabor, textura, aceitação global e intenção de compra. Os resultados das análises microbiológicas apontaram que tanto a CMS quanto os *Nuggets* apresentaram padrões higiênico-sanitários adequados para consumo. As análises físico-químicas caracterizaram um produto rico em nutrientes. Para a análise sensorial, os *nuggets* apresentaram boa aceitação dos atributos, concluindo-se que a utilização de CMS de tilápia para elaboração de *nuggets* é uma boa forma de aproveitar carcaças que seriam descartadas e que a massa de mandioca pode ser adicionada até 21,5% para obter *nuggets* preparados com CMS.

Palavras-chave: *Oreochromis niloticus*; *Manihot esculenta*; resíduo; peixe.

INTRODUCTION

Industrial fish processing is one of the main economic activities in several countries, and the development of this sector has increased the demands for fish products for human consumption, especially fish fillets, due to their practicality and lack of bones. The filleting process generates large amounts of edible (meat adhering to bones and shavings) and non-edible (bones, scales, viscera, and head) residues, representing a

significant waste of resources and environmental contamination source (Tahergorabi et al., 2013; Silva et al., 2014).

Nile tilapia (*Oreochromis niloticus* L.) is one of the most cultivated species worldwide (FAO, 2020); presents fillet yields ranging from 32% to 35%, generating large amounts of waste in production industries (Barroso et al., 2017). Filleting performance may vary according to the type of fish and processing method (Feltes et al., 2010), while the remainder is considered low commercial value waste, either underutilized or discarded by fillet processing industries (Signor et al., 2020).

Cassava (*Manihot esculenta* Crantz) is a South American crop widely cultivated in the past by indigenous people. It is currently an important source of subsistence for low-income populations, through family farming, and consumed by a large part of the population, mainly in the form of flour, during main meals (Cagnato and Ponce, 2017; Neves et al., 2020). Cassava is consumed in cooked, roasted, and fried forms, is a part of several dishes and is used in the development of new products (Franck et al., 2011; Vega et al., 2017).

Cassava cultivars can be classified according to their hydrocyanic acid (HCN) concentrations, as smooth cassava (table manioc or cassava), containing low HCN levels, fresh peeled roots (below 50 mg HCN kg^{-1}) and wild cassava (bitter), containing over 100 mg HCN kg^{-1} (Oliveira et al., 2020).

The development of restructured products using new ingredients has been used to create novel options for the growth of foodstuffs that add nutritional quality and commercial value to industrially generated waste (Ferreira et al., 2020). Meat breads have pleasant sensory characteristics, a crunchy, soft, moist outer layer, and a juicy interior (Tamsen et al., 2018).

Sustainable fish waste management practices and the application of viable technologies can contribute to the diversification of fish-derived products, increased employment and income generation and production chain sustainability (Gonçalves, 2011). Therefore, the aim of this study was to develop nuggets using Mechanically Separated Meat (MSM) from tilapia carcasses and cassava dough.

MATERIAL AND METHODS

Ten tilapia carcasses (eviscerated, without the head, fillets, and skin) were obtained from the filleting process performed at the Fish Market in Teresina, Piauí, Brazil, for five consecutive weeks, totaling 50 carcasses. After sampling, the carcasses were immediately stored in an isothermal box containing recyclable ice and transported to the Fish Sector belonging to the Center for Food Studies and Research and Processing (NUEPPA), at the Federal University of Piauí (UFPI).

The raw material was then prepared as follows: after viscera remain removal, the carcasses were washed under running water and immersed in hyperchlorinated water containing 5.0 ppm of free residual chlorine for 10 minutes. Subsequently, the carcasses were weighed, and processed using an SPx100 fish pulper to obtain Mechanically Separated Meat (MSM).

During each MSM processing sampling, five 100 g MSM portions were aseptically removed for microbiological analyses, and the remaining samples were stored in a domestic freezer (-18°C) until all results were released.

Five nugget formulations were developed using the tilapia MSM, with the addition of smooth casava (manioc or cassava) (Table 1), with ingredient variations.

After preparing the tilapia MSM, the ingredients listed in Table 1 were added to the MSM. The mixtures were then homogenized and manually molded into circular/flattened shapes and breaded.

The nugget breading process comprised three stages: a) pre-dusting: a layer of cassava flour was applied to the tilapia MSM nuggets; b) beating: a superficial layer of a liquid batter prepared with beaten raw eggs was applied to the tilapia MSM nuggets; and c) breading: breadcrumb flouring was applied to the tilapia MSM nuggets.

Subsequently, the nuggets were roasted in an industrial oven (PROGÁS 4000E) at 100ºC for 45 minutes. At the end of this process, the nuggets were packed in 300 g expanded polystyrene packaging, covered with plastic film, and kept in a domestic freezer at -18ºC. The nugget preparation process is described in the operational flowchart displayed in Figure 1.

Microbiological analyses

The following microbiological analyses were performed on tilapia MSM and nugget samples: coagulase-positive *Staphylococcus* counts, *Salmonella* sp. detection and *Escherichia coli*.

For the coagulase-positive *Staphylococcus* assessments, 0.1 mL were seeded on the surface of Petri dishes containing Baird Parker agar (BP) and incubated in an oven at 35°C for 24 to 48 hours. The results were expressed as colony-forming units per gram (CFU g^{-1}) (APHA, 2015).

