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Tambaqui (*Colossoma macropomum*) *sous vide*: characterization and quality parameters

Sous vide de tambaqui (*Colossoma macropomum*): caracterização e parâmetros de qualidade

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Abstract

The objective of this study was to evaluate the microbiological, physical and physico-chemical quality parameters of *sous vide* preparation of pen-reared tambaqui (*Colossoma macropomum*). To prepare the tambaqui *sous vide*, 200 g of fillet, 50 g of basil sauce (1:4 fish fillet:sauce ratio) and 10 mL of 5% sodium lactate were used. The product was then vacuum-packaged, pasteurized at 65 ºC for 12.5 min and refrigerated. The presence of *Salmonella* spp., sulfite-reducing Clostridium and *Listeria monocytogenes* was not detected in the samples analyzed. The coliform count at 45 ºC and coagulase-positive staphylococci were below the limit (10^3) permitted by the law in vigor. Water retention capacity and chloride content analyses revealed that the tambaqui fillet differed significantly ($P<0.05$) from the *sous vide* because of the addition of basil sauce. The total volatile basic nitrogen (TVB-N) and thiobarbituric acid reactive substances (TBARS) content of the fillet and *sous vide* were below the limits established by the law, indicating good quality. The lightness (L*) and yellow color (b*) of the fillet and the *sous vide* did not differ significantly ($P>0.05$), but the red color (a*) decreased in the *sous vide*, which is related to the addition of basil sauce. The chroma (C*) and hue angle (h^o) differed significantly ($P<0.05$), and the fillet samples were lighter in color, whereas the *sous vide* was characterized by yellow color. The n-6/n-3 ratios found for the fillet and the *sous vide* are within the recommended values, which is important for human metabolism. The fillet and *sous vide* also had high calcium, zinc, magnesium and potassium concentrations. It is concluded that tambaqui *sous vide* is a good source of nutrients, rich in fatty acids and minerals essential for human health.

Key words: *Colossoma macropomum,* quality, minerals, fatty acids

Resumo

O objetivo deste estudo foi avaliar os parâmetros de qualidade microbiológica, física e físico-química de *sous vide* de tambaqui (*Colossoma macropomun*) cultivado. Para a elaboração do *sous vide* foram utilizados 200 g de filé de tambaqui, 50 g de molho a base de manjericão (1:4 de filé de peixe: molho) e 10 mL de lactato de sódio a 5%, em seguida foram embalados à vácuo, pasteurizados a 65ºC durante 12,5 min e mantidos sob refrigeração. Nas amostras analisadas não foi detectada a presença de *Salmonella* spp, Clostridium sulfito redutores *e Listeria monocytogenes*. A contagem de coliformes a 45ºC e

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estafilococus coagulase positiva foram inferiores ao limite (10^3) permitido na legislação vigente. As análises de capacidade de retenção de água e teor de cloretos, do filé de tambaqui apresentaram diferença significativa (P<0,05) quando comparados ao *sous vide* devido a adição do molho de manjericão. As análises de bases voláteis totais (N-BVT) e teor de substâncias reativas ao ácido tiobarbitúrico (TBARS) no filé e no *sous vide* encontravam-se abaixo dos limites estabelecidos pela legislação indicando sua boa qualidade. A luminosidade (L*) e a cor amarela (b*) não mostraram diferença significativa (P>0,05) ao comparar o filé com o *sous vide*, porém o a* (cor vermelha) diminuiu o que está relacionado com a adição do molho do molho de manjericão. O croma (C*) e ângulo de tonalidade (hº) diferiram significativamente (P<0,05), foi constatado que as amostras de filé apresentaram uma cor mais clara e o *sous vide* foi identificado com a cor amarela. As razões n-6/n-3 encontradas no filé e no *sous vide* estão dentro do valor recomendado sendo importante para o metabolismo humano. Apresentaram também altas concentrações de cálcio, zinco, magnésio e potássio. Conclui-se, que o *sous vide* de tambaqui é boa fonte de nutrientes, rico de ácidos graxos e minerais essenciais para a saúde humana.
Palavras-chave: *Colossoma macropomum,* qualidade, minerais, ácidos graxos

Introduction

The tambaqui, *Colossoma macropomum* (*Characiformes, Serrasalmidae*), native to the Amazon Basin, has drawn much interest from fish farming because of its ability to make good use of many types of food and because it is an excellent plankton filter, in addition to exhibiting fast growth until the eighth month. Pen-reared fish grow under more stable conditions with a controlled growth rate and diet composition, and they can thus be more easily used in the preparation of products such as sausages, fishburgers, and *sous vide* (ARBELÁEZ-ROJAS et al., 2002; IZEL; MELO, 2004).

