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Characteristics and processing of canned Amazon River prawn (*Macrobrachium amazonicum*) in Amazon sauce

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Abstract

The canned Amazon River prawn with sauce (*tucupi* and *jambu*) was thermally prepared (121 ºC) at three different times (T1: 15 T2: 20 and T3: 25 minutes) in glass bottles. The product obtained 20.86% crude protein, with good acceptance by consumers (global acceptance >7) measured through centesimal and sensory analysis of the hedonic scale. Increased exposure caused obvious changes in the sensorial characteristics of the product, which were not evidenced by consumers in the sensorial analysis, and for this reason, texture profile analysis (TPA) and color (CIELAB) were carried out, in addition to analyses of concentration of Total Volatile Basic Nitrogen (TVB-N), hydrogen potential (pH) and microbiological performed during 12 months, in addition to yield and weight loss by cooking. The sensory analysis did not show a significant difference between the treatments, however, the yield reduced with the application of heat, with the best yield being in treatment T1 (58.76 ± 0.49 a). The centesimal analysis showed excellent values of protein content of 20.86% and lipid content of 0.33%. The treatments followed the variation in color and texture according to the application of heat, mainly concerning the increase in the b* value (10.84 ± 0.70 to 13.50±0.24) and reduction in cohesiveness (0.56 ± 0.05 to 0.50 ± 0.04), gumminess (368.81± 109.23 to 262.09 ± 63.78 g) and chewiness (999.30 ± 356.92 to 633.71 ± 221.56 g). Despite this, the product proved to be safe during the analyzed period without the development of the remaining bacteria, even with an increase in pH (4.2 to 5.9) and TVB-N (20.22 to 28.46 mg/100 g), despite this, there was no development of the bacteria analyzed, proving to be a product suitable for industrial implementation.

Keywords: Thermal processing; *tucupi*, *jambu*; Amazon food culture; texture profile; shrimp.

Highlights

- Exposure to high temperature drastically alters the sensorial properties (mainly texture, color, flavor, and aroma) of all ingredients (prawn, *tucupi* and *jambu*)
- The proportion of ingredients aided by weight loss by cooking the prawn caused changes in the *tucupi* sauce, causing strangeness to consumers
- Despite the alteration of all sensory and physical-chemical characteristics evaluated, the microbiological and TVB-N analyses showed that the product is safe for consumption, even after 12 months of production

1 Introduction

Fish stand out among the most commercialized food commodities around the world, reaching the *per capita* global intake of 20.2 kg in 2018 (Food and Agriculture Organization of the United Nations, 2022). However, fish is more perishable than other food, mainly for microbiological degradation, lipid oxidation, and enzymatic activity (Mei et al, 2019). Factors like temperature (owing to their heterothermic characteristic), pH close to the neutral values (mainly *post-mortem*), and greater concentration of protein nitrogen compounds can aid in bacterial development (Lunestad & Rosnes, 2008).

The Amazon is a heterogeneous mosaic of natural resources such as water, biodiversity, metals, minerals, and energy that promote the economic and social well-being of the residents (Mardas et al., 2013). The Amazon area belonging to the Brazilian territory is called "*Legal Amazon*" (IBGE, 2022), a region influenced by the presence of several indigenous ethnic groups and immigration of Portuguese and Africans, that helped in the development of a unique cuisine (Nishinari, 2020).

The Amazon River prawn (*Macrobrachium amazonicum*) is a species from South America with greater potential for aquaculture (Moraes-Riodades & Valenti, 2004). This prawn came from the *Palaemonidae* family and is present in Guyana, Suriname, French Guiana, Brazil, Colombia, Venezuela, Ecuador, Bolivia, Peru, Paraguay, and Argentina (Maciel & Valenti, 2009). Its sensorial characteristics such as flavor and texture are higher than *Macrobrachium rosenbergii*, thus explaining its better acceptance in the Amazon region (Moraes-Riodades & Valenti, 2001).

In the botanic variety from the Amazon Forest, *jambu* (*Acmella oleracea* (L.)) stands out for the development of some studies due to the spilanthol, that is, a bioactive compound (Barbosa et al., 2016). This chemical compound (alkamide) can provide a strong/spicy flavor and provokes numbness when it is intake (Romão et al., 2015). This plant has a great nutritional profile with high concentrations of fiber, carbohydrates, and minerals like calcium, magnesium, iron, zinc, potassium, copper, manganese, and sodium (Neves et al., 2019).

Tucupi is a liquid by-product of the production of cassava flour (*Manihot esculenta* Crantz)(Chisté & Cohen, 2011; EMBRAPA, 2019), which, as it is a cyanogenic plant, has a high concentration of cyanide in its composition, released in the form of hydrocyanic acid (HCN) in *tucupi*, thus increasing the acidity of the medium (Amorim et al., 2006; Chisté & Cohen, 2011), seeing that it is a fundamental characteristic for thermal sterilization in an acid medium (Gava et al., 2017), considering that acidity increases the sensitivity of microorganisms to thermal exposure (Evancho et al., 2009).

Among the gastronomic diversity from the Amazon region these elements, prawn, *tucupi,* and *jambu* are the most used ingredients for the typical dishes "*tacacá*" (Robert & Velthem, 2009). This is an indigenous food commonly produced during some festive events in the Brazilian Amazon (Modesto Junior & Alves, 2014).

However, due to the rapid degradation of its ingredients, mainly related to prawns, marketing to other regions is very difficult. Taking advantage of the physical-chemical characteristics of the *tucupi* sauce and the stability of the thermal sterilization process, it is noted that this research aimed to develop a canned Amazon River prawn in *tucupi* and *jambu* sauce, aiming to increase the shelf life and enable the production/commercialization of a food characteristic of Amazonian gastronomy in other regions.

