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# The production of sauce from minimally processed cabotiá (*cucurbita moschata*) pumpkin by-product

## *Produção de molho a partir de subproduto da abóbora cabotiá minimamente processada*

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**Abstract**

The waste generated by food industries can be used as by-products that enable the development of new foods enriched or not with nutrients, reducing waste generation and adding value to the final product. This work aimed to develop a sauce from a by-product of the minimally processed vegetable industry added with pea protein. After formulating and manufacturing the sauce, the physicochemical, sensory, and microbiological characteristics were evaluated according to current legislation. Cabotiá (*Cucurbita moschata*) pumpkin sauce presented desirable physicochemical characteristics, and microbiological analyses were within limits permitted by law. The acceptance test of the attributes concerning aroma, color, flavor, texture, and overall appearance proved good acceptance for all attributes evaluated, with an acceptability index above 85%. Thus, the sauce made from the residues of the cabotiá pumpkin can be an alternative for the industry, adding value to a by-product normally discarded.

**Keywords:** pumpkin; by-product; sauce.

**Resumo**

O resíduo gerado por indústrias alimentícias pode ser empregado na forma de subprodutos que possibilitam o desenvolvimento de novos alimentos enriquecidos ou não de nutrientes, que reduzam a geração de resíduos e agreguem valor ao produto final. Este trabalho teve como objetivo desenvolver um molho a partir de um subproduto da indústria de vegetais minimamente processados adicionado de proteína de ervilha. A partir da formulação e fabricação do molho, foram avaliadas as características físico-químicas, sensoriais e microbiológicas conforme as legislações vigentes. O molho de abóbora cabotiá cujo nome científico é Cucurbita moschata apresentou características físico-químicas desejáveis. As análises microbiológicas se enquadram nos parâmetros permitidos pela legislação. O teste de aceitação dos atributos aroma, cor, sabor, textura e aspecto global resultou na comprovação de boa aceitação para todos os atributos avaliados, com índice de aceitabilidade superior a 85%. Com isso, o molho elaborado a partir dos resíduos da abóbora cabotiá pode ser uma alternativa para a indústria, agregando valor a um subproduto que é normalmente descartado.

**Palavras-chave:** abóbora; subproduto; molho.

# 1. INTRODUCTION

Food waste throughout the production chain has generated great concern worldwide. Finding a way to avoid these losses is an alternative to feed thousands of families and reduce the impacts caused to the environment due to the inadequate destination of this waste (FAO, 2021). In order to solve this problem, a market trend was observed, which is known as ‘upcycled foods’; it aims to develop quality food using by-products that would otherwise be discarded (UPCYCLED FOOD, 2021).

Thus, using by-products as a basis for food formulations can be an alternative in combating waste, generating a product with high added value and contributing to the reduction of negative impacts caused to the environment. In this sense, it is worth mentioning the cabotiá (*Cucurbita moschata*) pumpkin: a vegetable used to manufacture minimally processed vegetables. Its pulp is the most used, while the peel, seeds, and fibrous part are usually discarded. The discarded parts contain various nutrients that the food industry can use. An alternative use for the fibrous part is the preparation of sauces since the consumption of this type of product has increased in recent years (SOUZA, 2020). In addition, the sauce is a product that may contain in its composition ingredients with significant advantages for the consumer’s health, such as proteins.

The use of plant proteins in food tends to grow due to the search for a healthier and more balanced diet. According to Ahuja and Mamtani (2021), the predilection for vegetarian and vegan diets by consumers will increase the demand of the protein industry, especially pea protein, which is attractive to food industries because it is considered a nutritious food with a relatively low allergenic index (SILVA, 2019).

Numerous authors have reported the use of pea protein aiming at protein enrichment in foods, as is the case of Vieito (2016), who developed a shortbread enriched with pea protein, calcium, and vitamin D. Hartmann, Dias, and Ziegler (2020) produced a Brazil nut vegetable drink with pea protein, while Brito (2010) developed a peanut paste using pea protein, which characterized a high protein product.

Allied with the search for products enriched with protein and the importance of producing foods that aim for the sustainability of the entire production chain, this study aimed to develop a sauce with added protein made with residue from minimally processed vegetable industries.

# 2. MATERIALS AND METHODS

## 2.1 Raw materials

The raw material (by-product) was supplied by a minimally processed industry in southern Brazil. The 80% pea protein was supplied by Gramkow, and the other ingredients were purchased with internal project resources.