The growth of fish farming in the Amazon and the conquest of new markets are linked to fish processing, offering products that meet the demands for consumer convenience (GAMA, 2008). With the proper processing of the raw material, fish farming becomes a good alternative to meet new market niches formed by increasingly demanding consumers in regards to product quality and hygiene (BOMBARDELLI et al., 2005).

The improvement of fish farming in the region should be followed by progress in the processing industry through the use of new equipment and production processes to offer the consumer market a great variety of products that add value to the activity (SUFRAMA, 2003). A product with good presentation (adequate cuts) and quality packaging can be the focus of marketing strategies to reach markets that seek quality foods that are easy to prepare (GALIMPIN-JOHAN et al., 2007).

The *sous vide* technique is a new product alternative that meets these requirements. It consists of combined vacuuming and controlled cooking, resulting in a ready-to-eat product that may be immediately consumed or refrigerated/frozen for later consumption. This product has better color, flavor, texture and nutrient-retention characteristics compared with traditional cooking processes, representing an interesting alternative for consumption. Many studies have indicated the viability of using the *sous vide* process with different types of meat and fish (GALIMPIN-JOHAN et al., 2007; SHAKILA et al., 2009; MOL et al., 2012).

The use of vacuum packaging and pasteurization for the preparation of *sous vide* is responsible for maintaining its sensory qualities and physico-chemical and microbiological stability during storage (CONSANSU et al., 2011). The pasteurization temperature used in the *sous vide* technique can reduce the loss of liquids, proteins, aromatic compounds and nutrients that are sensitive to heat, and it simultaneously improves the texture when compared to conventional cooking, delaying the appearance of undesirable odors and flavors during storage and preserving microbiological quality for long periods (DÍAZ et al., 2008, 2009; SEBASTIÁ et al., 2010).

The objective of this study was to prepare pen-raised tambaqui *sous vide* and analyze its microbiological and physico-chemical quality parameters.

Materials and Methods

Production of the raw material

A total of 110 kg of tambaqui (*Colossoma macropomum*) from the culture tanks of the Cacoal Community, located in the municipality of Santa Isabel do Pará, Brazil, was used. The tambaquis had the same genetic origin, were 10 months old and were fed two types of food: in the first stage, growth ration, with higher protein content, was offered, followed by fattening ration with lower protein and higher lipid and carbohydrate content, providing more free energy.

Slaughter was performed by thermal shock, where the fish, still living, were placed in Styrofoam boxes layered with ice. The fish were then transported to the laboratory, where they were washed and sanitized with sodium hypochlorite solution at 5 ppm for 15 minutes. Next, the tambaquis were filleted, weighed, and vacuum packaged (Fastvac sealer, F200) using Solupack polyethylene packaging with the following specifications: oxygen permeability: <45 cm^3 m^{-2} day; water vapor permeability: <10 g m^{-2}; and temperature resistance: 30 to 100 °C. The fillets were stored at –22 °C until being used to prepare the *sous vide*.

Preparation of tambaqui sous vide

The product was prepared following good food preparation practices, starting with the defrosting of the fillets under refrigeration and standardization into pieces measuring approximately 5 x 7 x 2.5 cm as the average size of the lumbar portion of the fillets. A sauce was prepared with 3% basil (*Ocimum basilicum*), 2% oregano (*Origanum vulgare*), 3% onion (*Allium caepa*), 16.5% apple cider vinegar, 16.5% rice vinegar, 4% salt and 55% water.

Portions of fish weighing approximately 200 g were placed in nylon/smooth coextruded with polyethylene *sous vide* packages (20 x 25 x 18 cm) (Solupack, Barueri, São Paulo, SP) along with 50 g of sauce for a 1:4 ratio and 10 mL of 5% sodium lactate (Dinâmica brand, 49-51% purity degree, max chlorides 0.05%, heavy metals 0.001%). After the addition of sauce, the samples were vacuum packaged using a sealer (Fastvac, F200, Rio de Janeiro), and the products were then pasteurized in a water bath (Quimis, Q-350-2, São Paulo) at 65 °C for 12.5 min, counting from the time when the center of the piece reached the process temperature (BALDWIN, 2012). Immediately after the thermal treatment, the samples were chilled in ice water to 0 °C, stored at refrigeration temperature (1±1 ºC) and analyzed.

Microbiological characterization of tambaqui and sous vide

The presence of *Salmonella* spp. was determined, and coagulase-positive staphylococci and coliform counts at 45 °C were performed as required by law (BRASIL, 2001). Mesophyllic and psychotrophic bacteria, molds and yeasts, and sulfite-reducing Clostridium were analyzed following the method described by Downes and Ito (2001), and *Listeria monocytogenes* was analyzed according to the AOAC (2000).