For the *Salmonella* spp. analyses, flasks containing 10^{-1} dilutions and 0.1% peptone water were incubated at 37°C for 24 hours. Subsequently, 0.1 mL were transferred to Rappaport-Vassiliadis broth and 1.0 mL to selenite-cystine broth, incubated at 37°C for 24 hours. Then, Petri dishes were sown with Salmonella-Shigella agar and Hektoen agar and incubated for 24 hours at 37°C, followed by biochemical screening and citrate testing. Polyvalent antisera "O" and "H" were used for serological confirmations (APHA, 2015).

Table 1. Ingredients (%) used for nugget preparation with tilapia Mechanically Separated Meat (MSM) and cassava dough.

Ingredients	Formulations (%)				
	F1	F2	F3	F4	F5
Tilapia MSM	86.0	64.5	43.0	21.5	0.0
Cassava dough	0.0	21.5	43.0	64.5	86.0
Salt	1.0	1.0	1.0	1.0	1.0
Onion	3.0	3.0	3.0	3.0	3.0
Garlic	1.0	1.0	1.0	1.0	1.0
Cassava flour	4.0	4.0	4.0	4.0	4.0
Egg	2.0	2.0	2.0	2.0	2.0
Breadcrumbs	3.0	3.0	3.0	3.0	3.0

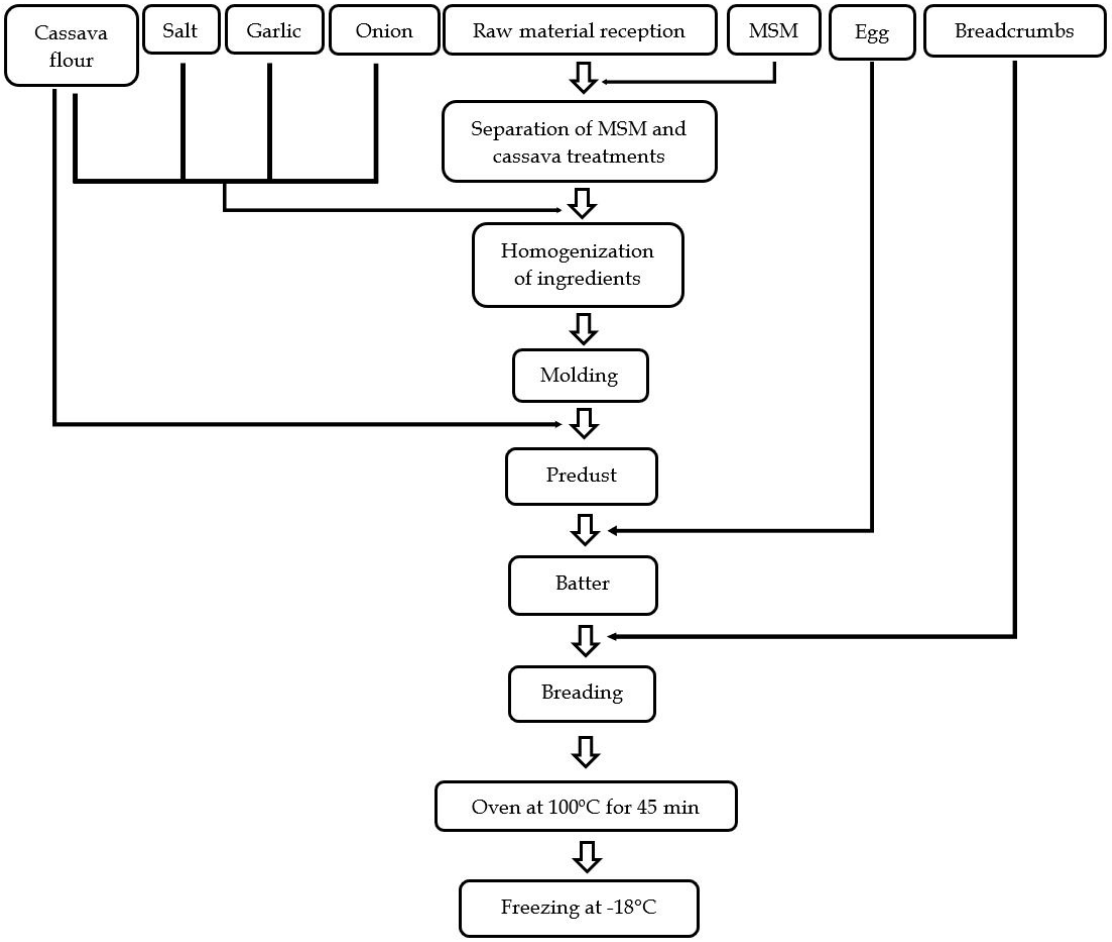

Figure 1. Flowchart demonstrating the tilapia MSM nugget production process carried out in the present study.

Escherichia coli counts were performed using the Most Probable Number (MPN) technique, by transferring 1.0 mL of serial dilutions to tubes containing lauryl tryptose broth and incubating the samples in an oven at 37ºC for 48 hours. For tubes exhibiting gas growth and production, aliquots with platinum handles were transferred to tubes containing EC broth and incubated in a water bath at 45.5ºC for 24 hours. Positive results were sown on Eosin Methylene Blue agar (EMB). Typical colonies were tested by the Indole, methyl red, Voges-Proskauer and citrate (IMVIC) method (APHA, 2015).

Physicochemical analyses

Crude proteins were determined using the Kjeldahl method, by obtaining total nitrogen applying a 6.25 nitrogen to protein factor (Brasil, 2014a). Lipid determinations were performed on a Sohxlet extractor using petroleum ether (Brasil, 2014b). Moisture contents were determined by oven drying the samples until constant weight. Ash contents were determined by sample incineration in a muffle furnace at 550ºC for four hours (Instituto Adolfo Lutz, 2008). Carbohydrate contents were determined by calculating total moisture, protein, lipids, and ashes and subtracting the total values by 100. Calorie values were calculated using the following conversion factors: 4 kcal g^{-1} proteins, 4 kcal g^{-1} carbohydrates and 9 kcal g^{-1} lipids (Brasil, 2003).