## 2.2 Sauce processing

The pumpkin residue, called a by-product from the part that involves the seed and a small fraction of pulp, was collected in the industry and transported in plastic packaging to the Faculdade Senai Chapecó (Chapecó, Santa Catarina State, Brazil). The by-product has a significant number of seeds wrapped in the fibrous part, requiring a manual selection to separate the seeds. The fibrous parts of the by-product were ground in the blender for better homogenization. The crushed raw material was added to a thermomix with water, protein, modified starch, xanthan gum, sugar, salt (sodium chloride — NaCl), yeast extract, antioxidant BHA (butylhydroxy-anisole) monosodium glutamate, potassium sorbate, spices (garlic, onion, pepper, and basil), annatto coloring, and vinegar. The ingredients were then cooked at 100 °C for 45 min. After cooking, the sauce was stored in plastic containers and cooled in the refrigerator. The formulation went through several previous tests to reach an acceptable consistency (Table 1).

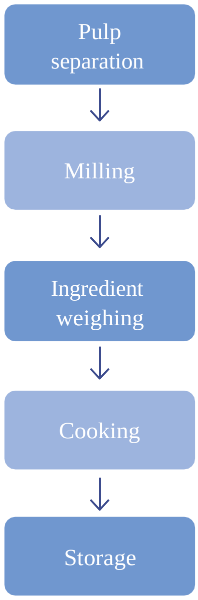
Table 1 - The formulation employed to produce the sauce.

| INGREDIENTS | QUANTITIES (%) |
|---|---|
| By-product | 26.31 |
| Water | 57.64 |
| Modified starch | 0.39 |
| Sunflower oil | 3.05 |
| Salt | 0.83 |
| Xanthan gum | 0.07 |
| Pea protein | 6.77 |
| Apple vinegar | 0.25 |
| Sugar | 0.25 |
| Antioxidant BHA | 0.02 |
| Yeast extract | 0.25 |
| Monosodium glutamate | 0.13 |
| Potassium sorbate | 0.10 |
| Garlic | 0.38 |
| Calabrian pepper | 0.06 |
| Basil | 0.06 |
| Onion | 3.13 |
| Urucum coloring | 0.38 |
| Total | 100 |

Source: The author (2022)

Figure 1 shows the flowchart of the sauce production.

Figure 1 - Flowchart of the manufacture of the by-product-based sauce.




Source: The author (2022)

## 2.3 Physicochemical analysis

This study evaluated the composition and physicochemical parameters of the cabotiá pumpkin by-product and the sauce produced with it, considering that the microbiological and sensory analyses were performed only with the final product to guarantee the analysis of its acceptance.

In order to characterize the by-product and the final product, analyses of ash, moisture, lipids, carbohydrates, proteins, pH, total soluble solids (TSS), and total titratable acidity (TTA) were performed. All analyses were performed in duplicate, and the ash analyses were carbonized and later incinerated in a muffle furnace until white ash was obtained. Humidity was measured by drying directly in an oven at 105 °C until constant weight, following the norms of the Adolfo Lutz Institute

(2008). The protein was determined according to ISO 1871:1975 (general instructions) to determine nitrogen using the Kjeldahl method and lipids by the Soxhlet method of the Adolfo Lutz Institute (IAL, 2008).

The pH measurements were made by the potentiometric method using a pH meter (ASKO©); TSS was determined by refractometry, and the values were expressed in °Brix. The ATT was measured by titration with 0.1N NaOH, both according to the standards of the IAL (2008). Color, water activity (aw), and viscosity analyses were performed only for the final product. The instrumental color analysis was performed using a CM-5 Konica Minolta analyzer, aw was verified using the ISO 18787:2017 method, and viscosity by rotational viscometer equipment (model 0860A21 - Quimis); analyses were carried out at the Senai Institute of Food Technology (LANAL/Chapecó).

## 2.4 Microbiological analysis

To evaluate the microbiological parameters of the sauce, *Salmonella* spp. and *Listeria monocytogenes* analyses and *Bacillus cereus* counts were performed by LANAL/Chapecó while applying ISO 7932:2004 for presumptive *Bacillus cereus* count, for *Listeria monocytogenes* detection the method 2004.02 da Association of Official Analytical Chemists ( AOAC, 2019), and for detection of *Salmonella* spp. (AFNOR 3M 01/16 - 11/16).