2 Material and method

2.1 Obtaining the ingredients

Amazon River prawn (*M. amazonicum*) (90.00 ± 0.85 mm in total length) and *jambu* (*A. oleracea*) were obtained from the market Ver-O-Peso, Belém-PA. 10 kg of whole prawn were stored with ice flakes in a 2:1 ratio, in a Styrofoam container and sent to the Fish Technology Laboratory (*Laboratório de Tecnologia do Pescado* - LATEPE), Bragança, Pará state, where they were processed upon receipt to avoid alterations due to deterioration as the transit time may vary (approximately 3 hours). Industrialized *tucupi* (Vovó da Floresta, CNPJ: 01.852.807/0001-15) was purchased at a supermarket in the region. Hygiene and processing conditions were carried out following decree Nº. 9.013, of March 29, 2017 (Brasil, 2017), and Decree Nº. 10,468, of August 18, 2020 (Brasil, 2020b).

2.2 Experimental design and processing

This experiment occurred in a completely randomized design with three different times of autoclave procedure (15, 20, and 25 minutes at 121 ºC) and five replicates. Samples of prawn (60 g), *tucupi* (39 g), and *jambu* (1 g) were placed into cylindrical glass bottles (volume 100 mL, dimensions 65 mm in height, and 50 mm in diameter). In adequate hygienic conditions the prawn was properly cleaned, peeled, removed from their cephalothoraxes and legs, then immersed in 10% brine for 10 minutes. The *tucupi* was previously boiled for 15 minutes with flavoring condiments. The *jambu* used in the experiment was previously bleached (Figure 1). The proportion of each ingredient was 60% of shrimp, 39% of *tucupi,* and 1% of whitened *jambu*. Thus, 24 samples were produced for further analysis over 12 months, after the sixth month a sample was used to perform Total Volatile Basic Nitrogen (TVB-N), pH and microbiology analyses every 3 months.

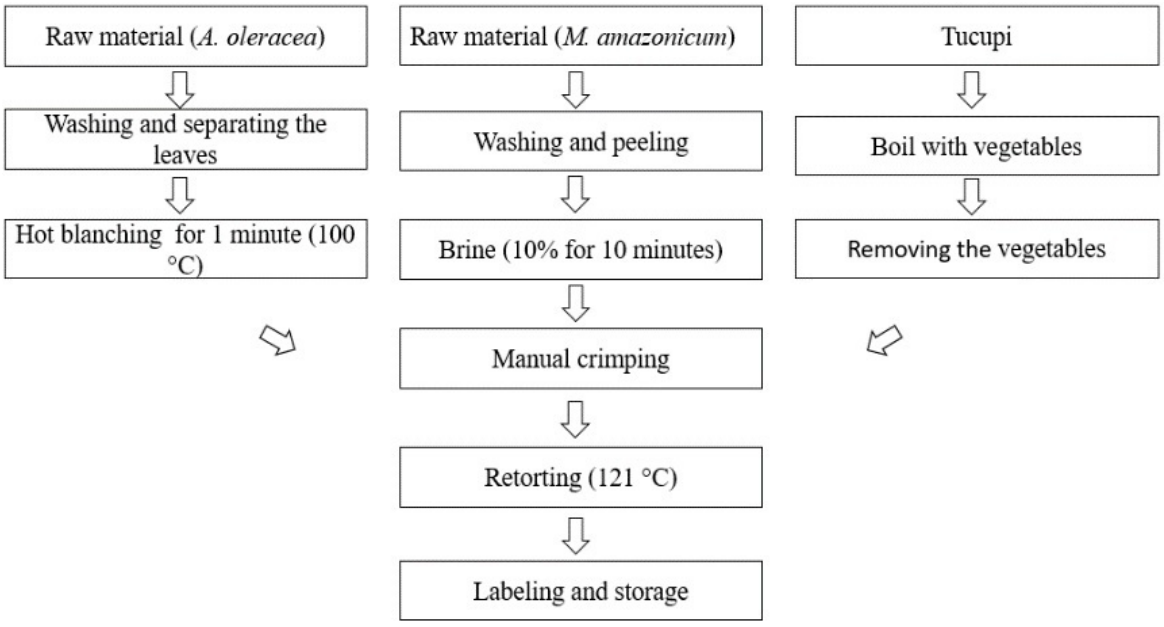

Figure 1. Processing of canned Amazon River prawn with *tucupi* and *jambu* sauce.

The prawns were arranged manually in the glass container, where the blanched *jambu* and hot *tucupi* were added, this procedure caused the removal of the air inside the glass by convection (exhaustion). The shutdown hermetic sealing of the containers (crimping) occurred manually and instantly after the addition of the sauce, then the containers were submitted to sterilization in an autoclave. After processing, the samples were kept at room temperature (25 °C).

2.3 Sensorial analysis

Sensory analysis was performed 3 days after sterilization, the analysis was applied to 40 people (not trained) recruited from the Federal University of Pará, Bragança *Campus*, with age variation from 19 to 68 years old, consisting of 62.5% being males and 37.5% females. The questionnaire used a nine-point Hedonic Scale test, a scale ranging from 1, "I disliked it extremely" to 9, "I like it extremely", evaluating the attributes of appearance, texture, flavor, aroma and color, and global acceptance (A.G). A frequency of consumption test was carried out with a scale ranging from 1, "I would only eat this if I was forced" to 9, "I would eat this whenever I had the opportunity". Purchase intention was measured using the 5-point test, a scale ranging from 1, "I certainly would not buy it" to 5, "I would certainly buy it" (Instituto Adolfo Lutz, 2008).

2.4 Yield and loss of weight by cooking

Performed five days after sterilization only with prawns and determined by the difference of weight caused by cooking procedure according to Manheem et al. (2012), as follows (Equation 1 and 2):

$$\text{Yield (\%)} = (\text{Final weight} / \text{Initial weight}) \times 100 \quad (1)$$

$$\text{Cooking weight loss (\%)} = ((\text{Initial weight} - \text{Final weight}) / \text{Initial weight}) \times 100 \quad (2)$$

2.5 Centesimal analysis

The centesimal analysis was carried out five days after sterilization of the product, using the drained product. Moisture analysis was carried out in an oven at 105 °C at a constant temperature, and protein analysis according to the Kjeldahl method. However, lipid extraction was carried out by direct soxhlet extraction method and mineral content was determined by combustion of the samples at 550 °C for 22 hours, all following the A.O.A.C methodology (AOAC, 1990). The carbohydrate content was determined by the difference of the other nutrients analyzed (Linhartová et al., 2018). The energy value was calculated using the methodology of Brasil (2020a), Normative Instruction N° 75, of October 8, 2020.