Physico-chemical analyses of tambaqui fillets and sous vide

The moisture, protein, lipid, ash, pH (AOAC, 2000), carbohydrates and caloric value (BRASIL, 2003) were analyzed. The determination of thiobarbituric acid-reactive substances (TBARS) followed the method proposed by Vyncke (1970), and the results were expressed in mg malonic aldehyde (MDA)/ kg of sample. Total volatile basic nitrogen (TVB-N) was determined according to Brasil (1999). Chloride analysis was performed by

quantifying Cl^- ions by direct titration with $AgNO_3$, using K_2CrO_4 as an indicator according to Mohr's method (AOAC, 2000).

Water activity (Aw) was measured using an Aqualab electronic hygrometer, 3TE (Decagon Devices Inc., USA). Color was measured using a colorimeter (Minolta, model CR 310) in the CIE space (Comission Internacionale de L'Eclairage), where: L* (lightness); a* (red color intensity); b* (yellow color intensity). The total color difference (Eq.1), saturation index (Eq.2) and hue angle (Eq.3) were calculated as follows:

$$\Delta E^* = \sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]} \quad \text{Eq. 1}$$

$$C^* = \sqrt{([(a^*)]^2 + ([b^*)]^2)} \quad \text{Eq. 2}$$

$$h^* = \tan^{-1}\left(\frac{a^*}{b^*}\right) \quad \text{Eq. 3}$$

The water retention capacity (WRC) analysis used the methodology adapted by Hamm (1960), where 5 g of sample was placed between two filter papers measuring 12.5 cm in diameter, 205 µm in thickness and 80 g m^2 in weight. The samples and filter papers were positioned between two polyurethane plates, and then submitted to a force of 5 N for five minutes. The sample was then weighed, and the result was expressed according to the equation: WRC (%) = (mf)/mi×100, where: mi = initial mass of sample; mf = final mass of the sample.

To determine the fatty acid profile, the lipids in the sample were esterified according to the methodology established by the AOCS (2002). All steps of the process were performed under a N_2 gas atmosphere, and the esters were read in a gas chromatographer, model CP 3380 VARIAN, equipped with a flame ionization detector (FID) and fused silica capillary column, model CP-Sil 88 (60 m x 0.25 mm, stabilized cyanopropyl). Next, 1 µl of sample was injected into a split system at 1:50 ratio using helium as the carrier gas with flow rate of 1 mL $minute^{-1}$. The injector temperature was set at 245 °C, the detector temperature at 280 °C, and the total analysis time at 45 minutes. The fatty acid content was expressed as total percentage of fatty acids detected. As a standard, 68D solution (NU CHECK) was used to establish correction factors for each of the certified fatty acids, which were used to transform the percentage peak into the area per weight (mg g^{-1} of total fatty acids). The methyl esters were quantified by integrating the peak areas using the program Star 6.0. All analyses were performed in triplicate.

Copper, iron, manganese, zinc, calcium, magnesium, potassium and sodium levels were determined using the flame atomic absorption technique in a spectrophotometer (Aa Spectrometer, Thermo Scientific, Model ICE 3000 Series, USA) according to the AOAC (2000). The results were expressed in mg kg^{-1} (ppm), dry and wet basis, to facilitate comparison with other studies and with the concentrations permitted by law (BRASIL, 1965, 2003, 2005).

Statistical analysis

The physico-chemical data were analyzed using analysis of variance (ANOVA) and Tukey's test at the significance level of 5% with the software Statistica version 5.0.

Results and Discussion

Microbiological analysis

The presence of *Salmonella* spp., sulfite-reducing Clostridium and *Listeria monocytogenes* was not detected in the analyzed tambaqui fillet and *sous vide* samples (Table 1). The coliform at 45 °C and coagulase-positive Staphylococci counts were below the limit (10^3) permitted by

law (BRASIL, 2001). These micro-organisms do not belong to the normal fish microbiota, and their presence can be associated with contamination of the fishing location or improper handling in the production chain, including the ice, equipment, tools, etc. that come into contact with the fresh fish (SANTOS et al., 2008; KUMAR et al., 2009). The results demonstrate the quality of the raw material and the rigorous hygienic-sanitary control during product preparation. Another factor that should be highlighted is the addition of sodium lactate, which reduces the pH and is used as an antimicrobial agent, extending the shelf life of products such as cured meats, fish and uncured meats (JUNEJA, 2006).

Table 1. Microbiological analyses of tambaqui fillet and *sous vide.*

Analysis	Fresh tambaqui	*Sous vide*
Salmonella spp.	Absent/25 g	Absent/25 g
Coagulase-positive Staphylococci	$<1 \times 10^{1a}$ CFU g^{-1}	$<1 \times 10^{1a}$ CFU g^{-1}
Coliforms at 45 ºC	2.3×10^{1a} MPN g^{-1}	$< 3^{b}$ MPN g^{-1}
Mesophile Count	6.6×10^{2a} CFU g^{-1}	3.8×10^{2b} CFU g^{-1}
Psychotrophic Count	2.8×10^{2a} CFU g^{-1}	$< 10^{b}$ CFU g^{-1}
Mold and Yeast Count	-	$<10^{2}$ CFU g^{-1}
Sulfite-Reducing Clostridium	Absent	Absent
Listeria monocytogenes	Absent	Absent

*MPN = most probable number; **CFU = colony-forming unit, *** different letters indicate that samples differ significantly ($p<0.05$) according to Tukey's test; the analyses were performed in triplicate.