The analyses for *Escherichia coli* was performed according to AOAC 991.14 and Coagulase positive *Staphylococci* according to ISO 6888-1 in the SENAI-Chapecó College's microbiology laboratory. For mold and yeast counts, the methodology used followed ISO 21527 and *Enterobacteriaceae according to* AOAC 2003.01. In addition, a total mesophil count was performed according to ISO 4833-1 to evaluate the overall quality of the sauce.

## 2.5 Sensory analysis

The application of sensory analysis is critical in the food industry to evaluate the quality and market acceptance of a given product. Through sensory evaluation, it is possible to propose changes in formulation, evaluate raw materials, processing, the shelf life of products, consumer tests, human perception studies, and correlation with physical, chemical, and instrumental measures (STONE and SIDEL, 2012).

The sensory analysis was applied in individual booths in the sensory analysis laboratory in Senai/Chapecó, where 50 untrained volunteer judges were submitted to the acceptance analysis test using a 9-point hedonic scale. All participants were advised about the study and signed an informed consent form before the tests.

The questionnaire with the questions was applied virtually using a printed QR *Code* that was fixed in the tasting booths. Using their mobile phones, the tasters read the QR Code at the end of the tasting, directing them to an online Google Forms page to answer the applied questions. The questionnaire asked for the names of the tasters, applied 8 multiple choice questions, and a final non-mandatory question for an observation about the sauce if the taster had one.

The first question applied was the age of the tasters, which were separated into 4 different age groups: 18–25 years, 26–32 years, 33–40 years, and 41 years or more. From the third question on, the acceptance test of the sauce begins, in which 6 attributes were determined for the product evaluation in the following sequence applied in the questionnaire: color, aroma, appearance, texture, taste, and overall score for the product.

The following evaluation scores were determined for each attribute: 9 - I liked it very much, 8 - I liked it a lot, 7 - I liked it moderately, 6 - I liked it slightly, 5 - I neither liked it nor disliked it, 4 - I disliked it slightly, 3 - I disliked it moderately, 2 - I disliked it a lot, and 1 - I disliked it very much. The color, aroma, appearance, texture, and flavor results were tabulated in Excel 2013 software. The acceptance index (AI) was calculated using Equation 1, and a good AI was considered as ≥ 70%.

$$AI(\%) = \frac{A}{B} \times 100 \qquad \text{(Eq. 1)}$$

Where:

AI - Acceptance index

A - Mean scored obtained for the product

B - Maximum score in the scale

## 2.6 Packaging and nutritional table

For the cabotiá pumpkin sauce packaging, glass packaging was used to ensure the product's characteristics and to add value. The label layout was developed in the online version of Canva. The ingredients and quantities used in its formulation were listed to calculate the nutritional value of the sauce. From this, its nutritional values were calculated based on the Brazilian Table of Food Composition (2020) (BTCF) and the suppliers' technical data sheets. The final product's total caloric value (TCV) was obtained using conversion factors for carbohydrates and proteins, 4 kcal/g, and for lipids, 9 kcal/g (BRASIL, 2003).

The requirements for preparing the labeling and nutritional table and definition of the amount per serving, home measure, list of ingredients, and the statement of claims were based on Normative Instruction No. 75 (BRASIL, 2020).

# 3. RESULTS AND DISCUSSION

The production of minimally processed cabotiá pumpkin results in the generation of various residues that are generally destined for composting or animal feed. According to information from companies producing this type of product, it is believed that 6.5% of the production losses correspond to the by-product used in this work. In order to know the characteristics of the by-product and evaluate the sauce produced with it, physicochemical, microbiological, and sensory analyses were performed.

## 3.1 Physicochemical characterization of the by-product

The use of a by-product that corresponds to a fraction of the cabotiá pumpkin *in natura* allowed us to compare with the values found in the BTCF (2020), which presents the chemical composition per 100 g for the pulp of cabotiá pumpkin without peel and seed. Given that the by-product is composed of a pulp fraction and a fibrous part that involves the seeds, we sought to evaluate its physicochemical composition along with the BTCF values (Table 2).