2.6 Total Volatile Basic Nitrogen (TVB-N) and hydrogen potential (pH)

The analyses were carried out five days after sterilization (first month) with the drained product, aiming to the assessment of product deterioration. TVB-N were quantified using homogenized samples and quantified by distillation of ammonia and volatile amines by steam dragging in a slightly alkaline medium and quantified by neutralization volumetry (AOAC, 1990). The pH of the topping sauce was quantified using a bench pH meter only in the *tucupi* sauce, the first quantification occurred in the topping sauce at the time of filling (first month), and later at the sixth, ninth, and twelfth month after sterilization. Both TVB-N and pH analyses were performed on the same day.

2.7 Microbiological analysis

Microbiological analysis was performed 5 days after sterilization with drained product, and then it was carried out every 3 months. The microorganisms analyzed were selected according to Normative Instruction No. 60, of December 23, 2019 (Brasil, 2019b), analyzing coliforms at 45 °C, coagulase-positive Staphylococci (CoPS) and *Salmonella* sp., while *Clostridium* sp. was also analyzed because it is the genus of bacteria that is extremely dangerous for commercially sterile foods due to its thermotolerance (André et al., 2017). The analytical methodology used is described in the Compendium of Methods for the Microbiological Examination of Food (Salfinger & Tortorello, 2015) and all analyses were performed in triplicate.

2.8 Determination of the Most Probable Number (MPN) of Coliforms at 45 ºC

The multiple tube technique was used, with three series of three tubes in each dilution (10^{-1}, 10^{-2} and 10^{-3}). Lauryl Tryptose Broth is used as a presumptive medium with incubation at 35 °C for 48 hours. After the reading, the positive tubes (which showed gas) were placed in *Escherichia coli* broth (EC), for confirmatory testing, and incubated at 44.5 ºC, in a water bath, for 24 hours. The evolution of MPN, of coliforms at 45 °C, was performed using the Hoskins table.

2.9 Coagulase-positive staphylococci

The surface sowing technique was used, inoculating 0.1 mL aliquots of the 10^{-1} and 10^{-2} dilutions on the surface of Baird-park Agar in duplicate. After incubation at 36 °C for 48 hours, colonies characteristic of staphylococci were enumerated and remained in the coagulase test. The results were expressed in CFU/g.

2.10 *Salmonella* sp.

The samples that accompanied the pre-enrichment in sterile buffered Peptone were inoculated, transferring 1 mL of the culture to 10 mL of Selenite Cystine Broth and 1 mL to 10 mL of Tetrathionate Broth, being incubated at 37 °C for 24 hours. The isolation of typical colonies was carried out by replicating them by sowing on surfaces in Salmonella-Shigella agar (SS) and Brilliant Green Agar (BGA), with incubation at 37 °C for 24 hours. Typical colonies were confirmed by biochemical tests using Triple Sugar Iron Agar (TSI), Lysine Iron Agar (LIA), Urea, and Citrate Broth and serological testing (polyvalent O and H serum).

2.11 Sulphite-reducing clostridia (*Clostridium* sp.)

The technique of sowing in depth with overlay was used, inoculating 1 mL aliquots of the 10^{-1} and 10^{-2} dilutions on the surface of the plates and adding Tryptose Sulphite Cycloserine Agar (TSC agar). After incubation at 36 ºC in anaerobiosis for 24 hours, the typical colonies (black) were enumerated, and five colonies were transferred to Thioglycollate Medium (TGM) and incubated at 46 ºC/4 h. The results were expressed in CFU/g.

2.12 Texture Profile Analysis (TPA)

Performed 60 days after sterilization only in the prawns, using a texturometer CT3 4500 - Texture Analyzer (Brookfield), and also a cylindrical probe TA11/1000, 25.4 mm in diameter, previously calibrated (Jo et al., 2021). The second segment (Nunak & Schleining, 2011) of 10 samples from each cooked shrimp treatment was highlighted in a homogeneous cubic shape with an 8 mm edge, the pre-test velocity was 2 mm/s, the test velocity 0.2 mm/s and the post-test velocity 10 mm/s test, trigger force was set to 0.5 g (Impaprasert et al., 2017), compression was 50% (4 mm) (Impaprasert et al., 2017; Wang et al., 2022), all at room temperature (25 °C). Texture variables (hardness, cohesiveness, springiness, adhesiveness, gumminess, and chewiness) were calculated as described by Bourne (2002) and Etemadian et al. (2011).

2.13 Colorimetric analysis

Colorimetric analysis was performed 30 days after sterilization, in triplicate, using a previously calibrated CR-400 colorimeter (Konica Minolta). Each constituent *in natura*, processed and final product (T1, T2 and T3) were evaluated referring to the CIELAB color spectrum (L*, a*, b*), where L* represents brightness, from white (100) to black (0), a* coordinate from red (+) to green (-) and b* coordinate from yellow (+) to blue (-), at room temperature (25 °C), methodology adapted from Parisenti et al. (2011).

2.14 Statistical analysis

Data were processed using the analysis of variance (ANOVA) and for samples with significant differences, the Tukey's test was applied, at 5% significance, using the statistic® 6.0 program. The values were shown as means with their respective standard deviations.

3 Result and discussion

3.1 Sensorial analysis and yield and loss of weight by cooking

The sensorial analysis demonstrated global acceptance higher than 7, but other sensorial results demonstrated mean values below the global and did not show any difference among the treatments (Table 1).

Table 1. Mean values of the results for sensorial analysis, yield, and weight loss by cooking the canned prawn with *tucupi* and *jambu* sauce.