Brazilian law does not establish limits for mesophiles, psychotrophics or molds and yeasts in fish or fish products; however, these micro-organisms indicate if the cleaning, disinfection and temperature control were properly conducted during the processing, and large populations (10^6) can reduce the product's shelf life (ICMSF, 2005). Table 1 indicates that the counts of these micro-organisms were lower than 1×10^3 CFU g^{-1}. The count of molds and yeasts in the *sous vide* samples was $<10^2$ CFU g^{-1}, which is similar to the value found by Díaz et al. (2011) in salmon *sous vide*.

A significant reduction ($P<0.05$) in coliform values at 45 ºC and mesophile and psychotrophic counts in tambaqui *sous-vide* was observed as a result of the pasteurization process (Table 1). Reductions in mesophilic and psychotrophic bacteria counts in *sous vide* fish of up to 3 log CFU g^{-1} in relation to the raw material have been reported by Shakila et al. (2009) and Can (2011).

Physico-chemical characterization of tambaqui fillets and sous vide

Table 2 presents the physico-chemical analysis values of tambaqui fillets and *sous vide.* The ash, lipid and protein contents and total caloric value differed significantly between samples ($P<0.05$), whereas the moisture and carbohydrates did not differ significantly ($P>0.05$). Mol et al. (2012) and Cosansu et al. (2011) analyzed whiting (*Merlangius merlangus euxinus*) and Atlantic bonito (*Sarda sarda*) *sous vide, respectively*, and found significant differences ($P<0.05$) in the moisture, lipid and protein values of fish samples after *sous vide* processing and no significant differences ($P>0.05$) in the ash or carbohydrate contents.

Table 2. Physico-chemical analyses of tambaqui fillet and *sous vide* (mean ± standard deviation).

Composition[1]	Tambaqui fillet	**Tambaqui *sous-vide***
Moisture (g 100 g^{-1})	$79.00^{a} \pm 0.34$	$78.73^{a} \pm 0.52$
Ash (g 100 g^{-1})	$0.91^{a} \pm 0.03$	$2.33^{b} \pm 0.28$
Lipids (g 100 g^{-1})	$1.10^{a} \pm 0.03$	$3.23^{b} \pm 0.94$
Protein (g 100 g^{-1})	$18.07^{a} \pm 0.60$	$14.67^{b} \pm 0.88$
Carbohydrates (g 100 g^{-1})	$0.92^{a} \pm 0.37$	$1.04^{a} \pm 0.39$
Caloric Value (Kcal/100 g)	$85.87^{a} \pm 0.38$	$91.88^{b} \pm 1.44$
pH	$6.34^{a} \pm 0.04$	$5.52^{b} \pm 0.51$
Aw	$0.94^{a} \pm 0.04$	$0.99^{b} \pm 0.00$
WRC (%)	$76.41^{a} \pm 0.74$	$86.66^{b} \pm 2.73$
TVB-N (mg N/100 g)	$11.17^{a} \pm 0.00$	$8.38^{b} \pm 0.00$
TBARS (mg MDA/kg)	$0.032^{a} \pm 0.00$	$0.163^{b} \pm 0.04$
Chloride (g/100 g)	$0.13^{a} \pm 0.01$	$0.75^{b} \pm 0.06$
L*	$78.38^{a} \pm 0.38$	$78.71^{a} \pm 0.18$
a*	$8.58^{a} \pm 0.48$	$0.28^{b} \pm 2.47$
b*	$24.18^{a} \pm 0.86$	$21.14^{a} \pm 1.00$
ΔE	-	10.67 ± 0.71
C*	$25.66^{a} \pm 0.65$	$21.21^{b} \pm 0.97$
hº	$70.44^{a} \pm 1.66$	$90.91^{b} \pm 6.73$

* Different letters indicate that samples differ significantly ($p<0.05$) according to Tukey's test; the analyses were performed in triplicate.

The pH values were found to be within the limits established by the Regulation of Industrial and Sanitary Inspection of Animal Products (RIISPOA – Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal) (BRASIL, 1952), for external (<6.8) and internal (<6.5) fish meat, and they differed significantly between the fillets and the *sous vide* (Table 2). Studies with Atlantic bonito fillets and *sous vide* found pH values of 6.07 and 4.71, respectively, because of the addition of lemon juice to the *sous vide* (COSANSU et al., 2011).

