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Valorization of cabotiá pumpkin *(Cucurbita maxima)* by-products in the development of instant puree mixes: Nutritional, functional, and sensory evaluation

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Abstract

The aim of this study was to valorize the waste from cabotiá pumpkin (peel and seeds) and use them to develop an instant puree mix, as well as to evaluate its nutritional, functional, and sensory properties. Three formulations were developed: F1: Pumpkin puree with milk, salt, and coloring; F2: Pumpkin puree with pumpkin peel, added with milk, salt, and coloring; and F3: Pumpkin puree with both peel and seeds, added with milk, salt, and coloring. The formulations were characterized in terms of nutritional, physicochemical, structural, and morphological properties, as well as bioactive compounds, bioaccessibility, antioxidant activity using 2,2-diphenyl-1-picrylhydrazyl, 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid, and ferric reducing antioxidant power, and microbiological and sensory analysis. The addition of cabotiá pumpkin waste resulted in increased levels of proteins, lipids, flavonoids, and total phenolic compounds, which contributed to higher antioxidant activity and bioaccessibility, as well as reduced sugar levels in the ready mixes. Microbiological analyses confirmed the food safety of the ready mixes. F1 and F2 received a score of 7.1 in sensory analysis, but F2 had a more pronounced flavor profile, making it more appealing to the tasters and increasing purchase intent. The addition of pumpkin peel flour enhanced consumer acceptance, possibly due to the presence of antioxidant and aromatic compounds. It was found that the ready mixes can be marketed as functional or nutraceutical foods of quick preparation, contributing to the reduction of agro-industrial waste.

Keywords: agro-industrial waste; bioaccessibility; sensory evaluation; nutritional properties.

Practical Application: The development of instant pumpkin puree mixes enriched with cabotiá peel and seeds offers a sustainable and nutritious solution for the food industry. By incorporating agro-industrial waste, the formulations reduce environmental impact while enhancing the nutritional profile of convenience foods.

1 INTRODUCTION

Belonging to the *Cucurbita* spp. genus, pumpkins are a good source of low-calorie carbohydrates, vitamins, minerals, and β-carotene (Kaur et al., 2020). Pumpkins are rich in bioactive compounds, including dietary fiber, proteins, minerals, polyphenols, flavanones, xanthophylls, vitamin C, tocopherols, carotenoids, zeaxanthin, and lutein, as well as high amounts of linoleic, palmitic, stearic, and oleic acids (Kulczyński et al., 2020). Studies suggest that consuming raw pumpkin can provide health benefits and should be encouraged, as this intake is linked to the prevention of cancer and degenerative conditions, primarily attributed to the presence of carotenoids, which have antioxidant properties and can eliminate free radicals (Batool et al., 2022; Hussain et al., 2022). Research indicates that pumpkin can meet the carotenoid needs of children and that its fiber compounds have potential for use as a food product. Due to its high nutrient content and market value, pumpkin is considered a valuable ingredient, widely used in various recipes and products with added value (Barros et al., 2024; İzli et al., 2022).

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However, the consumption of raw cabotiá pumpkin is low due to its difficulty in transportation and storage, as it is an unconventional size compared to other vegetables. Additionally, pumpkin is classified as a seasonal crop, typically harvested within 3–4 months and stored for a duration of 1–3 months (Halim et al., 2024). According to Huang et al. (2019), levels of sugars, starch, and carotenoids tend to increase with the fruit's maturation, in the case of cabotiá pumpkin. Dried pumpkin powder and flakes of dried pumpkin pulp have been used in various studies as a substitute for wheat flour in the formulation of bakery products, beverages, and gluten-free pasta, affecting the texture and sensory analysis of the products (Malkanthi & Hiremath, 2020; Mohammed et al., 2022). Pumpkin powder is a practical option as a β-carotene substitute in foods. In addition to imparting aroma, color, and moisture, it can be used in the creation of various ready-to-eat meals (Yok et al., 2016).

The use of plant by-products, or parts of the plant that are not consumed and thus wasted, is a way to improve the nutritional status of populations, as these plant residues are often rich in nutrients and bioactive compounds (Ali et al., 2022; Castillejo & Martínez-Zaroma, 2024). Among these residues, the seeds and peels of cabotiá pumpkin (*Cucurbita maxima*) are an excellent nutritional source, being rich in bioactive compounds and substances used as pharmaceuticals, such as carotenoids (β-carotene, lycopene, lutein, and α-carotene) (Stajčić et al., 2022; Suwannapong et al., 2023). According to Chari et al. (2018), the seeds, pulp, and peel of the pumpkin contain bioactive substances with various therapeutic properties. These include antibacterial, antidiabetic, antiviral, antifungal, anticancer, anti-inflammatory, cardioprotective, and antioxidant activities, as well as promoting wound healing and improving male fertility. These by-products can be used in food manufacturing and contribute to sustainability, an aspect that is increasingly gaining prominence in the food industry (Van Tai et al., 2023).

There is an increasing trend among consumers toward seeking and using practical, easy-to-prepare foods that, in addition to having nutritional quality, offer well-being and health benefits (Pinto et al., 2021). The development of new food products has become an increasingly valued specialty within the food industry, as new products are what ensure companies' continued presence in the market (Guiné et al., 2020). By combining the need for new food product development with functional aspects and the introduction of a sustainability concept, our work is directed. Ready-to-mix food preparations have been gaining more space on supermarket shelves each year, and consequently, on consumers' tables (Vermeulen et al., 2020). Thus, this study aims to investigate the potential of cabotiá pumpkin residues in formulating instant powder mixes for preparing puree. The research seeks to evaluate the nutritional, functional, and sensory properties of the developed mixes, promoting a sustainable alternative for utilizing food waste and contributing to innovation in the food sector.