Table 2 - Mean results obtained from the physicochemical analysis of the by-product and values found in the BTCF (2020)

| DETERMINATION | BY-PRODUCT | BTCF (2020)*** |
|---|---|---|
| Moisture content (%) | 92.65 ± 0.03 | 88.5 |
| Ash (%) | 0.91 ± 0.02 | 0.84 |
| Lipids (%) | 0.18 ± 0.08 | 0.54 |
| Proteins (%) | 1.60 ± 0.12 | 1.75 |
| Carbohydrates* (%) | 4.66 | 8.36 |
| pH | 6.45 ± 0.07 | - |
| TSS (ºBrix) | 8.90 ± 0.00 | - |
| TTA** | 0.14 ± 0.00 | - |

*Calculated by difference = (100 - moisture content - ash content - lipids - proteins).
**Titratable acidity expressed in g of citric acid/100 g.
***Chemical composition per 100 g.
The values are described by the mean and standard deviation.

Source: BTCF (2020)

It can be observed that only the ash and moisture contents of the by-product were higher than the BTCF (2020), which may be due to the maturity stage of the vegetable

## 3.2 Physicochemical characterization of the sauce

The current legislation does not establish identity and quality standards for sauces nor foresee physicochemical parameters and values for them, so there are no values for comparison. The results obtained for these analyses are presented in Table

Table 3 - Mean results obtained from the physicochemical analysis of the by-product.

| DETERMINATION | SAUCE |
|---|---|
| Moisture content (%) | 84.62 ± 0.15 |
| Ash (%) | 1.65 ± 0.01 |
| Lipids (%) | 0.71 ± 0.04 |
| Proteins (%) | 7.48 ± 0.03 |
| Carbohydrates* (%) | 5.54 |
| pH | 6.40 ± 0.00 |
| TSS (ºBrix) | 7.30 ± 0.00 |
| TTA** | 0.15 ± 0.02 |

*Calculated by difference = (100 - moisture - ashes - lipids - proteins).

**Titratable acidity expressed in g of citric acid/100 g.

The values are described by the mean and standard deviation.

Source: The author (2022)

The growth of microorganisms in food preparation varies according to factors such as the physicochemical composition, moisture, and pH, among others (ADDITIVES & INGREDIENTS, 2016). The moisture content was influenced by the cooking process, which promoted water evaporation during the sauce manufacture, resulting in a value close to 85%. Another nutrient that may have been altered is carbohydrates, where the addition of water may have caused their dissolution.

The results obtained show that the ash content increases with thermal processing, mainly due to the addition of salt in the formulation, which proves its relationship with the ash content considering that NaCl is an inorganic compound and, together with other minerals, influence the final result (RIBEIRO *et al.*, 2014). As for the lipid content, the addition of sunflower oil increased this component. We observed that the protein added to the formulation did not characterize the sauce as a product source of protein, considering that the current legislation recommends that the food must contain at least 10% of the daily reference value in order to receive this assignment (BRASIL, 2020). This indicates that adding pea protein flour (80%) may have increased the protein content of the sauce, although the final product did not obtain the necessary protein contribution.

Silva *et al.* (2014) reported that verifying the pH is crucial for monitoring deterioration caused by microorganisms. The value obtained is unfavorable in maintaining the shelf life of the product because values above 4.5 require other processes or the addition of additives to ensure food quality (BRAGION, 2012), such as the addition of citric acid to promote pH reduction and leaving the food within the safety range (SANTANA, 2013). Nonetheless, the sauce of this study has the preservative potassium sorbate that, in doses below 0.2%, contributes to the preservation of the final product (ADDITIVES & INGREDIENTS, 2019). According to Jose (2018), the correction with citric acid can contribute to increasing the ATT, although this additive was not used and, likewise, the sauce remained within the values classified within the range predicted by Assis (2019) of 0.08–1.95% (moderate to high), representing acceptance by consumers in this range. Giordano (2000) stated that acidity directly influences the product's taste and is also considered an indicator for food preservation.

The average TSS is less than 9 ºBrix for the by-product and the sauce. The low values can be explained by the presence of a large amount of pectin, a type of dietary fiber that, according to Han (2019), is responsible for the low presence of total soluble solids. According to Oliveira *et al.* (2016), the increase in TSS is directly proportional to the increase in viscosity (i.e., when one parameter increases the other also rises). The value obtained with the viscosity analysis was 3300 mPas, considering that this difference may be associated with the temperature at the time of the analysis and the rotation, which in this study was 20 ºC and 30 rpm, respectively. Another point that may have contributed to the increase in viscosity is the presence of xanthan gum in the sauce because the gum is a thickener and directly influences the color and texture of the product, making it pastier and with a more intense color (SILVA *et al.*, 2021).