The tambaqui fillet and *sous vide* had high and significantly different ($P<0.05$) aw content, despite the addition of sodium lactate. This high aw content facilitates micro-organism growth and the occurrence of chemical and enzymatic reactions. Díaz et al. (2011) found aw values of 0.92 in salmon *sous vide*, and according to the authors, the processing of the product in its own juice inside a package with good water vapor barrier capacity hinders micro-organism proliferation.

The WRC values for the fillet and *sous vide* differed significantly ($P<0.05$), which may be related to the addition of sodium lactate to the *sous vide*, as this additive is considered a good humectant. Pulgar et al. (2012) found WCR values of 79.8% for pork cheek *sous vide.*

The TVB-N values in the fillet and *sous vide* were much lower than the limit established by law of 30 mgN 100 g^{-1} (BRASIL, 1997). TVB-N has been used to objectively estimate fish quality, i.e., the degree of freshness. Table 2 indicates a significant reduction ($P<0.05$) in TVB-N values between the fillet and *sous vide* samples caused by the addition of the sauce ingredients, which can contribute to delay product deterioration. Cartonilho and Jesus (2011) found TVB-N values of 11 mg N/100 g in fresh tambaqui fillets. Can (2011) evaluated TVB in carp (*Cyprinus carpio*) fillets and *sous vide* and obtained 10 and 15 mgN 100 g^{-1}, respectively, with no significant difference ($P<0.05$) between samples.

The TBARS values found in the fillets and *sous vide* differed significantly (P<0.05), indicating an increase in this parameter after processing, with no effect on product quality. According to Schormuller (1968), TBARS values <3 mg MDA kg^{-1} in food indicate excellent quality, those between 3-5 mg MDA kg^{-1} indicate good quality, and the maximum allowed limit for food consumption is 8 mg MDA kg^{-1}. Yarnpakdee et al. (2012) found a TBARS value for fresh Nile tilapia (*Oreochromis niloticus*) of 0.3 mg MDA kg^{-1}. Can (2011) found TBARS values for fresh carp fillets and *sous vide* of 0.4 and 1.0 mg MDA kg^{-1}, respectively, similar to the value found by Díaz et al. (2011) in salmon *sous vide*.

The chloride content differed significantly (P<0.05) between the fillet and *sous vide* samples because of the addition of salt and lactate during the preparation of the sauce (Table 2). Oliveira et al. (2008) analyzed *Pimelodus* sp. fillets and found values higher than 0.85 g 100 g^{-1}; however, fish muscle contains approximately 0.08 g 100 g^{-1} to 1.00 g 100 g^{-1} of salt.

The instrumental color results (Table 2) indicate that the L* (lightness) and b* (yellow color intensity) parameters did not differ significantly between samples (P>0.05). The L* values indicated that the samples tended toward a white color. The analysis of the a* parameter (red color intensity) indicated that the samples differed significantly (P<0.05) after the processing of the fillets, with the red color lost due to pasteurization. The protein denaturation caused by pasteurization may affect the lightness of the fish, although it is not the only factor. According to Díaz et al. (2011), oxidation and other degradation phenomena can also modify muscle proteins and pigments related to fish color. Yagiz et al. (2009) and Díaz et al. (2011) evaluated the color parameters (L*, a* and b*) in salmon *sous vide* and found mean L* values of 75.0; for the a* and b* parameters, these authors found higher values for the b* parameter because salmon is reddish, unlike the tambaqui fillet, which is lighter in color. The total color difference (ΔE) was 10.67 ± 0.71 when comparing tambaqui fillet and *sous vide*. This value expresses how much the fillet color changed after processing using the *sous vide* technique. Picouet et al. (2011) analyzed salmon *sous vide* and observed less marked color loss compared to fresh salmon.

The chromaticity values (C*) differed significantly (P<0.05) between samples. Because chroma depends on a* and b* at the same intensity, the results indicated greater influence of the yellow color than red color, as expected, because tambaqui contains "white" meat. Díaz et al. (2011) analyzed salmon *sous vide* and observed higher dependency of the chroma on the a* parameter.

The hue angle (hº) differed significantly (P<0.05). The h° = 0° angle is fixed at the horizontal axis with a* (red), and rotating it counterclockwise, we have h° = 90° (yellow), h° = 180° (green) and h° = 270° (blue). The h° between 0° and 90° characterizes the red to yellow color quality. The h° results presented for fillets and *sous vide* (Table 2) approached 90° (yellow), indicating that the hue angle was affected by the chemical state of myoglobin, which is inversely related to the a* value. Because the *sous vide* preparation contains a pasteurization step, the cooking caused the denaturation of myoglobin, increasing the hue angle to values that approached yellow. Díaz et al. (2011) observed in salmon *sous vide* that the hº value tended towards red because of the color of the fish used in the study.