1.1 Relevance of the work

This study is highly relevant as it promotes sustainability and the reuse of agro-industrial waste by transforming cabotiá pumpkin peel and seeds into a functional instant puree mix. The research highlights nutritional gains, such as increased proteins, lipids, and bioactive compounds, along with greater antioxidant activity and microbiological safety. The formulation with peel (F2) showed better sensory acceptance, revealing its potential for innovation in healthy and practical foods. The development of these products contributes to the circular economy, reduces waste, and meets the growing demand for nutraceutical foods, reinforcing their scientific, environmental, and commercial importance.

2 MATERIAL AND METHODS

2.1 Material

The cabotiá pumpkin (*Cucurbita maxima*) was purchased at a public market in the city of João Pessoa-PB, totaling 30 kg of fruit. Gallic acid, hydrochloric acid, Folin-Ciocalteu reagent, sodium carbonate, sodium bicarbonate, sodium hydroxide, 2,6-dichlorophenol indophenol (DCFI), 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), ferric-reducing antioxidant power (FRAP), sulfuric acid, 3,5-dinitrosalicylic acid, methanol, ethanol, and Hexene (Merck, Germany). Sterile peptone water, lauryl sulfate tryptose broth, brilliant green bile broth, Escherichia coli broth, Plate Count Agar, Eosin Methylene Blue Agar, Dicloran Rose Bengal Chloramphenicol, selenite cystine broth, Muller–Kauffman novobiocin tetrathionate broth, Salmonella Shigella agar, and Hektoen agar sourced from KASVI, Brazil.

2.2 Preparation of instant pumpkin puree formulations

The instant pumpkin puree formulations were created using pumpkin as the main ingredient. Initially, the pumpkins were subjected to a sanitation step involving washing and soaking in a sodium hypochlorite solution at a concentration of 100 ppm. The pumpkins were then cut into sections, and the pulp, peel, and seeds were separated manually. The pulp underwent pre-cooking by immersion in boiling water at 100 °C for 25 min in a thermostatic bath (QUIMIS, model Q226). After this heat treatment, the softened pulp was mashed and then passed through a 60-mesh sieve to produce a smooth and uniform paste.

Following this, each pumpkin component (pulp, peel, and seeds) was dehydrated in an air circulation oven (SOLIDSTEEL, model SSDs) at a maintained temperature of 50 °C with an airflow speed of 1 m/s. The drying process continued until each component reached a stable weight. Once dried, the components were individually ground into a fine powder and passed through a 20-mesh sieve to ensure uniform particle size.

Instant formulations were then assembled with varying proportions of the dried pumpkin fractions. Each formulation included pulp flour, ranging from 68 to 73% of the total mixture. In some versions, peel flour was incorporated at either 3 or 4%, replacing part of the pulp flour. A specific formulation also included 2% seed flour. Additionally, whole milk powder (25%) was added, along with salt (1.5%) and a natural annatto colorant (0.5%), which was prepared as per the method described by Franca et al. (2024).

The final mixture was blended for 3 min using a mixer (Philips Wallita, model RI2622) to ensure even distribution of ingredients. The formulations were packaged in laminated bags and stored at room temperature (25 °C). A summary of the composition of each instant pumpkin puree formulation can be found in Table 1.

2.3 Determination of nutritional composition

The nutritional composition of the formulations was assessed following the Association of Official Analytical Chemists (AOAC, 2005). The moisture content was assessed following method 934.06, ash content using method 940.26, total protein via method 920.152, and lipids through method 948.22. The carbohydrate content was determined by difference. The results were expressed as grams of moisture, ash, protein, and lipids per 100 g of the sample.

2.4 Physical and physicochemical parameters

2.4.1 Water activity

The water activity was determined using the Aqualab model 3TE (Decagon, WA, USA) at room temperature.

2.4.2 Hygroscopicity and solubility

Hygroscopicity was evaluated using the method described by Cai and Corke (2000). Approximately 1 g of each powder sample was placed in a desiccator containing saturated NaCl to maintain a relative humidity of 75 ± 1% at 25 °C. After seven days, the water absorbed by the samples was quantified and expressed as grams per 100 g of dry sample. Solubility was determined following the procedure outlined by Cano-Chauca et al. (2005). A 0.5 g powder sample was dispersed in 150 mL of distilled water and stirred vigorously for 5 min using a magnetic stirrer. The mixture was then centrifuged at 3500 rpm for 10 min. Subsequently, a 12.5 mL aliquot of the supernatant was dried at 105 °C until reaching a constant weight, and solubility was calculated based on the difference in weight.

2.4.3 Total and reducing sugars

The content of total soluble sugars and reducing sugars was quantified using the Lane-Eynon reaction, as per Instituto Adolfo Lutz (2008).

Table 1. Ingredients used to develop each ready-mix formulation.

Ingredients (%)	F1	F2	F3
Pulp powder	73	69	68
Peel flour	-	4	3
Seed flour	-	-	2
Whole milk	25	25	25
Salt	1.5	1.5	1.5
Annatto dye	0.5	0.5	0.5

F1: Pulp with milk, salt, and coloring; F2: Pulp + pumpkin peel with added milk, salt, and coloring; F3: Pulp + peel + pumpkin seed with added milk, salt, and coloring.