Water activity (Aw) assessments were performed using a Portable Water Activity device (Decagon Pawkit digital) on 5.0 g of each sample.

Hydrogen potential (pH) analyses were performed on 10 g of each sample transferred to a beaker containing 100 mL of distilled water and determined by a bench potentiometer electrode (21pH/mv meter, Hanna) introduced into each sample (Instituto Adolfo Lutz, 2008). All physicochemical nugget analyses were carried out in triplicate.

Sensory analyses

The sensory analyses were approved by the UFPI Human Research Ethics Committee (CEP), under Certificate of Presentation for Ethical Appreciation (CAAE) nº 89732318.3.0000.5214.

The sensory analyses were carried out at the Federal Institute of Education, Science and Technology of Piauí (IFPI) Sensory Analysis Laboratory, by 120 untrained tasters. The tasters were selected through interviews, in order to identify candidates presenting food allergies or intolerance to any of the ingredients present in the nugget formulations, which were applied as an exclusion factor.

The three tilapia MSM nugget formulations with the best aspect, consistency, and presentation closest to those recommended by Brazilian legislation were chosen for the sensory analyses

(F1, F2 and F3). Microbiological analyses (*Escherichia coli*, coagulase-positive *Staphylococcus* counts and *Salmonella* spp. detection) were carried out for these formulations according to Brazilian legislation standards (Brasil, 2019).

The tasters received cards displaying the following sensory parameters: acceptance test using a hedonic scale, purchase intention and order of preference. They also received water at room temperature for the blank test between samples. Color, aroma, flavor, texture, and global acceptance were evaluated through a structured 9-point scale, ranging from 1 ("I really did not like it") to 9 ("I really liked it"). Purchase intention was assessed by a scale ranging from 1 ("I would certainly not buy it") to 5 ("I would certainly buy it").

Statistical analysis

The results were evaluated by an analysis of variance (ANOVA). All microbiological parameters were normalized by $\log10^{(x+1)}$ transforming. The sensory analysis data were organized in Microsoft Office Excel 2010 spreadsheets and evaluated by a Kruskal-Wallis test. The order of preference assessment was performed using the Friedman test according to Newell and MacFarlane, at a significance level of 5% (Newell and Macfarlane, 1987). Comparisons between means were performed by the Tukey test, adopting a significance level of 5%. All statistical analyses were performed using the Sigmastat 4.0 software.

RESULTS

Microbiological analyses

No significant differences (p <0.05) were noted for *Escherichia coli* counts, coagulase-positive *Staphylococcus* counts and *Salmonella* spp. detection in the tilapia MSM and nugget samples (Table 2).

Physicochemical analyses

Table 3 displays the physicochemical results for the tilapia MSM nuggets containing cassava.

Sensory analyses

The results of the sensory analysis for the three tilapia MSM nuggets formulations containing cassava are presented in Table 4. The Figure 2 present the hedonic scale scores for the sensory parameters, indicating pattern of homogeneous values within each formulation.

Table 2. Results of the microbiological analyses of edible tilapia fillet waste MSM and tilapia MSM and cassava nuggets.

Sample		Coagulase-positive *Staphylococcus* (CFU g^{-1})	*Escherichia* coli (MPN g^{-1})	*Salmonella* sp.
CMS	Collect 1	<1.0	<0.3	Absent
	Collect 2	<1.0	<0.3	Absent
	Collect 3	0.6±1.5	<0.3	Absent
	Collect 4	1.4±1.9	<0.3	Absent
	Collect 5	1.3±1.8	<0.3	Absent
Legislation	(Brasil, 2019)	3.0 CFU g^{-1}	2.7 MPN g^{-1}	Absent /25 g
Nugget	F1	<1.0	<0.3	Absent
	F2	<1.0	<0.3	Absent
	F3	<1.0	<0.3	Absent
	F4	<1.0	<0.3	Absent
	F5	<1.0	<0.3	Absent
Legislation	(Brasil, 2019)	4.0 CFU g^{-1}	2.7 MPN g^{-1}	Absent /25g

MSM = Mechanically Separated Meat; CFU g^{-1} = Colony Forming Units per gram in logarithmic numbers. Probability (p <0.05). MPN g^{-1}: Most Probable Number per gram in logarithmic numbers. Formulation: F1 (86.0:0.0); F2 (64.5:21.5); F3 (43.0:43.0); F4 (21.5:64.5), and F5 (0.0:86.0).

Table 3. Physicochemical results for the tilapia MSM nuggets prepared in the present study.

Determination	Nugget formulations				
	F1	F2	F3	F4	F5
Protein (%)	19.1±2.0^{a}	14.8±1.1^{b}	9.8±0.9^{c}	6.1±1.1^{d}	2.6±0.5^{e}
lipids (%)	11.6±1.4^{a}	6.3±2.6^{bc}	7.2±1.3^{b}	4.8±1.9^{bc}	3.6±0.5^{c}
Moisture (%)	43.4±1.4^{b}	48.1±1.1^{ab}	47.6±1.5^{ab}	47.4±3.1^{ab}	52.9±1.9^{a}
Ash (%)	2.6±0.17^{a}	2.6±0.10^{a}	2.3±0.12^{b}	1.6±0.03^{c}	1.3±0.04^{d}
Carbohydrates (%)	23.1±1.8^{d}	28.0±2.7^{c}	32.8±1.5^{b}	39.9±4.6^{a}	39.5±2.6^{a}
Calories (kcal/100g)	273.8±11.0^{a}	228.3±16.6^{ab}	236.4±10.8^{ab}	228.0±7.0^{ab}	201.1±7.7^{b}
Water activity	0.80±0.04	0.82±0.01	0.83±0.01	0.85±0.03	0.84±0.02
pH	6.47±0.17	6.40±0.21	6.38±0.10	6.41±0.08	6.46±0.14

Means on the same line followed by different letters differ from each other by the Tukey test (p <0.05). Data are expressed as means ± standard deviation. MSM: Cassava (%) in each formulation: F1 (86.0:0.0), F2 (64.5:21.5), F3 (43.0:43.0), F4 (21.5:64.5) and F5 (0.0:86.0).