Parameters	Treatments			
	T1	T2	T3	*p*-value
Global acceptance (G.A.)	7.35 ± 1.02	7.15 ± 1.57	6.92 ± 1.62	0.058
Appearance	6.92 ± 1.44	6.72 ± 1.60	6.42 ± 1.68	0.365
Texture	6.82 ± 1.65	6.90 ± 1.60	6.82 ± 1.50	0.972
Flavor	7.05 ± 1.52	7.22 ± 1.58	6.75 ± 1.85	0.564
Smell	6.72 ± 1.57	6.70 ± 1.54	6.30 ± 1.92	0.544
Color	6.77 ± 1.62	6.72 ± 1.69	6.85 ± 1.62	0.943
Frequency of intake	6.13 ± 2.10	6.33 ± 1.65	6.23 ± 2.06	0.900
Purchase intention	3.57 ± 1.11	3.85 ± 1.10	3.50 ± 0.96	0.300
Yield (%)	58.76 ± 0.49^{a}	57.84 ± 0.88^{ab}	55.08 ± 1.77^{b}	0.021
Weight loss by cooking (%)	41.24 ± 0.49^{a}	42.16 ± 0.88^{ab}	44.92 ± 1.77^{b}	0.021

Different letter in the row mean statistical difference by Tukey's test ($p < 0.05$).

These sensorial values were below than others observed by Majumdar et al. (2017) which produced giant river prawn (*M. rosenbergii*) with curry sauce, demonstrating global acceptance above 8.

Considering that the elaborated product uses the traditional food culture of the Amazon region and that there is no similar canned shrimp on the national market, possibly the comparison with the traditional product (*tacacá*) occurred on the part of the tasters, which may have harmed the perception of the product since the process of thermal sterilization changes its sensorial and nutritional characteristics (Awuah et al., 2007; Cheng et al., 2017; Durance, 1997).

The yield presented variation inversely proportional to the application of heat. Weight loss due to cooking increased proportionally with the time of heat application (Table 1). This can be explained by damage to the shrimp tissue, a consequence of exposure to heat, which results in protein denaturation (actin, myosin, and sarcoplasmic proteins) and loss of water retention capacity (Badiani et al., 2002; Niamnuy et al., 2007).

The values of weight loss by cooking are higher than those obtained by Bhat et al. (2017) of 20.15 when cooking Pacific white shrimp (*Penaeus vannamei*), a lower value when observing the best treatment (T1) of 41.24 ± 0.49, which can be explained by the greater exposure to the heat in canned prawn (121 °C for 15 minutes in T1).

3.2 Centesimal analysis

The results of the centesimal analysis (Table 2) demonstrated that the developed product has a satisfactory percentage of protein and a low percentage of fat. The percentage values of protein (20.86) were lower than those obtained by Furuya et al. (2006), who analyzed batches of fresh Amazonian shrimp, obtaining an average percentage of 24.80. The reduction in the protein content in the canned can be explained by the presence of *jambu* and *tucupi* sauce present in the canned since these components do not contribute to protein fractions.

Table 2. Results of centesimal analysis (100 g) for all samples of canned Amazon River prawn with *tucupi* and *jambu* sauce compared with giant river prawn with curry sauce (Majumdar et al., 2017).

Analysis	Canned Amazon River Prawn in *tucupi* and *jambu* sauce	Canned Giant River Prawn in curry sauce
Energy (Kcal)*	92.57	-
Moisture (%)	74.30	75.26
Protein (%)	20.86	17.66
Carbohydrate (%)	1.54	-
Lipid (%)	0.33	4.03
Ash (%)	2.97	0.44

*Kcal/100 g.

However, comparing the values found in this work with those obtained by Majumdar et al. (2017), who produced canned giant river prawn (*M. rosenbergii*) in curry sauce, one can see a higher concentration of proteins and ash in addition to lower fat content in canned of Amazon River prawn (Table 2).

3.3 Total Volatile Basic Nitrogen (TVB-N) and Hydrogen Potential (pH)

The Total Volatile Basic Nitrogen (TVB-N) is the main chemical indicator of the degree of freshness of shrimp, the increase of these bases is carried out by the action of endogenous enzymes or by microbial activity (Kamal et al., 2000; Liu et al., 2020), these groups of amines alter the physical-chemical and sensorial characteristics of the product, causing an increase in the pH (Kim et al., 2023).

The TVB-N changed from 20.22 mg/100 g, in the sixth month, to 28.41 mg/100 g in the twelfth month (figure 2), fitting within the limits established by Brazilian legislation of 30 mg/100 g according to RIISPOA Decree N°. 9.013, of March 29, 2017 (Brasil, 2017) and Technical Identity and Quality Regulations (*Regulamentos Técnicos de Identidade e Qualidade - RTIQ*) for fresh prawns (Brasil, 2019a), showing the efficiency of processing in slowing down product spoilage. Values were better than those obtained by Liu et al. (2020) who stored dried white shrimp (*Penaeus vanameii*) and obtained values greater than 30 mg/100 g in 15 days of storage at a pH close to 8, similar pattern was observed by Kim et al. (2023) who evaluated the pH and TVB-N of 3 different species of fish at different temperatures, the fish at 20 °C obtained TVB-N values greater than 50 mg/100 g and pH close to 7, after 7 days of storage.

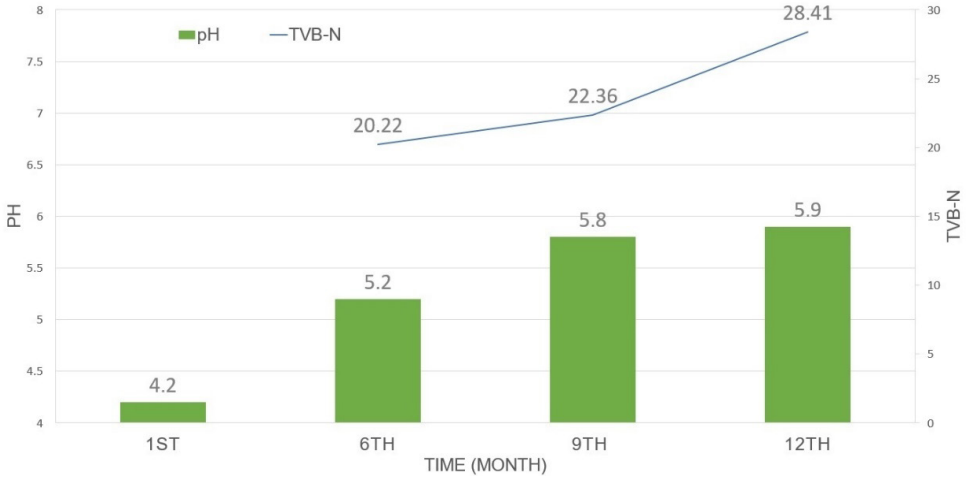

Figure 2. Graph of change in pH and Total Volatile Basic Nitrogen (TVB-N), in the 12-month storage period.