2.5 Scanning electron micrographs

The samples were prepared by mounting them on adhesive tape and coating them with a thin layer of gold particles. Micrographs of the formulations were captured using a scanning electron microscope (Shimadzu, SSX-550) operated at 15 kV and a magnification of 500x, following the procedure outlined by Almeida et al. (2022).

2.6 X-ray diffraction

The diffractograms were recorded using a Shimadzu X-ray diffraction (XRD) diffractometer, model XRD-7000, operating at 30 mA and 40 kV. Samples were scanned using Cu-Kα radiation (λ = 0.15444 nm) over a range of 5°–60° at a scanning speed of 5°/min. The relative crystallinity was determined by calculating the ratio of the crystalline area to the total area (crystalline plus amorphous), following the method described by Wu et al. (2021).

2.7 Analysis of bioactive compounds

2.7.1 Total carotenoids

The samples (1 g) were placed in approximately 18 x 130 mm test tubes, and 10 mL of an acetone-hexane mixture (4:6) was added. The supernatant was used to measure the absorbance using a spectrophotometer (UV190, Bel Photonics UV-M51) at wavelengths of 453, 505, 645, and 663 nm (Nagata & Yamashita, 1992).

2.7.2 Flavonoids

Flavonoid quantification was performed following the methodology described by Francis (1982). An amount of 1 g of the sample (powder or mixture) was placed in Falcon tubes, and 10 mL of ethanol-HCL solution was added. The samples were incubated at 4 °C for 24 h in a refrigerator (ELECTROLUX, RE31) and then centrifuged (DAIKI, 80-2BDM) at 3000 rpm for 10 min at 10 °C. After centrifugation, an aliquot was removed, and its absorbance was measured at 374 nm using a spectrophotometer (UV190, Bel Photonics UV-M51).

2.7.3 Vitamin C

The analysis of ascorbic acid was performed using spectrophotometry (Pearson, 1976), which involves the reaction of ascorbic acid with DCFI and measuring the absorbance at 520 nm using a spectrophotometer (UV190, Bel Photonics UV-M51), according to the procedure described by Oliveira (2019).

2.7.4 Total phenolic compounds (TPC)

The aqueous extract was prepared using a ratio of 1:10 of powder to water. Total phenolic content was determined using the Folin-Ciocalteu spectrophotometric method at 750 nm, utilizing a spectrophotometer (UV190, Bel Photonics UV-M51). Results were expressed as mg of gallic acid equivalents (GAE) per 100 g. A standard curve was generated with gallic acid at concentrations ranging from 0.005 to 0.175 mg/mL under the same conditions as the samples, achieving an R^2 value of 0.999 (Singleton & Rossi, 1965).

2.8 Antioxidant activities

The aqueous extracts of the samples were prepared as described in section 2.9.4 for TPC determination. The antioxidant activity was assessed using the ABTS (2,2'-azobis-3-ethylbenzothiazoline-6-sulfonic acid) method, following the procedure outlined by Rufino et al. (2007a). A 30 µL aliquot of the extract was combined with 3.0 mL of ABTS radical solution, and after 6 min, the absorbance was measured at 734 nm. Results were expressed in µM Trolox equivalents per gram of sample, with Trolox (purity ≥ 97%, Sigma-Aldrich, St. Louis, MO, USA) as the standard.

The DPPH (1,1-diphenyl-2-picrylhydrazyl) method for measuring antioxidant activity was carried out as per Rufino et al. (2007b). A 0.1 mL aliquot of the extract was mixed with 3.9 mL of a 0.06 mM DPPH solution, and the absorbance was recorded at 515 nm every min until it stabilized. Results were expressed in µM Trolox equivalents per gram of sample, with Trolox (purity ≥ 97%, Sigma-Aldrich, St. Louis, MO, USA) as the standard.

For the FRAP assay, the procedure described by Rufino et al. (2006) was followed. A 90 µL aliquot of the extract was mixed with 270 µL of deionized water and 2.7 mL of FRAP reagent. The mixture was shaken for 2 min and then incubated in a water bath (QUIMIS, Q226) at 37 °C for 30 min. Absorbance was measured at 595 nm, with the FRAP reagent used as a blank. Results were expressed in µM of ferrous sulfate (FeSO4) equivalents per gram of sample.

2.9 Simulated *in vitro* gastrointestinal digestion

The formulations were assessed through an in vitro gastrointestinal digestion simulation, based on adaptations of methods from Gawlik-Dziki et al. (2009) and Santos et al. (2023). A 1 g sample of each formulation was subjected to a synthetic oral phase, where an amylase solution (75 U/mL) at pH 7 was used. This phase was conducted at 37 °C for 2 min in a shaking water bath (QUIMIS, model Q226) set at 180 rpm. Subsequently, a pepsin solution (2,000 U/mL) adjusted to pH 3 was added to simulate the gastric phase, and the mixture was incubated for 2 min. For the duodenal phase, a mixture of bile salts (4.4 mg/mL) and pancreatin (100 U/mL) was introduced, with the pH adjusted to 6.5–7, and the reaction continued for 2 more minutes, resulting in a total digestion time of 6 min. At the end of the digestion process, the enzymatic activity was halted by placing the samples on ice. The TPC was then measured after both the gastric and intestinal phases, and the bioaccessibility of phenolic compounds was calculated using Equation 1.

$$\text{Bioacessibility} = \frac{B}{A}\, x\ 100\% \tag{1}$$

Where: A represents TPC before in vitro gastric digestion and B represents TPC after the intestinal phase.