Table 4. Results of tilapia MSM nugget sensory analyses.

Determination	Nugget formulations		
	F1	F2	F3
Color	7.5±1.3[a]	6.8±1.7[b]	6.7±1.6[b]
Flavor	7.5±1.5[a]	7.0±1.6[b]	6.5±1.8[b]
Texture	7.2±1.6[a]	6.9±1.7[b]	6.5±1.8[b]
Aroma	7.4±1.3[a]	6.9±1.6[ab]	6.5±1.7[b]
Global acceptance	7.4±1.4[a]	7.0±1.6[ab]	6.6±1.6[b]
Overall average	7.4	6.9	6.6
Purchase intention	4.1±0.9[a]	3.7±1.1[b]	3.4±1.4[b]
Order of preference	174[b]	202 [ab]	224[a]

Means on the same line followed by different letters differ from each other by the Tukey test (p <0.05). Data are expressed as means ± standard deviation. MSM: Cassava (%) in the nugget formulations: F1 (86.0:0.0), F2 (64.5: 21.5) and F3 (43.0:43.0). Different letters on the same line indicate significant differences (p <0.05), according to Friedman test.

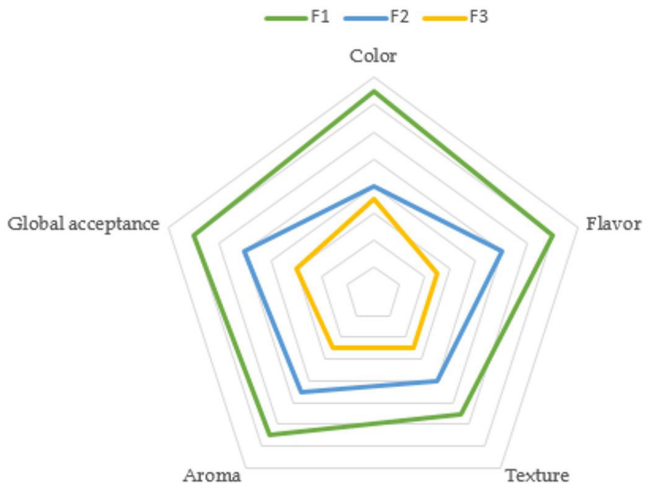

Figure 2. Hedonic scale scores for color, flavor, texture, aroma, and global acceptance.

DISCUSSION

Microbiological analyses

The Brazilian National Health Surveillance Agency RDC nº 60, of December, 2019 (Brasil, 2019), determines a maximum limit for *Escherichia coli* of the 2.7 MPN g^{-1}; the treatments exhibited <0.3 MPN g^{-1}. Regarding coagulase-positive *Staphylococcus* counts, the two initial treatments (Collect 1 and Collect 2) exhibited <1.0 CFU g^{-1}, while the others presented mean values between 0.6 and 1.4 CFU g^{-1}, all below the legislation that establishes values of up to 3.0 CFU g^{-1} (Brasil, 2019). The *Salmonella* sp. analyses indicated absence of this microorganism in all samples, in conformity with the legislation, requiring the absence of this microorganism in 25 g samples (Brasil, 2019). Based on these results, tilapia MSM presented adequate hygienic-sanitary standards to be used as raw material for the tilapia MSM nuggets.

Concerning the nugget analyses, all samples presented <0.3 MPN g^{-1} for *Escherichia coli*, within the requirements of the Brazilian National Agency of Health Surveillance RDC nº 60, of December 23, 2019 (Brasil, 2019). Coagulase-positive *Staphylococcus* counts were lower than those established by the current legislation (4.0 CFU g^{-1}) and *Salmonella* sp. was absent from all samples, in accordance with the current standards (Brasil, 2019). Therefore, the tilapia MSM nuggets containing cassava presented adequate hygienic-sanitary standards and were deemed suitable for consumption.

Physicochemical analyses

Tilapia muscle contains from 10.75% at 17.74% high nutritional standard proteins (Bernadino Filho and Xavier, 2019; Sales and Maia, 2012; Rebouças et al., 2012), while tilapia MSM contains 15.9% high nutritional standard proteins (Fogaça et al., 2015), and cassava, 0.6% when cooked and 1.1% raw, although when peeled and cooked, this value decreases to 0.6% (NEPA, 2011). Normative Instruction No. 6 (NI Nº 06), of February 15, 2001 (Brasil, 2001) establishes 10% as the minimum protein content for breaded food items. The experimental nuggets prepared herein exhibited significant variations (p <0.05) concerning minimum protein content with increasing MSM and cassava amounts. Consequently, nuggets prepared with over 43% cassava content were not in accordance with the NI N°06 (Brasil, 2001). Therefore, it was noted that a maximum of 64.5% MSM provides adequate protein levels for cassava nugget preparation. Regarding this parameter, only formulations 1 and 2 (F1 and F2) were in accordance with the established standards.