Fatty acid profile of tambaqui fillet and sous vide

Table 3 presents the compositions of saturated, monounsaturated and polyunsaturated fatty acids of the tambaqui fillet and *sous vide*, which differed significantly. High contents of oleic acid (C18:1), palmitic acid (C16:0) and linoleic acid (C18:0), the major representatives of the omega-6 fatty acid series, were found in tambaqui fillets. In the tambaqui *sous vide*, high amounts of trans-11 vaccenic acid (C18:1 vac), palmitic acid (C16:0) and linolenic acid (C18:2), the major representatives of the omega-3 fatty acid series, were found. According to Tonial et

al. (2011), linoleic acid (omega-6) is the precursor of arachidonic acid (C 20:4n-6), an important fatty acid for fetal development, blood pressure control and platelet aggregation control, and linolenic acid (omega-3) is the precursor of polyunsaturated fatty acids such as eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3), which are directly involved in the reduction of risk factors related to cardiovascular diseases, psoriasis, depression and diabetes.

Tonial et al. (2011) evaluated the fatty acid composition of fillets of tilapia (*Oreochromis niloticus*) fed a diet supplemented with soybean oil and found values for saturated fatty acids that varied from 39.65 to 35.11%, monounsaturated fatty acids from 44.68 to 44.63% and polyunsaturated acids from 15.49 to 21.13%.

Aiura and Carvalho (2004) evaluated the effect of tannin on the fatty acid profile and yield of Nile tilapia fillets and found higher percentages of unsaturated fatty acids such as oleic (C18:1) and linoleic (C18:2) acid, where the percentage of polyunsaturated fatty acids (PUFA) varied from 26.02 to 29.99%, respectively, for treatments containing 0.08% and 0.60% tannic acid.

According to the Department of Health and Social Security (HMSO, 1984), diets with PUFA/SFA ratio higher than 0.45 are considered healthy for humans from the nutritional point of view. In the tambaqui fillets, the PUFA/SFA ratio exceeded this value; however, in the *sous vide* sample, the ratio was slightly below the limit (Table 3). Aiura and Carvalho (2004) analyzed the polyunsaturated fatty acids/saturated fatty acids (PUFA/SFA) ratio in tilapia fillets supplemented with tannic acid and found values higher than the minimum recommended (HMSO, 1984). Jabeen and Chaudhry (2011) determined the fatty acid composition of fresh water fish species and found that the PUFA/SFA ratio varied from 0.20 to 0.44%, indicating a good supply of polyunsaturated fatty acids in relation to saturated fatty acids, therefore indicating that these foods are considered healthy.

The **ω**3, **ω**6 contents and the **ω**6/ **ω**3 ratios found in the tambaqui fillets and *sous vide* are presented in Table 3. Simopoulos (1991) recommends maintaining the n-6/n-3 ratio at 5 to 10. In this study, the n-6/n-3 ratios for the fillets were within the recommended value; however, the tambaqui *sous vide* exhibited values higher than recommended. According to Novelo et al. (2008), a balanced n-6/n-3 ratio in the diet is essential for human metabolism, leading to the prevention of cardiovascular and degenerative diseases and the improvement of mental health. Prato and Biandolino (2012) analyzed the fatty acid composition of important fish species from the Mediterranean Sea and found ratios ranging from 0.23 to 0.40. Tonial et al. (2011) found values for the ω6/ ω3 ratio ranging from 7.9 to 13.98 in tilapia fillets.

Table 3. Fatty acid profile of tambaqui fillet and *sous vide*.

Fatty Acid (%)	Fillet	*Sous vide*
C14:0	2.78^{a}±0.01	1.94^{b}±0.03
C14:1	0.42^{a}±0.00	0.36^{b}±0.00
C16:0	26.30^{a}±0.00	28.23^{b}±0.61
C16:1	5.12^{a}±0.07	3.30^{b}±0.06
C18:0	5.34^{a}±0.21	12.85^{b}±0.09
C18:1	27.29±0.00	Nd
C18:1vac	0.52^{a}±0.00	35.04^{b}±0.23
C18:2	24.44^{a}±0.00	13.30^{b}±0.11

continue

continuation

C18:3	2.30[a]±0.00	1.34[b]±0.08
C20:0	Nd	0.30±0.01
C20:1	Nd	0.15±0.00
C20:2	Nd	0.59±0.00
C20:3	Nd	0.19±0.00
C20:4	Nd	0.03±0.00
C20:5	0.73[a]±0.05	0.42[b]±0.07
C22:0	Nd	0.12±0.00
C22:1	2.45[a]±0.04	0.89[b]±0.05
C22:6	2.31[a]±0.00	0.79[b]±0.02
C24:0	Nd	0.09±0.00
C24:1	Nd	0.06±0.00
SFA	34.42[a]±0.08	43.53[b]±0.07
MUFA	35.80[a]±0.00	39.80[b]±0.03
PUFA	29.78[a]±0.00	16.67[b]±0.06
PUFA/SFA	0.86[a]±0.03	0.38[b]±0.21
∑n-6	26.74[a]±0.13	14.86[b]±0.08
∑n-3	3.04[a]±0.03	1.21[b]±0.00
n-6/n-3	8.79[a]±0.00	12.28[b]±0.00

*SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; **n-6:** omega-6 fatty acids; **n-3:** omega-3 fatty acids; **PUFA/SFA**: polyunsaturated fatty acids/saturated fatty acids ratio; **n-6/n-3:** omega-6/omega-3 fatty acids ratio; **nd:** not detected; * different letters indicate that samples differ significantly ($p<0.05$) according to Tukey's test; the analyses were performed in triplicate.