2.10 Microbiological analysis

The total and thermotolerant coliform count, Escherichia coli, mesophilic aerobic microorganism count, and Salmonella analysis of the powdered formulations were conducted to evaluate their quality, safety, and stability over a 30-day period. These analyses followed the standardized microbiological methods outlined by the American Public Health Association (Salfinger & Tortorello, 2015), as detailed in Supplementary Material S1. For the tests, 25 g of each powdered formulation were mixed with 225 mL of sterile peptone water (0.1% w/v) and homogenized. A series of decimal dilutions were then prepared using sterile peptone water for further microbiological testing.

2.11 Sensory analysis

The sensory evaluation of this study was approved by the Ethics Committee of the Federal University of Paraíba (Ethics Presentation Certificates (CAAE), No. 0449321.7.0000.5188). To assess the sensory characteristics of instant mixtures, a preference and overall acceptance test was conducted with 80 diverse participants. The participants evaluated the appearance, aroma, texture, and taste of the puree samples on a 9-point hedonic scale, where 1 represented "extremely disliked" and 9 represented "extremely liked." The puree samples were prepared and kept warm throughout the evaluation to simulate domestic consumption conditions and ensure product fidelity. Each participant evaluated the samples individually and only once. Statistical analysis was performed using two-way analysis of variance (ANOVA) without repetition to determine significant differences between the samples. Tukey's test and Dunnett's test were used for post-hoc comparisons.

2.12 Statistical analysis

The analyses were conducted in triplicate, and the results are presented as mean values ± standard deviation. Statistical analysis was carried out using one-way ANOVA, followed by Tukey's test, with significance set at $p < .05$. Data were analyzed using the Assistat software (available for free at: http://www.assistat.com).

3 RESULTS AND DISCUSSION

3.1 Physicochemical analyses of the ready-to-eat mixtures

The physicochemical characteristics of the ready-to-eat cabotiá mixtures are presented in Table 2. Moisture determination is an important parameter since the water content in food influences both storage and commercialization (Raschen et al., 2014). To increase product shelf life and prevent clumping, mold, and insects, the moisture content of the formulations should be below 14% (Wachirasiri et al., 2009). According to Akter et al. (2023), the moisture content for powdered products is around 7.61%, similar to the values found for the ready-to-eat mixtures derived from pumpkin residues. Kar et al. (2023) reported that moisture values of 3.23% for pumpkin seeds and 6.34% for ash content. The ash content of the formulations ranged from 5.88 to 6.10% (Table 2), with the addition of peel and seed residues significantly increasing this parameter ($p < .05$).

The results for water activity were < 0.6, indicating that the cabotiá ready-to-eat mixtures demonstrated excellent stability during storage, thus preventing the growth of microorganisms such as fungi, bacteria, and yeasts, resulting in a long shelf life (Ohanenye et al., 2020). The protein content ranged from 11.22

Table 2. Physicochemical characterization of ready-made mixtures obtained from the use of cabotiá pumpkin waste.

Parameters	F1	F2	F3
Moisture (%)	7.77 ± 0.36^{C}	7.94 ± 0.40^{B}	8.73 ± 0.06^{A}
Ash (%)	5.88 ± 0.25^{B}	6.10 ± 0.18^{A}	5.88 ± 0.61^{B}
Water activity	0.201 ± 0.11^{A}	0.216 ± 0.15^{A}	0.212 ± 0.14^{A}
Proteins (%)	11.25 ± 0.18^{B}	11.22 ± 0.17^{B}	11.78 ± 0.19^{A}
Lipids (%)	10.47 ± 0.40^{A}	9.27 ± 0.27^{B}	10.70 ± 0.69^{A}
Hygroscopicity (%)	12.09 ± 0.01^{B}	12.06 ± 0.02^{BC}	12.17 ± 0.03^{A}
Solubility	96.48 ± 0.14^{A}	96.69 ± 0.23^{A}	96.51 ± 0.09^{A}
Vitamin C (mg/ 100g ascorbic acid)	23.67 ± 1.79^{AB}	24.70 ± 1.80^{A}	21.20 ± 1.60^{B}
Total soluble sugar (mg 100g^{-1} ascorbic acid)	23.51 ± 0.84^{A}	20.31 ± 0.99^{B}	20.22 ± 0.57^{B}
Reducing sugars (%)	11.01 ± 0.09^{B}	11.36 ± 0.09^{B}	13.02 ± 0.14^{A}

Data were means ± standard deviation. Equal superscript letters in the same column do not differ significantly at 0.05 probability level by the Tukey's test. F1: Pulp with milk, salt, and coloring; F2: Pulp + pumpkin peel with added milk, salt, and coloring; F3: Pulp + peel + pumpkin seeds with added milk, salt, and coloring.