The pH increased over the period of analysis, ranging from 4.2, at the time of addition of the dressing, to 5.9, in the last analysis, after 12 months. The pH values after 6 and 9 months were 5.2 and 5.8, respectively. It should be noted that at the time of the commercial sterilization process, the pH of the topping sauce was below 4.6, which is the appropriate value to inhibit the development of bacteria of the genus *Clostridium* (Evancho et al., 2009). The reaction of the amines with the groups that receive content in the *tucupi* is a neutralization reaction and gives the medium an increase in pH, enzymatic action, or even bacterial activity (although no development of the bacteria received has been shown, bacteria that cause risk the health) (Kamal et al., 2000; Liu et al., 2020; Talukder et al., 2020).

3.4 Microbiological analysis

Despite the significant increases for pH over the 12 months, canned prawns did not show visual alterations, discarding the presence of microorganisms. This was confirmed by the microbiological analysis that it did not present the development of the genera analyzed. Fitting within the limits established by Brazilian legislation of Resolution of the Collegiate Board (RDC) No. 12, of January 02, 2001 (Brasil, 2001) and Normative Instruction Nº. 60, of December 23, 2019 (Brasil, 2019b). This result indicated sterilization efficiency (Table 3).

Table 3. Evolution of microbiological analyses over 12 months after production of canned prawns.

Analyses	Analysis dates				
	3rd month	6th month	9th month	12th month	Legislation
Coliforms	<3 MPN/mL	<3 MPN/mL	<3 MPN/mL	<3 MPN/mL	$>10^3$ MPN/mL
Salmonella	Absence	Absence	Absence	Absence	Absence
Staphylococci	<10 CFU/g	<10 CFU/g	<10 CFU/g	<10 CFU/g	$>10^3$ CFU/g
Clostridium	<10 CFU/g	<10 CFU/g	<10 CFU/g	<10 CFU/g	-

3.5 Texture analysis

The hardness values (Table 4) ranged from 669 g to 521 g, for T1 and T3, respectively, similar to the values obtained by Majumdar et al. (2017) in canned *M. rosenberguii* in curry sauce at 116 °C, with hardness values ranging from 580 g to 680 g, with 53 and 63 minutes of exposure, respectively. However, much lower than the hardness of *Fenneropenaeus chinensis* (1087.57 g) cooked at 32 °C for 10 minutes, obtained by Li et al. (2017) and cooled *Pneus vannamei* (2011.70 g), obtained by Xu et al. (2019).

Table 4. Mean values of the analysis for texture among the treatments (T1, T2, and T3).

Analysis	Treatments			
	T1	T2	T3	*p*-value
Hardness (g)	669.75 ± 218.21	680.97 ± 180.72	521.53 ± 115.06	0.095
Cohesiveness	0.56 ± 0.05[a]	0.56 ± 0.04[a]	0.50 ± 0.04[b]	0.015
Springiness (mm)	2.68 ± 0.38	2.58 ± 0.23	2.37 ± 0.29	0.087
Adhesiveness (mJ)	0.12 ± 0.09	0.14 ± 0.07	0.17 ± 0.08	0.368
Gumminess (g)	368.81 ± 109.23[a]	377.55 ± 101.20[a]	262.09 ± 63.78[b]	0.017
Chewiness (g)	999.30 ± 356.92[a]	984.19 ± 317.20[a]	633.71 ± 221.56[b]	0.018

Different letter in the row mean statistical difference by Tukey's test ($p < 0.05$).

The characteristics of muscle tissue, referring to the loss of the ability to retain water, protein denaturation, and collagen gelatinization, express the sensitivity of shrimp to exposure to acidity and heat. Therefore, the application of heat reduces the hardness of muscle tissue, comparing such hardness values with those of fresh or frozen shrimp.

The attributes cohesiveness, gumminess, and chewiness differed, with T3 having the lowest values in relation to the other treatments. The reduction in cohesiveness can be justified by the great protein denaturation that occurred in the shrimp muscle tissue and collagen gelatinization, factors that also affect the gumminess and chewiness, in the sterilization process, a reaction accentuated by the acidity (pH = 4.2) of the *tucupi* sauce.

3.6 Colorimetric analysis

The treatment with the highest a* value (7.08) expressing a more reddish color, therefore more attractive to the consumer, was T3 (Table 4). Color values for processed Amazonian shrimp are similar to those obtained by Majumdar et al. (2017) canned M. rosenbegii in curry sauce, with a* values of 3.83, 4.86, and 5.37 after 53, 57, and 63 minutes of exposure at 116 °C, respectively.

The color of fresh shrimp is a great indicator of shrimp quality and the quality is reflected in bluish and grayish tones, due to the α-crustacynin in their tissues, but their coloration becomes more reddish with positive a* values after heat treatment due to astaxanthin that is disposed in the disruption of α-crustacynin (Buchwald & Jencks, 1968; Li et al., 2017; Parisenti et al., 2011) which can be seen in Table 5.

Table 5. Mean values of standard color CIELAB of Amazon River prawn tucupi and jambu, nature and after sterilization.