Mineral composition of tambaqui fillet and sous vide

The mineral concentration present in the samples was calculated by plotting specific calibration curves for each element, with at least four points, and having a linear regression coefficient higher than 0.997. The minimum limits of determination for each element were Cu (0.0001 mg L^{-1}), Fe (0.006 mg L^{-1}), Mn (0.002 mg L^{-1}), Zn (0.003 mg L^{-1}), Ca (0.004 mg L^{-1}), Mg (0.01 mg L^{-1}), K (0.009 mg L^{-1}) and Na (0.02 mg L^{-1}). All limits are below the maximum tolerance values determined by law (BRASIL, 1965, 2003; DRI, 2004; BRASIL, 2005).

Table 4 presents the concentrations in mg/kg on a dry basis (d.b) and wet basis (w.b) of the following minerals: Cu, Fe, Mn, Zn, Ca, Mg, K and Na for tambaqui fillet and *sous vide.* The contents of potassium (K) calcium (Ca), magnesium (Mg) and sodium (Na) were the highest in these samples.

Decree no. 55,871 of March 26, 1965 (BRASIL, 1965) establishes maximum tolerance limits for inorganic contaminants found in fish. The maximum permitted limit for copper (Cu) is 30 ppm (30 mg kg^{-1}), i.e., the products cannot be sold if they surpass this limit. In the present study, Cu values of 0.14 mg kg^{-1} and 0.15 mg kg^{-1} were found for tambaqui fillet and *sous vide*, respectively, which are much lower than the values permitted by law. Resolution RDC no. 269 of September 22, 2005 (BRASIL, 2005), which discusses the daily recommended intake (DRI) of minerals for adults, establishes that the DRI for Cu is 0.9 mg. The values found in the present study correspond to only 15% of the DRI. Souza et al. (2009) found Cu values in tilapia, catfish, *Astyanax* spp. and *piau* meat of 4.8 mg kg^{-1}, 5.4 mg kg^{-1}, 11.9 mg kg^{-1} and 6.5 mg kg^{-1}, respectively, due to local water contamination.

Table 4. Concentration of minerals in tambaqui fillet and *sous vide* (mean ± standard deviation).

Mineral (mg kg^{-1})	Fillet *	Fillet **	*Sous vide**	*Sous vide* **
Cu	0.67^{a}±0.41	0.14^{A}±0.09	0.69^{a}±0.43	0.15^{A}±0.09
Fe	57.65^{a}±0.35	12.11^{A}±0.07	82.19^{b}±1.74	17.48^{B}±0.37
Mn	6.84^{a}±0.01	1.44^{A}±0.00	4.83^{b}±0.19	1.05^{B}±0.19
Zn	38.98^{a}±0.81	8.19^{A}±0.17	30.34^{b}±1.70	6.45^{B}±0.36
Ca	3059.60^{a}±1.18	642.50^{A}±1.50	2595.60^{b}±0.90	538.46^{B}±1.40
Mg	2053.50^{a}±0.52	437.80^{A}±0.80	2247.40^{a}±0.40	439.87^{A}±0.60
K	32080.70^{a}±1.50	6736.90^{A}±1.80	39688.90^{b}±1.20	8441.80^{B}±0.76
Na	0.00^{a}±0.00	0.00^{A}±0.00	4527.80^{b}±0.03	963.10^{B}±0.30

* dry basis; ** wet basis. Different letters indicate that samples differ significantly ($p<0.05$) according to Tukey's test; the analyses were performed in triplicate.

The Fe, Mn, Zn, Ca, K and Na content differed significantly ($P<0.05$) between the studied samples. Only the Cu and Mg contents did not differ significantly ($P>0.05$) The daily recommended intake (BRASIL, 2005) for iron (Fe) is 14 mg. The *sous vide* contained approximately 17.5 mg Fe per 1 kg of product, whereas the fresh tambaqui contained 12.11 mg kg^{-1}. It is important to recall that basil sauce was added to the *sous vide* and that it contains many ingredients that could have caused these differences. Souza et al. (2009) found Fe values in tilapia, catfish, *Astyanax* spp. and *piau* meat of 52.3 mg kg^{-1}, 21.9 mg kg^{-1}, 48.8 mg kg^{-1} and 50.6 mg kg^{-1}, respectively. These levels are caused by the presence of this mineral in large amounts in the soil, water, atmosphere and industrial processes (BIRUNGI et al., 2007), and depending on the fish habitat, the mineral composition can vary.