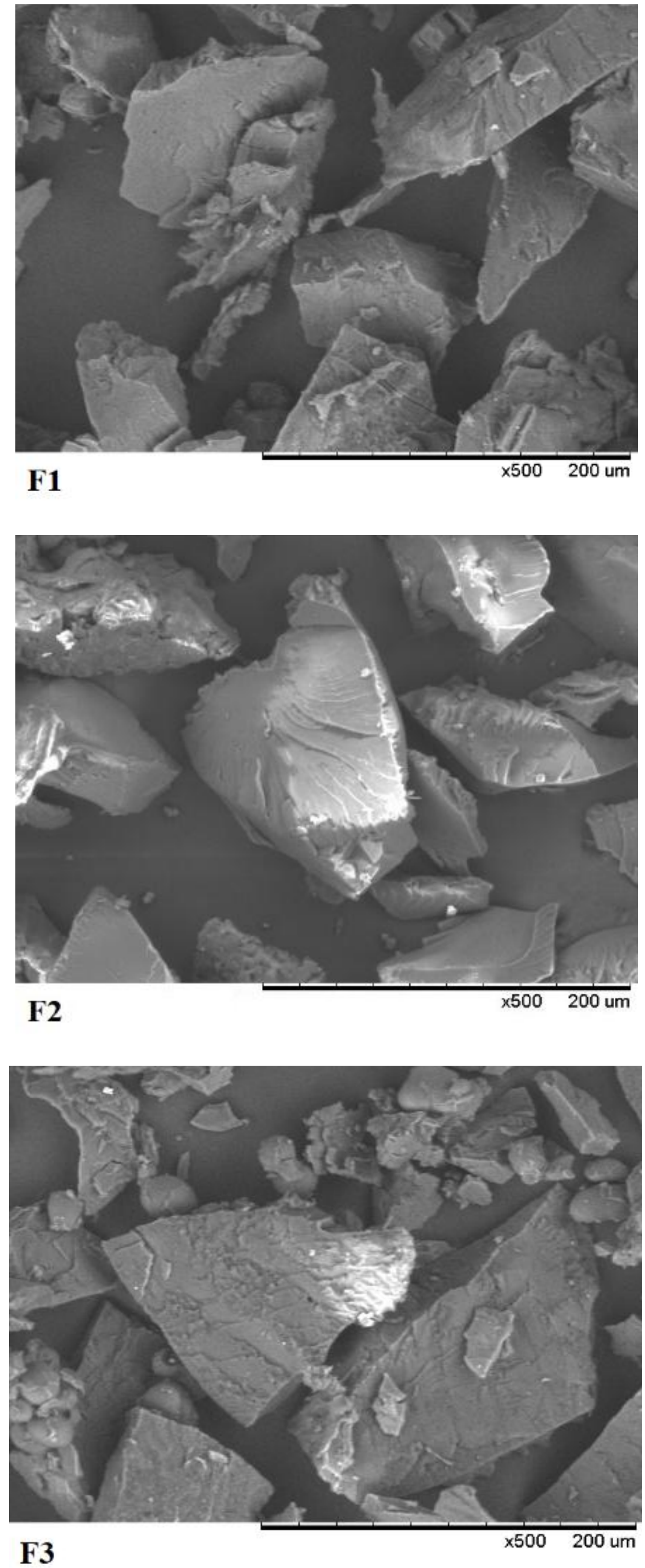
to 11.78%, while the lipid content varied from 9.27 to 10.70%, close to the findings of Halim et al. (2024), who reported 10.18 to 14.6% for protein and 1.4 to 12.8% for lipids in juice made from pumpkin residues. It was noticeable that the addition of pumpkin peel and seeds to the ready-to-eat mixtures increased the protein and lipid content of the formulations.

Hygroscopicity is closely linked to the moisture content of the formulations. A moisture content below 10% is classified as non-hygroscopic; between 10.1 and 15% as slightly hygroscopic; between 15.1 and 20% as hygroscopic; between 20.1 and 25% as very hygroscopic; and above 25% as extremely hygroscopic (Akther et al., 2020). The ready-to-eat mixtures were classified as slightly hygroscopic, as they had values below 15%. Solubility ranged from 96.48 to 96.69%, which is an important indicator of fiber functionality, particularly in terms of viscosity stability. The ready-to-eat mixtures showed high solubility values with no significant difference, indicating a good parameter for the final product.

The vitamin C content of the cabotiá ready-to-eat mixtures (21.20–24.70 mg/100g) aligns with the findings of Malkanthi and Hiremath (2020), who reported that pumpkin pulp contains 6.19–54.6 mg/100g of vitamin C, with lower values when in the powder form. The total and reducing sugar content values ranged from 20.22 to 23.51% and 11.01 to 13.02%, respectively. Guiné et al. (2011) reported total sugar values of 17.09–18.66% and reducing sugar values of 14.62–15.83%, varying with the drying temperature of pumpkin flours.

3.2 Morphology of instant mixtures

The images are from the scanning electron microscopy analysis, showing surface aspects at 500x magnification for the formulations (Figure 1). The mixtures present surface



F1: Pulp with milk, salt, and dye; F2: Pulp + pumpkin peel with added milk, salt, and dye; F3: Pulp + peel + pumpkin seed with added milk, salt, and dye.

Figure 1. Morphological aspects of the ready mixtures obtained from the waste of the cabotiá squash.

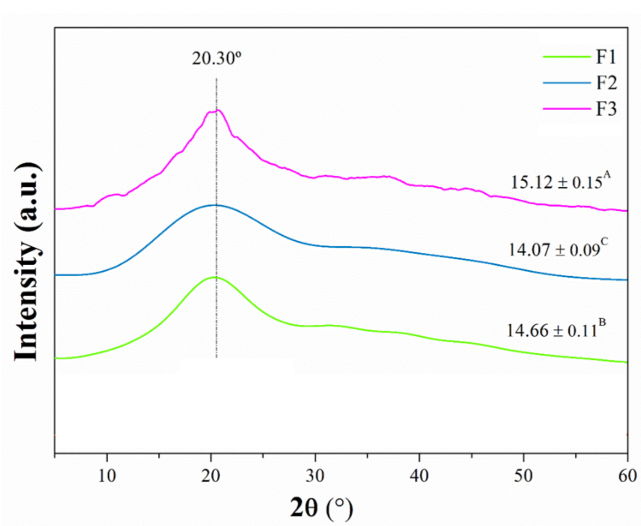
irregularities, more pronounced roughness, and polyhedral geometry. When pumpkin peel (F2) is added to utilize this residue in the ready mix, greater homogeneity in particle size and surface appearance is observed. The addition of pumpkin seeds (F3) retains the initial geometry, but there is a greater number of particles of smaller diameter.