Standard CIELAB	Prawn				
	Nature	T1	T2	T3	*p*-value
L*	40.99 ± 0.01[a]	40.14 ± 0.05[b]	35.32 ± 0.05[c]	50.91 ± 0.15[d]	0.001
a*	-0.67 ± 0.01[a]	6.59 ± 0.14[b]	3.92 ± 0.07[c]	7.08 ± 0.24[d]	0.001
b*	2.22 ± 0.24[a]	19.97 ± 0.16[b]	15.73 ± 0.03[c]	25.36 ± 0.36[d]	0.001
			Tucupi		
L*	36.06 ± 0.05[a]	32.22 ± 0.24[b]	29.86 ± 0.17[c]	31.27 ± 0.23[b]	0.001
a*	-1.55 ± 0.20[a]	-0.73 ± 0.02[b]	-0.44 ± 0.06[b]	1.00 ± 0.03[c]	0.001
b*	9.59 ± 0.31[a]	17.88 ± 1.14[b]	16.49 ± 0.16[bc]	19.42 ± 0.29[bd]	0.001
			Jambu		
L*	19.55 ± 1.52[a]	7.53 ± 0.05[b]	10.52 ± 0.03[c]	7.65 ± 0.03[b]	0.001
a*	-7.39 ± 0.15[a]	-0.65 ± 0.16[b]	-0.36 ± 0.08[b]	-0.66 ± 0.08[b]	0.001
b*	12.44 ± 0.08[a]	8.46 ± 0.02[b]	7.18 ± 0.04[c]	9.27 ± 0.02[d]	0.001

Different letters in the row mean statistical difference by Tukey's test ($p < 0.05$).

Tucupi in nature is characterized by its yellowish color, expressed in the b* value of 9.59, but the hue was accentuated by thermal processing, reaching a value of 19.42 in T3. This increase can be explained by the Maillard reaction, which also justifies the decrease in the L* value from 36.06 in fresh *tucupi* to 29.86 in T2. *Jambu* in nature has a dark green color expressed in the value of L* and a* of 19.55 and -7.39, respectively. However, it became even darker after processing, reaching values of L*= 7.53 and a*= 0.65, in T1.

In the CIELAB color patterns of the final product (Table 6), a tendency for the product to turn yellow can be observed with the increase in the b* value, with T3 (13.50) being significantly higher than the values of T1 and T2. There was also a slight oscillation in the reddish color, where only T2 (-0.17) did not show positive values, tending towards green tones.

Table 6. Mean values of standard for CIELAB for the final products.

Standard CIELAB	Products			
	T1	T2	T3	*p*-value
L*	21.37 ± 0.22[a]	20.30 ± 0.14[b]	22.53 ± 0.25[c]	0.001
a*	2.17 ± 0.12[a]	-0.17 ± 0.05[b]	1.65 ± 0.06[c]	0.001
b*	10.84 ± 0.70[a]	11.36 ± 0.06[a]	13.50 ± 0.24[c]	0.001

Different letters in the row mean statistical difference by Tukey's test ($p < 0.05$).

4 Conclusion

Despite good acceptance, the canned product presented drastic physical, chemical, and sensory changes, mainly related to color, texture, and pH. Possibly a change in the proportion of ingredients to the closest to the traditional dish, tacacá, could reduce these changes and improve product acceptance, despite this, analyses showed that the product is suitable for industrial production.

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References

Amorim, S., Medeiros, R., & Riet-Correa, F. (2006). Intoxication by cyanogenic plants in Brazil. *Ciência Animal*, *16*(161), 17-2617. Retrieved in 2023, July 23, from https://www.cabidigitallibrary.org/doi/full/10.5555/20073193771.

André, S., Vallaeys, T., & Planchon, S. (2017). Spore-forming bacteria responsible for food spoilage. *Research in Microbiology*, *168*(4), 379-387. PMid:27989764. http://dx.doi.org/10.1016/j.resmic.2016.10.003

Association of Official Analytical Chemists – AOAC. (1990). *Official methods of analysis of the Association of Official Analytical Chemists* (Vol. 15). Arlington: AOAC.

Awuah, G. B., Ramaswamy, H. S., & Economides, A. (2007). Thermal processing and quality: Principles and overview. *Chemical Engineering and Processing*, *46*(6), 584-602. http://dx.doi.org/10.1016/j.cep.2006.08.004

Badiani, A., Stipa, S., Bitossi, F., Gatta, P. P., Vignola, G., & Chizzolini, R. (2002). Lipid composition, retention and oxidation in fresh and completely trimmed beef muscles as affected by common culinary practices. *Meat Science*, *60*(2), 169-186. PMid:22063241. http://dx.doi.org/10.1016/S0309-1740(01)00119-X

Barbosa, A. F., de Carvalho, M. G., Smith, R. E., & Sabaa-Srur, A. U. O. (2016). Spilanthol: Occurrence, extraction, chemistry and biological activities. *Revista Brasileira de Farmacognosia*, *26*(1), 128-133. http://dx.doi.org/10.1016/j.bjp.2015.07.024

Bhat, T. H., Chouksey, M. K., Balange, A. K., & Nayak, B. B. (2017). Effect of heat treatment at different stages of rigor on the quality of pacific white shrimp (*Litopenaeus vannamei*). *Journal of Aquatic Food Product Technology*, *26*(7), 770-780. http://dx.doi.org/10.1080/10498850.2017.1288184

Bourne, M. C. (2002). Texture, viscosity, and food. In M. C. Bourne (Ed.), *Food texture and viscosity: Concept and measurement* (2nd ed., pp. 1-32). Cambridge: Academic Press. http://dx.doi.org/10.1016/B978-012119062-0/50001-2

Brasil. Ministério da Agricultura e Pecuária. (2017). Decreto nº 9.013, de 29 de março de 2017, que dispõe sobre o regulamento da inspeção industrial e sanitária de produtos de origem animal, que disciplina afiscalização e a inspeção industrial e sanitária de produtos de origem animal. *Diário Oficial da República Federativa do Brasil*, Brasília.

Brasil. Ministério da Agricultura e Pecuária. (2019a) Instrução normativa nº 23, de 20 de agosto de 2019, Regulamento Técnico que fixa a identidade e os requisitos de qualidade que devem apresentar o camarão fresco, o camarão resfriado, o camarão congelado, o camarão descongelado, o camarão parcialmente cozido e o camarão cozido. *Diário Oficial da República Federativa do Brasil*, Brasília.

Brasil. Ministerio da Saúde. Agência Nacional de Vigilância Sanitária. (2019b). Instrução normativa n° 60, de 23 de dezembro de 2019, que dispõe sobre os padrões microbiológicos para os alimentos e sua aplicação. *Diário Oficial da República Federativa do Brasil*, Brasília.