A decrease in Mn content from 1.44 mg kg^{-1} to 1.05 mg kg^{-1} was observed after the addition of ingredients in the preparation of the tambaqui *sous vide*, which affected the content of this mineral. The daily recommended intake (BRASIL, 2005) should be 2.3 mg Mn^{-1}, and the fresh tambaqui and *sous vide* samples represented 63% and 46% of the DRI, respectively.

The zinc contents are presented in Table 4, where a significant decrease ($P<0.05$) was observed in the contents for fresh and *sous vide* fish. According to Brasil (2005), the DRI for Zn is 7 mg, and for the fresh and *sous vide* tambaqui, the consumption of 1 kg of these products ensures the necessary DRI for human consumption. Souza et al. (2009) found Zn values in tilapia, catfish, *Astyanax* spp. and *piau* meat of 19.6 mg kg^{-1}, 26.2 mg kg^{-1}, 73.7 mg kg^{-1} and 22.6 mg kg^{-1}, respectively. These high Zn levels may be the result of the study area being within an agricultural region, where the need for input application is known and can be carried by rainwater to contaminate fishing lagoons (BIRUNGI et al., 2007). Although the tambaquis used in this study were obtained from culture tanks, the zinc contents were lower than those found by Souza et al. (2009).

High Ca values were found for both types of samples and represented more than half of the DRI required by law (1000 mg). The Ca content decreased significantly ($P<0.05$) after the *sous vide* preparation. Ersoy and Ozeren (2009) analyzed the effect of catfish cooking methods on mineral composition and found that the Ca content for all cooking methods (baking, grilling, microwaving and frying) increased significantly ($P<0.05$) in relation to fresh catfish.

High Mg contents were found in the fresh and *sous vide* tambaqui (Table 4), which were twice the indicated DRI value of 269 mg. Ersoy and Ozeren (2009) analyzed the effects of catfish cooking methods on Mg content and found that all cooking

methods (baking, grilling, microwaving and frying) increased it significantly (P<0.05) in relation to the fresh catfish, reaching values of 265 mg kg^{-1}, 247 mg kg^{-1}, 230 mg kg^{-1}, 248 mg kg^{-1} and 184 mg kg^{-1}, respectively.

Dietary Reference Intakes (DRI, 2004) are another commonly used reference for nutritional recommendations, wherein the daily potassium intake for an adult is 4700 mg. This value was considered for potassium because the Brazilian law does not establish a value for this element. For both fresh and *sous vide* tambaqui, the K content was approximately 1.5 and 2 times higher, respectively, than the DRI when consuming 1 kg of the product. The addition of the sauce ingredients significantly increased (P<0.05) this value. Ersoy and Ozeren (2009) analyzed the effect of catfish cooking methods on mineral composition and found K values for fresh, cooked, grilled, microwaved and fried catfish of 1817 mg kg^{-1}, 2486 mg kg^{-1}, 2694 mg kg^{-1}, 2373 mg kg^{-1} and 2770 mg kg^{-1}, respectively.

Marengoni and Santos (2006) analyzed the mineral composition of both *piavuçu* and Nile tilapia fillets farmed in four fish-and-pays in terms of potassium, magnesium, iron and zinc contents, and they found that most minerals differed between species and the types of fish-and-pays. According to these authors, the content of minerals is more strongly influenced by water quality, the environment and food than it is by the physiological conditions of the fish (age, sex and sexual maturation).

Resolution RDC no. 360 of December 23, 2003 (BRASIL, 2003) establishes the daily intake limit for Na at 2400 mg. Table 4 indicates that fresh tambaqui exhibited sodium values below the limit of detection (0.02 mg L^{-1}), whereas the tambaqui *sous vide* exhibited sodium values of 963.1 mg/kg, i.e., this value represents approximately 41% of the daily recommended intake of sodium. Ersoy and Ozeren (2009) analyzed the effect of catfish cooking methods on mineral composition and found Na values for fresh, baked, grilled, microwaved and fried catfish of 308 mg kg^{-1}, 341 mg kg^{-1}, 287 mg kg^{-1}, 375 mg kg^{-1} and 471 mg kg^{-1}, respectively, where the Na content for baked, microwaved and fried fish increased significantly, whereas for grilled fish, it decreased.

Conclusion

The use of pen-reared tambaqui in the preparation of *sous vide* was found to be an excellent alternative for the inclusion of the product in the market, as it is a rich source of nutrients such as fatty acids and minerals essential for human health, and the process reduced the microbial load, increasing the shelf life of the product.

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