3.3 Structural analysis by X-ray diffraction

Figure 2 shows the diffractograms with their respective crystallinity peaks. For all samples, the only peak was found near 20.30º, indicating that pumpkin pulp has an amorphous nature, and even with the addition of peel and seed residues, this profile remains unchanged. Moraes et al. (2022) found peaks close to 21º for germinated pumpkin flour. According to Siwatch et al. (2017), the amorphous region has low intensity, which is important for certain applications, such as in hydrogel production, due to the higher water absorption. More defined peaks indicate a higher degree of crystallinity. In this case, F3 showed a value of 15.12%, which was higher than the other formulations, suggesting that the addition of pumpkin seeds along with the other ingredients positively influenced this parameter.

3.4 Bioactive compounds and antioxidant activity

Table 3 shows the total carotenoid, flavonoid, TPC concentrations, and antioxidant activity (ABTS, DPPH, and FRAP) of all the instant mixtures of cabotiá pumpkin puree. All the bioactive compounds analyzed showed significant variations among the prepared formulations ($p < .05$). The total carotenoids had relatively low concentrations, ranging from 0.493 (F3) to 0.661 mg/100g (F1). It was observed that the puree formulated exclusively with pumpkin pulp powder (F1) had a higher concentration of carotenoids compared to the formulations that included seed and peel powder (F2, F3). This difference can be explained by the fact that cabotiá pumpkin pulp is known to contain considerable amounts of carotenoids, while the seeds and peel have relatively lower concentrations of this compound (Hussain et al., 2021).



F1: Pulp with milk, salt, and dye; F2: Pulp + pumpkin peel with added milk, salt, and dye; F3: Pulp + peel + pumpkin seed with added milk, salt, and dye.

Figure 2. Analysis of the crystalline peaks of the ready mixes produced with pumpkin waste.

Therefore, the predominant presence of pulp in F1 contributes to its higher total carotenoid concentration.

On the other hand, the flavonoid and TPC content showed a notable increase in the formulations that included cabotiá seeds and peel, with F3 standing out, containing 32.83 mg/100g of flavonoids and 117.81 mg GAE/100g of TPC. This increase can be attributed to the presence of peel and seeds in the F3 formulation, which are known for their high concentrations of flavonoids and phenolic compounds. Although cabotiá pumpkin pulp is rich in various bioactive compounds, it does not have the same concentration of flavonoids and phenolic compounds found in the peel and seeds (Kulczyński & Gramza-Michałowska, 2019). Thus, the inclusion of these parts of the vegetable seems to enhance the total flavonoid and TPC content in the formulation. The synergistic combination of pulp, peel, and seeds in F3 may have contributed to a potentiating effect on the concentration of these bioactive compounds, highlighting the importance of fully utilizing the vegetable to maximize the antioxidant profile of instant mixtures.

The antioxidant activity of the instant pumpkin puree mixtures showed significantly higher values for F3 ($p < .05$), regardless of the determination method, with increases of 2.45 times for ABTS, 1.75 times for DPPH, and 1.55 times for FRAP compared to F1. These results indicate that the F3 formulation has superior antioxidant capacity, which can be attributed to its higher TPC content. Phenolic compounds are widely recognized

Table 3. Bioactive compounds, total phenolic compounds, antioxidant activities, and bioaccessibility of ready-made mixtures from cabotiá squash.

Parameters	F1	F2	F3
Total carotenoids (mg/100g)	0.661 ± 0.122^{A}	0.595 ± 0.071^{B}	0.493 ± 0.123^{C}
Flavonoids (mg/100g)	22.02 ± 2.26^{B}	31.00 ± 3.53^{A}	32.83 ± 3.40^{A}
TPC (mg GAE/100g)	72.19 ± 2.04^{C}	85.06 ± 1.37^{B}	117.81 ± 1.88^{A}
ABTS (μM Trolox/g)	3.56 ± 0.22^{C}	6.81 ± 0.34^{B}	8.75 ± 0.49^{A}
DPPH (μM Trolox/g)	7.11 ± 0.19^{C}	9.73 ± 0.92^{B}	12.45 ± 0.54^{A}
FRAP (μM $FeSO_4$/g)	5.92 ± 0.26^{C}	8.44 ± 0.12^{B}	9.21 ± 0.41^{A}
***In vitro* digestibility**			
Phase 1 (mg GAE/100g)	32.87 ± 1.19^{A}	49.06 ± 1.27^{A}	82.18 ± 0.88^{A}
Phase 2 (mg GAE/100g)	9.96 ± 0.29^{A}	17.52 ± 0.37^{A}	32.13 ± 1.03^{A}
Bioaccessibility (%)	13.80	20.60	27.28

Data were means ± standard deviation. Equal superscript capital letters in the same line do not differ significantly at 0.05 probability level by the Tukey's test. F1: Pulp with milk, salt, and coloring; F2: Pulp + pumpkin peel added with milk, salt, and coloring; F3: Pulp + peel + pumpkin seed added with milk, salt, and coloring. ABTS: 2,2'-azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid; DPPH: 2,2-diphenyl-1-picrylhydrazyl; FRAP: ferric reducing antioxidant power; TPC: total phenolic compounds. Phase 1: after the gastric phase; Phase 2: after the intestinal phase.

for their significant contribution to the antioxidant activity of vegetables. According to Singh et al. (2022), total phenolics are responsible for 58–82% of the antioxidant activity observed in many vegetables. The F3 formulation, which contains a combination of pulp, peel, and seeds, presents high levels of TPC (117.81 mg GAE/100g). Our results indicate that the higher TPC content may explain the observed increase in the antioxidant activity, as these compounds have the ability to neutralize free radicals and inhibit oxidation, improving antioxidant efficiency.