Fish can be classified according to their lipid muscle content as lean (less than 2.0%), moderate (from 2.0 to 5.0%) and fatty (over 5.0%) (Cortez Netto et al., 2010). Tilapia muscle lipid content ranges from 2.17 to 15.37% (Bernadino Filho and Xavier, 2019). However, the MSM obtained from filleting shavings contains an average of 7.62% lipid muscle content (Fogaça et al. 2015), probably due to muscle detachment (including part of the ventral abdominal muscles) and other adhered structures (bones and connective tissue) during carcass crushing. Bordignon et al. (2010) reported 11.6% lipids in breaded croquettes prepared with Nile tilapia MSM, similar to formulation 1 (F1) developed in this study, that contained 86% MSM (Table 3). Although other ingredients were used to prepare our formulations (Table 1), lipid levels increased significantly (p <0.05) when higher MSM percentages were used and were, thus, considered the component that most influenced this parameter in the nugget formulations.

Tilapia muscle contains about 78% moisture content (Dallabona et al., 2013) while tilapia MSM contains around 73.9% (Fogaça et al., 2015) and cooked cassava, 68.7% (NEPA, 2011). For the establishment of a product with adequate moisture content, good storage conditions aid in preserving sensory characteristics and crispness (Poiani and Montanuci, 2019). Moisture content can vary according to the ingredients used to prepare the fish product formulations, i.e., breaded moisture content ranges from 62.3% to 65.1% (Veit et al., 2012) and nuggets, from 58.2% to 59.4% (Silva et al., 2015). Moisture contents were significantly different among the tested formulations (p <0.05) according to

the amounts of MSM and cassava (Table 3), and higher in the formulations containing higher cassava levels.

The fixed mineral residue contents (ashes) in nuggets were significantly different between treatments (p <0.05), noted as higher when containing higher fish contents and lower cassava levels (Table 3). Depending on the habitat, food and individual characteristics, ash concentrations in freshwater fish can vary up to 3.3% (Borgstrom, 1962; Contreras-Guzmán, 2002) and in cooked cassava, up to 0.4% (NEPA, 2011). Ash concentrations have been reported as varying according to the tilapia MSM product, 1.53% for snacks containing tilapia MSM flour (Magalhães et al., 2019) and 3.36% for breaded croquettes (Bordignon et al., 2010). According to Daga et al. (2020), where the wastes are composed by bones, which may have been incorporated into the MSM.

Normative Instruction No. 6, of February 15, 2001 (Brasil, 2001) establishes that breaded products must contain a maximum of 30% of total carbohydrates. In this regard, only formulations 1 and 2 (F1 and F2) were complying to this norm (Table 3), containing 23.1% and 28.0% carbohydrates, respectively. Levels varied significantly (p <0.05) between the experimental nugget treatments (Table 3), increasing with increasing cassava concentrations. Veit et al. (2012) produced tilapia breads containing between 18.8% to 21.1% carbohydrates, while Souza et al. (2010) formulated nuggets from a tilapia protein concentrate and reported a carbohydrate content of 7.0%. The significant variations reported by these authors compared to the present study can be attributed to the particular formulation of each product.

Cassava carbohydrate concentrations can change, depending on the cassava variety and technological treatment applied to the product. For example, cassava contain 36.2% carbohydrates which, after cooking, decrease to 30.1% (NEPA, 2011). Live fish can also contain between 0.3 to 1.0% of carbohydrates, mainly in the form of glycogen and mucopolysaccharides (Ogawa and Maia, 1999), although this amount can be reduced to traces in fillets (NEPA, 2011), due to glycogen consumption after fish death. Thus, the main source of carbohydrates in the prepared nuggets were the cooked cassava and manioc flour, which are also used as binding agents in the preparation of the nugget dough, and breadcrumbs, which may also have contributed to carbohydrate levels.

The results of the nugget calorie analysis indicated significant differences between treatments (p <0.05), with increasing calorie levels in products containing higher fish concentrations. On average, 100 g of fish meat contain 93.7 cal (Pigott and Tucker, 1990; NEPA, 2011) provided by protein and lipid contents. Cooked cassava dough contains 126 kcal per 100 g (NEPA, 2011), referring especially to carbohydrates. Thus, the caloric value observed for the F1 samples, containing higher MSM concentrations, is probably due to the lipids present in the tilapia carcasses while the F5 caloric value (MSM-free) is attributed to the carbohydrate levels of cassava.

The water activity values of the nugget formulations were not significantly different (p <0.05) between formulations (Table 3). The Aw values that favor the development of microorganisms comprise 0.91 for bacteria, 0.88 for yeasts and 0.80 for filamentous fungi (Maia et al., 2020). High water activity increases the predisposition for fungi, yeast, and bacteria development (Picanço et al., 2018). Because of this, the nuggets were maintained frozen below -18.0°C, in order to inhibit microbial multiplication.

Tilapia carcasses, classified as waste from manual filleting processes carried out in a public market, were used to prepare the nuggets. Although the fillet processing was carried out in an environment that is not in compliance with good manufacturing practices, the carcasses exhibited adequate sensory conditions and pH values between 6.13 to 6.25, below the established value of 7.00 recommended by Brazil's fresh fish meat legislation (Brasil, 2017). The traders filleted freshly killed tilapia supplied by local fish farmers so, although the conservation conditions were not adequate, pH values were still within the expected range. The nugget pH values ranged from 6.38 to 6.47 (Table 3). Although other ingredients were used for nugget preparation, which may have interfered in pH values, the MSM may have been the predominant factor for these pH variations, indicating that the quality of the raw material and its pH must be observed in order to obtain quality products.