The color was analyzed to express it objectively through numbers, avoiding confusion and ensuring a product within the specifications. According to the coordinates presented in Table 4, the brightness of the sample is considered lighter because of the scale of the L* coordinate ranges from 0 (black) to 100 (white) (FERREIRA and SPRICIGO, 2017).

Table 4 - Colorimetry analysis of the sauce

| COORDINATES | SAUCE |
|---|---|
| L | 54,78 |
| a | 4,88 |
| b | 18,91 |

*L: Luminosity; a: Red/green coordinate; b: Yellow/blue coordinate.

Source: The author (2022)

According to the color values, we can see that the sauce is closer to yellow because the raw material is the cabotiá pumpkin and used in the formulation of annatto coloring, which tends to be yellow. Water activity analysis is directly linked to product quality and controls and monitors microbial growth, with aw between 0 and 0.20 indicating that the water is strongly bound. In contrast, water activity values in the range of 0.70 to 1.00 determine that most of the water is free, which can be used in chemical and enzymatic reactions and to develop microorganisms. The results obtained in the study were 0.940 using ISO 18787:2017 as a reference, which shows that the sauce has high aw. However, the addition of potassium sorbate is considered effective in controlling microorganisms, being an additive recommended to act in pH ranges from 6.0 to 6.5, which is the case of this study (ADDITIVES & INGREDIENTS, 2019).

## 3.3 Results of the microbiological analyses

Normative Instruction No. 60 (BRASIL, 2019), establishes the microbiological parameters for foods. According to this regulation, the sauce is considered ready-to-eat food produced with heat, and the microbiological parameters are illustrated in Table 5. The results of the microbiological analysis were within limits established by legislation on the standards for the microbiological control of food.

Table 5 - Results of microbiological analysis of the sauce with protein source by-product.

| PARAMETERS | RESULTS (CFU/G) | LIMIT OF NI NO. 60 |
|---|---|---|
| Presumptive enumeration of *Bacillus cereus* | $<1.0x10^{+2}$ | $10^2$ |
| Detection of *Listeria monocytogenes* in 25 g | Absence | $10^2$ |
| Detection of *Salmonella* spp. in 25 g | Absence | Absence |
| Total mold and yeast count | $<1.0x10^{+1}$ | 10 |
| *E. coli* count | $<1.0x10^{+1}$ | 10 |
| Coagulase positive staphylococcal count | $<1.0x10^{+1}$ | $10^2$ |
| Enterobacteria | $<1.0x10^{+1}$ | 10 |

Source: The author (2022)

According to Cano (2014), the presence of microorganisms in quantities above recommended by current legislation indicates contamination occurring in processing, which may be due to failures in good manufacturing practices (GMP) and from microorganisms that have multiplied given inefficient heat treatment, causing physical, chemical, and sensory changes in food. The results of the analyses indicate that the sauce developed did not present results higher than those recommended by the legislation, indicating that the GMPs were performed.

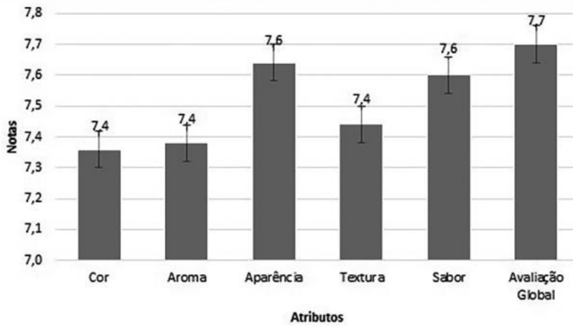
The results obtained in the analysis of *Bacillus cereus* were within the maximum limit established. However, because it is a microorganism with the characteristic to sporulate and presents the soil as a natural reservoir, it makes vegetables, cereals, and condiments more prone to contamination (ARAÚJO et al., 2019; PAIVA, 2016). Soares et al. (2008) conducted environmental studies of the air and countertop surfaces in food services and found the presence of *B. cereus* in the samples collected, reinforcing the importance of correctly sanitizing the food manufacturing environment, emphasizing that contamination can occur not only through the vegetables and cereals employed in the preparation of ready-to-eat foods but also from the handling environment.