3.5 Bioaccessibility

When comparing the TPC content at identical stages of digestion for the instant pumpkin puree mixtures, a general trend of reduction was observed between Phase 1 (after the gastric phase) and Phase 2 (after the intestinal phase) (Table 3) ($p < .05$). This reduction can be attributed to several interrelated factors. As described by Santos et al. (2024), enzymatic degradation is one of the main factors responsible for the reduction of TPC during digestion. Gastric and intestinal enzymes can degrade phenolic compounds, reducing their concentration in the intestinal phase. Additionally, interactions with other substances present in the intestine, such as bile salts and pancreatic enzymes, can affect the stability and availability of phenolic compounds. Another important factor is the impact of the gastrointestinal environment, especially the pH changes from the gastric phase to the intestinal phase. Wang et al. (2024) highlighted that pH variation can significantly influence the solubility and stability of phenolic compounds. The acidic environment of the stomach may cause initial solubilization and possible degradation of phenolic compounds, while the higher pH in the intestine may further alter the form and availability of these compounds (Li et al., 2023).

The bioaccessibility values, which ranged from 13.80 (F1) to 27.28% (F3), reflect the efficiency with which phenolic compounds are released and absorbed in the gastrointestinal tract (Santos et al., 2023). Bioaccessibility is closely associated with the interactions between the food matrix and the conditions within the gastrointestinal tract. Formulations containing components such as pulp, peel, and seeds of the cabotiá pumpkin (as in F3) may provide a more favorable matrix for the release and absorption of phenolic compounds, resulting in greater bioaccessibility. Additionally, we believe that the matrix formed by the peel and seed components may act as a physical barrier that further protects phenolic compounds from excessive enzymatic degradation during digestion, resulting in greater bioaccessibility, supporting evidence from previous observations (Ribas-Agustí et al., 2018). Overall, the results of this study showed that the instant mixtures prepared with the addition of pumpkin pulp, seed, and peel powder successfully enhanced the bioactive fractions and increased their bioaccessibility. This is an important factor to consider in the development of instant foods with functional potential.

3.6 Microbiological analysis

The microbiological analysis of the mixtures demonstrated compliance with quality and food safety requirements, indicating that these products are suitable for consumption. The analysis focused on key microbial parameters, including the presence of pathogenic microorganisms and the overall microbial load, which are critical in assessing food safety. The results presented in Table 4 showed that the microorganism levels in the pumpkin puree mixtures were within the acceptable limits established by food safety standards (Codex Alimentarius). Specifically, the absence of harmful pathogens such as *Salmonella* and *E. coli* was confirmed, which is essential to ensure the safety of the products developed in this study. Additionally, the total microorganism count was low (< 10 CFU/g), indicating effective processing and storage conditions that inhibit microbial growth.

3.7 Sensory analysis

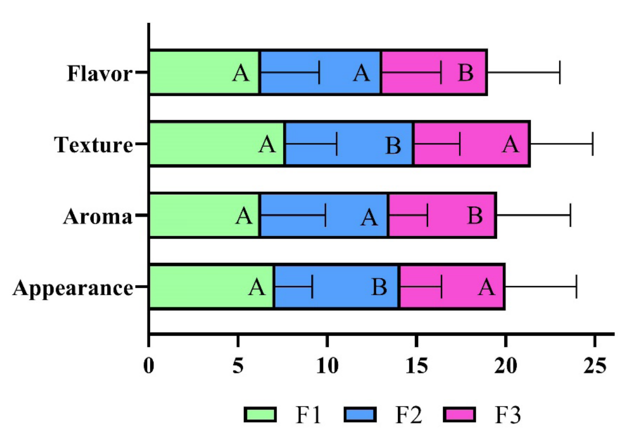
The sensory evaluation results of the pumpkin puree formulations (F1, F2, and F3) provided significant insights into consumer preferences and acceptance of this type of product. The formulations differed based on their composition: F1 contained pumpkin pulp with added milk and salt; F2 included 4% pumpkin peel flour along with milk, salt, and pumpkin pulp; and F3 contained milk, salt, pumpkin pulp, 3% pumpkin peel flour, and 2% seed flour.

Figure 3 shows the average scores for appearance, aroma, texture, and flavor. The results indicate that F1 achieved an average score of 7.1, categorizing it as "moderately liked," while F2 followed closely with a similar score of 7.0, also within the "moderately liked" range. In contrast, F3 received a lower

Table 4. Microbiological analyses of instant pumpkin puree mixes.