Brasil. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. (2001). Resolução de Diretoria Colegiada - RDC nº 12, de 02 de janeiro de 2001, que aperfeiçoa das ações de controle sanitário na área de alimentos, visando a proteção à saúde da população e a regulamentação dos padrões microbiológicos para alimentos. *Diário Oficial da República Federativa do Brasil*, Brasília.

Brasil. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. (2020a) Instrução normativa nº 75, de 8 de outubro de 2020 que estabelece os requisitos técnicos para a declaração da rotulagem nutricional dos alimentos embalados. *Diário Oficial da República Federativa do Brasil*, Brasília.

Brasil. Secretaria-Geral. Subchefia para Assuntos Jurídicos (2020b). Decreto nº 9.013, de 29 de março de 2017, que dispõe sobre o regulamento da inspeção industrial e sanitária de produtos de origem animal, que disciplina a fiscalização e a inspeção industrial e sanitária de produtos de origem animal, instituídas pela Lei nº 1.283, de 18 de dezembro de 1950, e pela Lei nº 7.889, de 23 de novembro de 1989. *Diário Oficial da República Federativa do Brasil*, Brasília.

Buchwald, M., & Jencks, W. P. (1968). Optical properties of astaxanthin solutions and aggregates. *Biochemistry*, *7*(2), 834-843. PMid:5644142. http://dx.doi.org/10.1021/bi00842a042

Cheng, L., Sun, D. W., Zhu, Z., & Zhang, Z. (2017). Effects of high pressure freezing (HPF) on denaturation of natural actomyosin extracted from prawn (*Metapenaeus ensis*). *Food Chemistry*, *229*, 252-259. PMid:28372171. http://dx.doi.org/10.1016/j.foodchem.2017.02.048

Chisté, R., & Cohen, K. (2011). Teor de cianeto total e livre nas etapas de processamento do *tucupi. Revista do Instituto Adolfo Lutz*, *70*(1), 41-46. http://dx.doi.org/10.53393/rial.2011.v70.32589

Durance, T. (1997). Improving canned food quality with variable retort temperature processes. *Trends in Food Science & Technology*, *8*(4), 113-118. http://dx.doi.org/10.1016/S0924-2244(97)01010-8

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. (2019). *Mandioca: Agregação de valor e rentabilidade de negócios* (Vol. 1). Brasília: EMBRAPA.

Etemadian, Y., Shabanpour, B., Mahoonak, A. R. S., Shabani, A., & Alami, M. (2011). Cryoprotective effects of polyphosphates on Rutilus frisii kutum fillets during ice storage. *Food Chemistry*, *129*(4), 1544-1551. http://dx.doi.org/10.1016/j.foodchem.2011.06.005

Evancho, G., Tortorelli, S., & Scott, V. (2009). Microbiological spoilage of canned foods. In W. Sperber & M. Doyle (Eds.), *Compendium of the microbiological spoilage of foods and beverages* (pp. 185-221). New York: Springer. http://dx.doi.org/10.1007/978-1-4419-0826-1_7

Food and Agriculture Organization of the United Nations – FAO. (2022). *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation*. Rome: FAO. http://dx.doi.org/10.4060/cc0461en

Furuya, W. M., Hayashi, C., Silva, A. B. M., Santos Júnior, O. O., Souza, N. E., Matsushita, M., & Visentainer, J. V. (2006). Composição centesimal e perfil de ácidos graxos do camarão-d'água-doce. *Revista Brasileira de Zootecnia*, *35*(4), 20-23. https://doi.org/10.1590/S1516-35982006000600001

Gava, A., Silva, C., & Frias, J. (2017). *Tecnologia de alimentos: Principios e aplicações* (7. ed.). São Paulo: Nobel.

Impaprasert, R., Piyarat, S., Sophontanakij, N., Sakulnate, N., Paengkanya, S., Borompichaichartkul, C., & Srzednicki, G. (2017). Rehydration and textural properties of dried konjac noodles: Effect of alkaline and some gelling agents. *Horticulturae*, *3*(1), 20. http://dx.doi.org/10.3390/horticulturae3010020

Instituto Adolfo Lutz – IAL. (2008). *Métodos físico-químicos para análise de alimentos* (7. ed.). São Paulo: IAL.

IBGE - Instituto Brasileiro de Geografia e Estatística. (2022). *IBGE divulga atualização de recortes territoriais legais do país*. Retrieved in 2023, July 23, from https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/34358-ibge-divulga-atualizacao-de-recortes-territoriais-legais-do-pais

Jo, D. M., Park, S. K., Khan, F., Kang, M. G., Lee, J. H., & Kim, Y. M. (2021). An approach to extend the shelf life of ribbonfish fillet using lactic acid bacteria cell-free culture supernatant. *Food Control*, *123*, 107731. http://dx.doi.org/10.1016/j.foodcont.2020.107731

Kamal, M., Rahman, M. M., Yasmin, L., Islam, M. N., Nurullah, M., & Mazid, M. A. (2000). Studies on the post-mortem changes in shrimp and prawn during ice storage: Pt. 2. Biochemical aspects of quality changes. *Bangladesh Journal of Fisheries*, *4*(1), 91-96.