Sensory analyses

Formulation 1 (86% tilapia MSM and no cassava dough) received the best acceptance values for all tested parameters (color, flavor, texture, aroma, global acceptance, and purchase intention) compared to the other formulations (p <0.05) with all values above 7 ("I liked it moderately") and a means of 7.4. The most noteworthy acceptance factors for the F1 treatment were color, flavor, and texture (Table 4).

F2 (64.5% tilapia MSM and 21.5% cassava dough) and F3 (43.0% tilapia MSM and 43.0% cassava dough), presented general average acceptance scores of 6.9 and 6.6, classified as "I liked it slightly". The results indicate that nuggets prepared with tilapia MSM and cassava dough showed good acceptance by untrained tasters, although higher cassava dough content led to slightly reduced acceptance, but still presenting overall good scores.

According to Figure 2, the results maintained a pattern of homogeneous values within each formulation. However, some of these attributes exhibited a slight drop, namely F1 concerning the texture parameter and F2 regarding the color parameter, while F3 exhibited better color and global acceptance performance and equal color, flavor, and texture values.

Concerning purchase intention, the results ranged from 3.4 ("I have doubts if I would buy it") to 4.1 ("I would probably buy it"), with higher values noted for the formulations containing higher fish levels (F1 and F2). This indicates that consumer acceptance of breaded products is on the rise, as these items present good appearance, odor, and taste (Dill et al., 2009).

Significant differences (p <0.05) were observed for the order of preference test. Formulation 1 (F1) obtained the best evaluation, followed by Formulation 2 (F2) and Formulation 3 (F3), respectively. These values endorse the results of the acceptance and purchase intention analyses, highlighting that the most accepted formulations contained the highest fish percentages.

According to Coelho et al. (2017), several factors can influence food consumption, including habits, cultural standards, age, and brand preference. The sensory test was performed by mostly

high school students, aged 18-24 (75%), followed by testers aged 25-35 (21%), 36-50 (2%) and over 50 (2%). In general, young people usually consume breaded food in snack bars and fast-food chains.

The results for all tests indicate that formulations 1 and 2 (F1 and F2) are the most viable for production, as they meet breaded product legislation recommendations (Brasil, 2001) and obtained better sensory evaluation acceptance scores. Thus, the inclusion of cassava dough in nuggets produced with tilapia carcass MSM is proven a nutritionally interesting and economically viable option to take advantage of fillet waste fileting from public and industrial markets, which would otherwise be discarded by the municipal waste collection system.

CONCLUSIONS

The use of nuggets prepared from edible tilapia filleting waste MSM and cassava dough is an interesting way to take advantage of tilapia carcasses that would otherwise be discarded. The nuggets are nutritious, exhibit adequate hygienic-sanitary standards and are suitable for human consumption. Cassava dough can be added up to 21.5% in order to obtain edible tilapia fillet residue MSM nuggets suitable according to current standards and exhibiting good sensory acceptance.

REFERENCES

APHA – American Public Health Association. 2015. Compendium of methods for the microbiological examination of food. 5ª ed. Washington: American Public Health Association. 995p.

Barroso, R.M.; Pincinato, R.B.M.; Munoz, A.E.P. 2017. Informativo de mercado da tilápia: o mercado da tilápia – 2° trimestre de 2017. Palmas: Embrapa Pesca Aquicultura. 1p.

Bernadino Filho, R.; Xavier, L.C.A. 2019. Obtaining, income and characterization of CMS produced from Nile Tilapia filetage waste. Revista Brasileira de Agrotecnologia, 9(2): 1-4. https://doi.org/**10.18378/rebagro.v9i2.7534**.

Bordignon, A.C.; Souza, B.E.; Bohnenberger, L.; Hilbig, C.C.; Feiden, A.; Boscolo, W.R. 2010. Elaboração de croquete de tilápia do Nilo (*Oreochromis niloticus*) a partir de CMS e aparas do corte em 'V' do filé e sua avaliação físico–química, microbiológica e sensorial. Acta Scientiarum. Animal Sciences, 32(1): 109-116. https://doi.org/**10.4025/actascianimsci.v32i1.6909**.

Borgstrom, G. 1962. Fish as food. New York: Academic Press. 534p.

Brasil, 2001. Instrução Normativa nº 6, de 15 de fevereiro de 2001. Aprova os Regulamentos Técnicos de Identidade e Qualidade de Paleta Cozida, Produtos Cárneos Salgados, Empanados, Presunto tipo Serrano e Prato Elaborado Pronto ou Semipronto Contendo Produtos de Origem Animal, Regulamento Técnico de Identidade e Qualidade de Empanados. Diário Oficial da União, Brasília, 19 de fevereiro de 2001, Seção 1, p. 60.

Brasil, 2003. Resolução RDC nº. 360, de 23 de dezembro de 2003. Agência Nacional de Vigilância Sanitária - ANVISA. Regulamento Técnico sobre Rotulagem Nutricional de Alimentos Embalados. Diário Oficial da União, Brasília, 23 dezembro de 2003, nº. 251, Seção 1, p. 28.

Brasil, 2017. Decreto n. 9.013, de 29 de março de 2017. Regulamenta a Lei nº 1.283, de 18 de dezembro de 1950, e a Lei nº 7.889, de 23 de novembro de 1989, que dispõem sobre a inspeção industrial e sanitária de produtos de origem animal-RIISPOA. Diário Oficial da União, Brasília, 30 de março de 2017, nº. 62, Seção 1, p. 3.