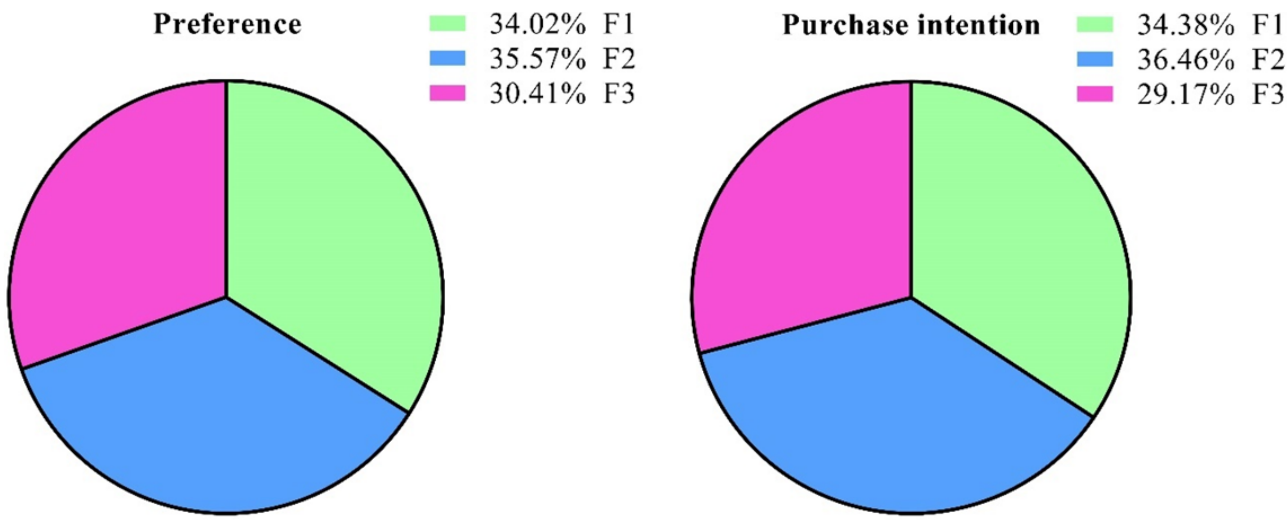
Parameters	F1	F2	F3
Total coliforms (NMP/g)	15	15	15
Thermotolerant coliforms	0	0	0
Mold and yeast	< 10	< 10	< 10
E. coli	-	-	-
Salmonella	-	-	-

F1: Pulp with milk, salt, and coloring; F2: Pulp + pumpkin peel with added milk, salt, and coloring; F3: Pulp + peel + pumpkin seed with added milk, salt, and coloring.



F1: Pulp with milk, salt, and coloring; F2: Pulp + pumpkin peel added with milk, salt, and coloring; F3: Pulp + peel + pumpkin seed added with milk, salt, and coloring.

Figure 3. Evaluation of the appearance, aroma, texture, and flavor of instant pumpkin puree mixtures.



F1: Pulp with milk, salt, and coloring; F2: Pulp + pumpkin peel added with milk, salt, and coloring; F3: Pulp + peel + pumpkin seed added with milk, salt, and coloring.
Figure 4. Result of the preference and purchase intention test for the three instant pumpkin puree mix formulations.

average score of 5.9, which fell into the neutral category of "neither liked nor disliked." The statistical analysis using two-way ANOVA revealed a significant difference in acceptance, particularly for flavor, between F2 and the other formulations. This suggests that the addition of 4% pumpkin peel flour in F2 may have enhanced the flavor profile, making it more appealing to participants compared to the other formulations.

The sensory results can be attributed to the functional properties of the pumpkin components used. Pumpkin pulp is known for its sweet and mild flavor, which likely contributed to the higher acceptance of F1. However, the addition of pumpkin peel flour in F2 seems to have introduced desirable flavor notes that resonated well with participants. The presence of antioxidant and aromatic compounds in the peel of *Cabotiá* pumpkin may have a significant impact on the flavor and aroma of culinary preparations. Compounds such as polyphenols, flavonoids, and carotenoids can contribute to the development of unique and complex flavor notes, ranging from subtle floral or fruity tones to more pronounced earthy or nutty nuances (Martínez et al., 2021). On the other hand, the F3 formulation, which included both peel and seed flour, received a neutral score. This may indicate an imbalance in flavor and aroma, where the combination of different flours, including seed flour, did not harmonize as effectively as in F2.

In terms of preference and purchase intention, Figure 4 shows the scoring system for the obtained formulations. The results indicate a clear preference for F1 and F2, with participants expressing a higher likelihood of purchasing these products compared to F3. This finding highlights the importance of flavor and overall acceptance in influencing consumer behavior, which is crucial for market success.

4 CONCLUSIONS

The addition of cabotiá pumpkin residues (peel and seeds) resulted in an increase in protein, lipid, flavonoid, and TPC content, which contributed to higher antioxidant activity and bioaccessibility, as well as a reduction in sugar levels in the instant mixes. The formulations showed an amorphous structure and polyhedral geometry, with particle size influenced by the components added to the mix, with F2 showing greater homogeneity. Microbiological analyses confirmed the food safety of the instant mixes made from pumpkin residues, indicating that the product was processed and handled under satisfactory hygienic conditions. F1 and F2 received a score of 7.1 in the sensory analysis, but the flavor profile was more pronounced in F2, making it more appealing to participants. The addition of pumpkin peel flour increased consumer acceptance, introducing desirable flavor notes, possibly due to the presence of antioxidant and aromatic compounds. Furthermore, the purchase intention was higher for formulations F1 and F2. It was found that the instant mixes can be marketed as functional or nutraceutical foods, contributing to the reduction of agro-industrial waste.

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