Kim, D. Y., Park, S. W., & Shin, H. S. (2023). Fish freshness indicator for sensing fish quality during storage. *Foods*, *12*(9), 1801. PMid:37174339. http://dx.doi.org/10.3390/foods12091801

Li, X. X., Liu, S., Su, W., Cai, L., & Li, J. (2017). Physical quality changes of precooked Chinese shrimp Fenneropenaeus chinensis and correlation to water distribution and mobility by low- field NMR during frozen storage. *Journal of Food Processing and Preservation*, *41*(6), e13220. https://doi.org/10.1111/jfpp.13220

Linhartová, Z., Krejsa, J., Zajíc, T., Másílko, J., Sampels, S., & Mráz, J. (2018). Proximate and fatty acid composition of 13 important freshwater fish species in central Europe. *Aquaculture International*, *26*(2), 695-711. http://dx.doi.org/10.1007/s10499-018-0243-5

Liu, X., Zhang, C., Liu, S., Gao, J., Cui, S. W., & Xia, W. (2020). Coating white shrimp (*Litopenaeus vannamei*) with edible fully deacetylated chitosan incorporated with clove essential oil and kojic acid improves preservation during cold storage. *International Journal of Biological Macromolecules*, *162*, 1276-1282. PMid:32610051. http://dx.doi.org/10.1016/j.ijbiomac.2020.06.248

Lunestad, B. T., & Rosnes, J. T. (2008). Microbiological quality and safety of farmed fish. In Ø. Lie (Ed.), *Improving farmed fish quality and safety* (pp. 399-427). Sawston: Woodhead Publishing. http://dx.doi.org/10.1533/9781845694920.2.399

Maciel, C. R., & Valenti, W. C. (2009). Biology, fisheries, and aquaculture of the Amazon River prawn *Macrobrachium amazonicum*: a review. *Nauplius*, *17*(2), 61-79.

Majumdar, R. K., Roy, D., & Saha, A. (2017). Textural and sensory characteristics of retort-processed freshwater prawn (*Macrobrachium rosenbergii*) in curry medium. *International Journal of Food Properties*, *20*(11), 2487-2498. http://dx.doi.org/10.1080/10942912.2016.1242139

Manheem, K., Benjakul, S., Kijroongrojana, K., & Visessanguan, W. (2012). The effect of heating conditions on polyphenol oxidase, proteases and melanosis in pre-cooked Pacific white shrimp during refrigerated storage. *Food Chemistry*, *131*(4), 1370-1375. http://dx.doi.org/10.1016/j.foodchem.2011.10.001

Mardas, N., Bellfield, H., Jarvis, A., Navarrete, C. & Comberti, C. (2013). *Amazonia Security Agenda. Strengthening the water, energy, food and health security nexus in the region and beyond. Summary of Findings and Initial Recommendations* (Vol. 1). South Africa: Climate & Development Knowledge Network.

Mei, J., Ma, X., & Xie, J. (2019). Review on natural preservatives for extending fish shelf life. *Foods*, *8*(10), 490. PMid:31614926. http://dx.doi.org/10.3390/foods8100490

Modesto Junior, M. S., & Alves, R. N. B. (2014). *Rentabilidade da produção artesanal de derivados de mandioca: Tucupi e goma* (Boletim de Pesquisa e Desenvolvimento, No. 93, 20 p.). Belém: Embrapa Amazônia Oriental.

Moraes-Riodades, P. M. C., & Valenti, W. C. (2001). Freshwater prawn farming in brazilian amazonia show potential for economic, social development. *The Advocate*, 73-74.

Moraes-Riodades, P. M. C., & Valenti, W. C. (2004). Morphotypes in male Amazon River Prawns, *Macrobrachium amazonicum. Aquaculture (Amsterdam, Netherlands)*, *236*(1-4), 297-307. http://dx.doi.org/10.1016/j.aquaculture.2004.02.015

Neves, D. A., Schmiele, M., Pallone, J. A. L., Orlando, E. A., Risso, E. M., Cunha, E. C. E., & Godoy, H. T. (2019). Chemical and nutritional characterization of raw and hydrothermal processed *jambu* (*Acmella oleracea* (L.) R.K. Jansen). *Food Research International*, *116*, 1144-1152. PMid:30716900. http://dx.doi.org/10.1016/j.foodres.2018.09.060

Niamnuy, C., Devahastin, S., & Soponronnarit, S. (2007). Quality changes of shrimp during boiling in salt solution. *Journal of Food Science*, *72*(5), S289-S297. PMid:17995744. http://dx.doi.org/10.1111/j.1750-3841.2007.00349.x

Nishinari, K. (2020). *Textural characteristics of world foods* (1st ed.). Chichester, UK: John Wiley & Sons. http://dx.doi.org/10.1002/9781119430902.

Nunak, N., & Schleining, G. (2011). Instrumental textural changes in raw white shrimp during iced storage. *Journal of Aquatic Food Product Technology*, *20*(4), 350-360. http://dx.doi.org/10.1080/10498850.2011.575986

Parisenti, J., Beirão, L. H., Mouriño, J. L., Vieira, F. N., Buglione, C. C., & Maraschim, M. (2011). Effect of background color on shrimp pigmentation. *Boletim do Instituto de Pesca*, *37*(2), 177-182.

Robert, P. D., & Velthem, L. V. (2009). A hora do tacacá. *Anthropology of Food*, 1-14. https://doi.org/10.4000/aof.6466

Romão, N., Silva, F. C., Viana, R. N., & Ferraz, A. B. F. (2015). Análise fitoquímica e potencial antioxidante do extrato das flores de *Spilanthes acmella*. *South American Journal of Basic Education, Technical and Technological*, *2*(2), 23-32.

Salfinger, Y., & Tortorello, M. L. (Eds.). (2015). *Compendium of methods for the microbiological examination of foods.* Washington: American Public Health Association. http://dx.doi.org/10.2105/MBEF.0222

Talukder, S., Mendiratta, S. K., Kumar, R. R., Agrawal, R. K., Soni, A., Luke, A., & Chand, S. (2020). Jamun fruit (*Syzgium cumini*) skin extract based indicator for monitoring chicken patties quality during storage. *Journal of Food Science and Technology*, *57*(2), 537-548. PMid:32116363. http://dx.doi.org/10.1007/s13197-019-04084-y

Wang, Y., Wang, X., Lin, C., Yu, M., Chen, S., Guo, J., Rao, P., Miao, S., & Liu, S. (2022). Heat-induced structural changes in fish muscle collagen related to texture development in fish balls: Using eel ball as a study model. *Food Science & Nutrition*, *10*(2), 329-341. PMid:35154671. http://dx.doi.org/10.1002/fsn3.2462

Xu, N., Shi, W., Wang, X., & Wang, Z. (2019). Effect of ice water pretreatment on the quality of Pacific White Shrimps (*Litopenaeus vannamei*). *Food Science & Nutrition*, *7*(2), 645-655. PMid:30847143. http://dx.doi.org/10.1002/fsn3.901

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