Brasil, 2019. Instrução Normativa N°. 60, de 26 de dezembro de 2019. Lista de Padrões Microbiológicos para Alimentos Prontos para Oferta ao Consumidor. Diário Oficial da União, Brasília, 26 de dezembro de 2019, nº. 249, Seção 1, p. 133.

Brasil, Ministério da Agricultura Pecuária e Abastecimento. 2014a. Determinação de proteína bruta em produtos de origem animal por acidimetria. MET POA/SLAV/39/02/01. Available at: <https://docplayer.com.br/22798948-Determinacao-de-proteina-bruta-em-produtos-de-origem-animal-por-acidimetria.html> Accessed: Dec. 04, 2019.

Brasil, Ministério da Agricultura Pecuária e Abastecimento. 2014b. Determinação gravimétrica da gordura total de carnes, pescados e produtos derivados. MET POA/SLAV/50/02/01. Available at: <https://www.gov.br/agricultura/pt-br/assuntos/laboratorios/credenciamento-e-laboratorios-credenciados/legislacao-metodos-credenciados/arquivos-metodos-da-area-poa-iqa/met-poa-slav-50-02-determinacao-da-gordura-total-em-carnes-e-pescados.pdf/@@download/file/met-poa-slav-50-02-determinacao-da-gordura-total.pdf> Accessed: Dec. 06, 2019.

Cagnato, C.; Ponce, J.M. 2017. Ancient Maya manioc (*Manihot esculenta* Crantz) consumption: Starch grain evidence from late to terminal classic (8th–9th century CE) occupation at La Corona, northwestern Petén, Guatemala. Journal of Archaeological Science: Reports, 16: 276-286. https://doi.org/**10.1016/j.jasrep.2017.09.035**.

Coelho, A.C.S.; Faria Junior, C.H.; Sousa, K.N.S. 2017. Fatores que influenciam a compra de peixes por classe social no Município de Santarém-PA. Revista Agroecossistemas, 9(1): 62-83. http://dx.doi.org/**10.18542/ragros.v9i1.4773**.

Contreras-Guzmán, E.S. 2002. Bioquímica de pescados e invertebrados. Santiago: Centro de Estudios en Ciencia y Tecnología de Alimentos - Universidade de Santiago de Chile. 309p.

Cortez Netto, J.P.; Boscolo, W.R.; Feiden, A.; Maluf, M.L.F.; Freitas, J.M.A.; Simões, M.R. 2010. Formulation, microbiological analyses, centesimal composition and acceptability of breaded catfish (*Rhamdia quelen*), pacu (*Piaractus mesopotamicus*) and tilapia (*Oreochromis niloticus*). Revista do Instituto Adolfo Lutz, 69(2): 181-187.

Daga, J.A.; Anschau, S.P.; Rodrigues, M.L.; Oliveira, S.R.; Bittencourt, F.; Feiden, A. 2020. Yield of mechanically separated meat in natura and post-smoking of *Clarias gariepinus* at different weight categories. Boletim do Instituto de Pesca, 46(1): e527. https://doi.org/**10.20950/1678-2305.2020.46.1.527**.

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

Dill, D.D.; Silva, A.P.; Luvielmo, M.M. 2009. Processamento de empanados: sistemas de cobertura. Estudos Tecnológicos, 5(1): 33-49.

FAO – Food and Agriculture Organization of the United Nations. 2020. The state of world fisheries and aquaculture. Rome: Sustainability in Action. 244p. https://doi.org/**10.4060/ca9229en**.

Feltes, M.M.C.; Correia, J.F.G.; Beirão, L.H.; Block, J.M.; Ninow, J.L.; Spiller, V.R. 2010. Alternativas para a agregação de valor aos resíduos daindustrialização de peixe. Revista Brasileira de Engenharia Agrícola e Ambiental, 14(6): 669-677. https://doi.org/**10.1590/S1415-43662010000600014**.

Ferreira, H.K.A.; Signor, F.R.P.; Figueiredo, E.S.; Signor, A.; Reidel, A.; Signor, A.A. 2020. Hidrolisados proteicos de resíduos da indústria de processamento de tilápia: caracterização centesimal, microbiológica e aminoácidos. Brazilian Journal of Development, 6(8): 59516-59527. https://doi.org/**10.34117/bjdv6n8-226**.

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

Franck, H.; Christian, M.; Noël, A.; Brigitte, P.; Joseph, H.D.; Cornet, D.; Mathurin, N.D. 2011. Effects of cultivar and harvesting conditions on the texture and taste of boiled cassava roots. Food Chemistry, 126(1): 127-133. https://doi.org/**10.1016/j.foodchem.2010.10.088**.

Gonçalves, A.A. 2011. Tecnologia do Pescado: Ciência, Tecnologia, Inovação e Legislação. São Paulo: Editora Atheneu. 608p.

Instituto Adolfo Lutz. 2008. Métodos físico-químicos para análise de alimentos. 4th ed. São Paulo: Instituto Adolfo Lutz. 1020p.

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

Maia, G.P.A.G.; Belisário, C.M.; Carvalho, V.D.F.; Cavalcante, M.D. 2020. Chemical physical characterization of rapadura added with clay almond marketed in the region of Rio Verde, Goiás State, Brazil. Social Development, 9(9): e18996464. https://doi.org/**10.33448/rsd-v9i9.6464**.

NEPA – Núcleo de Estudos e Pesquisas em Alimentação. 2011. TACO - Tabela Brasileira de Composição de Alimentos. 4ª ed. Campinas: Universidade Estadual de Campinas (Unicamp ed.). 161p. Available at: <https://www.cfn.org.br/wp-content/uploads/2017/03/taco_4_edicao_ampliada_e_revisada.pdf>. Accessed: July. 02, 2021.