## 3.4 Sensory analysis

When asked about the age range of the testers, 42% were between 18 and 25 years old, 36% were between 26 and 32 years old, 20% were between 33 and 40 years old, and 6% were 41 years old or older. Another important point evaluated was the frequency of consuming foods with added protein, and 80% of the testers are assiduous consumers of this product. This is justified by the increasing demand of consumers for healthy foods, especially consumers adherent to other types of diets, such as vegetarians and vegans (MULLER, 2018).

The mean scores given to the global acceptance attributes and standard deviation were expressed in Figure 2, where it can be observed that the highest means were in relation to the global evaluation (7.7) and appearance (7.64), followed by flavor (7.6), texture (7.44), aroma (7.38), and color (7.36). All these values correspond to a degree of acceptance between ‘liked very much’ and ‘liked moderately’ on the hedonic scale used. The acceptance percentage was calculated using Equation 1, resulting in 85.6%.

Figure 2 - Average scores given to the attributes and overall acceptance.




Source: The author (2022)

At the end of the sensory analysis responses, a non-mandatory response observation was proposed to the tasters. It highlighted observations of liking the sauce and about the sauce having a not very pleasant peppery taste.

## 3.5 Packaging presentation and nutrition labeling

According to BRASIL (2003), nutritional labeling is any description intended to inform consumers about the nutritional properties of food. According to the RDC No. 91, packaging for food is the wrapping that is in direct contact with the food intended to contain them, from its manufacture until its delivery to the consumer, in order to protect them from external agents, changes, contamination, and adulteration (BRASIL, 2001). With this, a package was developed for packaging the sauce, illustrated in Figure 03.

Figure 3 - Packaging for packaging and commercializing the final product, front, and back.


Source: From the author (2022)

The development of the nutritional table showed that the cabotiá sauce has important characteristics for consumers are listed in Table 6.

Table 6 - Nutritional table of the cabotiá pumpkin sauce, 60 g serving.

| NUTRITIONAL INFORMATION SERVING SIZE 60 G (3 TABLESPOONS) | | |
|---|---|---|
| AMOUNT PER SERVING | | % DV (*) |
| Energy value | 41.81 kcal or 174.9 kj | 2.1 |
| Carbohydrates | 2.1g | 0.7 |
| Proteins | 3.6g | 7.2 |
| Total fats | 2.0g | 3.1 |
| Saturated fats | 0.2g | 1.1 |
| Trans fats | 0.0g | 0.0 |
| Dietary fiber | 0.6g | 2.3 |
| Sodium | 151.8 mg | 7.6 |

(*) %Daily values based on a 2000 kcal or 8400kJ diet. The daily values may be higher or lower depending on the energy needs.

Source: The author (2022)

Just as the nutritional information must be on the label, the list of ingredients used to make the product must also be available and described according to the amount added, in descending order, from the largest to the smallest amount. The ingredients and additives used to produce the sauce are shown in Table 7.

Table 7 - Description of the ingredients and additives used in the development of the sauce.

| INGREDIENTS: |
|---|
| Water, cabotiá pumpkin, pea protein, onion, sunflower oil, salt, modified starch, garlic, yeast extract, apple cider vinegar, annatto coloring, sugar, flavor enhancer, monosodium glutamate, potassium sorbate preservative, xanthan gum thickener, basil, BHA antioxidant. |

Source: The author (2022)

According to the nutritional table generated from the ingredients used in the formulation of the product, it cannot be considered a source of protein according to Normative Instruction 75 because the percentage of daily value is above 10% of the portion based on a diet of 2000 kcal or 8400kJ.

## 4. CONCLUSION

Our findings allow us to state that the manufacture of the sauce using the by-product of the minimally processed gourd process was efficient because it presented desirable physicochemical characteristics, taking into account that no similar studies were found in the literature. Some parameters such as pH and aw could compromise the shelf life of the product, although the microbiological analyses proved that there was no growth of microorganisms, and the use of preservatives is a key factor for maintaining the characteristics of the final product.

In addition, the cabotiá pumpkin by-product sauce showed good acceptance regarding color, appearance, odor, texture, and flavor, which reflected directly in a good overall impression of the product. With this, the sauce was presented according to the current legislation, being an alternative for the use of the by-product generated in the minimally processed food industry, still known as waste and of low added value, and that can represent great profitability with its production on an industrial scale.

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