Neves, E.C.A.; Nascimento, G.C.; Ferreira, A.R.; Neves, D.A.; Fukushima, A.R.; Leoni, L.A.B.; Clerici, M.T.P.S. 2020. Classificações e características nutricionais e tecnológicas de farinhas de mandioca comercializadas em Belém, Pará, Brasil. Brazilian Journal of Food Technology, 23(1): 1-11. https://doi.org/**10.1590/1981-6723.14319**.

Newell, G.J.; Macfarlane, J.D. 1987. Expanded tables for multiple comparison procedures in the analysis of ranked data. Journal of Food Science, 52(6): 1721-1725. https://doi.org/**10.1111/j.1365-2621.1987.tb05913.x**.

Ogawa, M.; Maia, E.L. 1999. Manual de pesca: Ciência e Tecnologia de Pescado. São Paulo: Varela. 430p.

Oliveira, I.R.; Carvalho, H.W.L.; Carvalho, L.M.; Pimentel, M.A.G. 2020. Boas práticas de cultivo para a elevação da produtividade da mandioca BRS Kiriris. 2nd ed. Sete Lagoas: Embrapa Milho e Sorgo. 16p.

Picanço, Y.S.; Oliveira, S.S.; Almeida, M.; Otani, F.S.; Pereira, E.J.; Santos, G.C. 2018. Análise de atividade de água e umidade na qualidade do mel produzido em comunidades da reserva extrativista Tapajós - Arapiuns, Santarém, Pará. Revista Agroecossistemas, 10(2): 1-10. http://dx.doi.org/**10.18542/ragros.v10i2.5146**.

Pigott, G.M.; Tucker, B.W. 1990. Seafood: effects of technology on nutrition. New York: Marcel Dekker. 362p.

Poiani, M.R.; Montanuci, F.D. 2019. Caracterizações físicas e tecnológicas e perfil de textura de cookies de farinha de uva e linhaça. Brazilian Journal of Food Technology, 22(1): 1-14. https://doi.org/**10.1590/1981-6723.07418**.

Rebouças, M.C.; Rodrigues, M.C.P.; Castro, R.J.S.; Vieira, J.M.M. 2012. Caracterização do concentrado protéico de peixe obtido a partir dos resíduos da filetagem de tilápia do Nilo Semina. Ciências Agrárias, 33(2): 697-704. http://dx.doi.org/**10.5433/1679-0359.2012v33n2p697**.

Sales, R.O.; Maia, E.L. 2012. Chemical composition and lipids classes of the freshwater fish tilapia do Nilo, *Oreochomis niloticus*. Revista Brasileira de Higiene e Sanidade Animal, 6(2): 17-30. http://dx.doi.org/**10.5935/1981-2965.20120004**.

Signor, F.R.P.; Signor, A.A.; Coldebella, P.F.; Simões, G.S.; Boscolo, W.R. 2020. Increase in the nutritional quality of tilapia mechanically separated meat and application in fish patties. Brazilian Journal of Development, 6(7): 47047-47061. https://doi.org/**10.34117/bjdv6n7-369**.

Silva, J.F.X.; Ribeiro, K.; Silva, J.F.; Cahú, T.B.; Bezerra, R.S. 2014. Utilization of tilapia processing waste for the production of fish protein hydrolysate. Animal Feed Science and Technology, 196(1): 96-106. https://doi.org/**10.1016/j.anifeedsci.2014.06.010**.

Silva, R.A.; Bonnas, D.S.; Silva, P.F. 2015. Aproveitamento dos resíduos gerados no processamento de postas de surubim (*Pseudoplatystoma corruscans*) para elaboração de nuggets. Contextos da Alimentação – Revista de Comportamento. Cultura e Scuola, 3(2): 38-48.

Souza, J.F.; Bitencourt, N.N.; Gomes, C.S.; Oliveira, J.K.; Santos, R.M.; Reis, I.A.O.; Nunes, M.L.; Narain, N. 2010. Desenvolvimento e caracterização físico-química e sensorial de nuggets formulados com concentrado protéico de pescado –marine beef. Scientia Plena, 6(3): 1-4.

Tahergorabi, R.; Beamer, S.K.; Matak, K.E.; Jaczynski, J. 2013. Chemical properties of *w*-3 fortified gels made of protein isolate recovered with isoelectric solubilisation/precipitation from whole fish. Food Chemistry, 139(1): 777-785. https://doi.org/**10.1016/j.foodchem.2013.01.077**.

Tamsen, M.; Shekarchizadeh, H.; Soltanizadeh, N. 2018. Evaluation of wheat flour substitution with amaranth flour on chicken nuggets properties. Lebensmittel-Wissenschaft + Technologie, 91(2): 580-587. https://doi.org/**10.1016/j.lwt.2018.02.001**.

Vega, O.; Carvajal, L.M.; Rodríguez, F.; Marín, M.C.; Ramírez, C.; Simpson, R.; Valdenegro, M. 2017. Effect of thermal pretreatments and cooking characteristics on physicochemical, rheological, and sensorial properties of food products based on cassava (*Manihot esculenta* Crantz). Journal of Food Process Engineering, 41(1): 1-9. https://doi.org/**10.1111/jfpe.12612**.

Veit, J.C.; Maluf, M.L.F.; Simões, M.R.; Feiden, A.; Boscolo, W.R. 2012. Inclusão de hidrolisados proteicos de tilápia do nilo (*Oreochromis niloticus*) em empanados de peixe. Arquivos de Ciências da Saúde da UNIPAR, 16(2): 85-92.