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Spread developed with peanuts, baru almonds, and ora-pro-nóbis mucilage: chemical, technological, and bioactive characteristics

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Abstract

The number of people changing their eating habits towards healthier foods is increasing. Among foods, peanut butter is widely consumed all around the world. However, the lipid content of peanut butter is high, which ends up being a reason for restriction for some consumers. One strategy is to replace peanuts with baru almonds, an almond native to the Brazilian Cerrado, using ora-pro-nóbis mucilage to maintain the characteristics. Therefore, the objective of this study was to develop and evaluate the spread with peanuts, baru almonds, and ora-pro-nóbis mucilage. Different baru almond and ora-pro-nóbis mucilage concentrations substituted the peanut concentration on the spread. Chemical, physical, technological, bioactive, and storage characteristics were evaluated. Spread with the highest amount of ora-pro-nóbis mucilage (0.2 g/100 g of butter) showed a 16% increase in protein content. The mineral profile was improved in the formulations developed compared with spreads. The firmness of the spread did not show a significant difference from the peanut-based control formulation. Furthermore, antioxidant activity was higher in a developed spread. During storage, up to 30 days, most formulations maintained their initial pH and acidity, with changes in color parameters. Spread showed great nutritional value, being an interesting food alternative to improve diet quality.

Keywords: vegetable cream; nutritional information; new products; *Dipteryx alata; Pereskia aculeata*.

Practical Application: Ora-pro-nóbis mucilage and baru are promising ingredients for more nutritious spreads.

1 INTRODUCTION

Among commercially available foods, nut-based pastes, especially peanuts, stand out as practical and tasty food. However, this oilseed has a very high lipid content of about 46.0% (Zhang et al., 2022), meaning that high consumption of peanut-based pastes leads to health problems. In this sense, baru almonds could be regarded as a viable substitute due to the high concentrations of bioactive compounds and beneficial nutritional profile (Campidelli et al., 2022).

Of the native flora of the Cerrado biome, the baru almond (*Dipteryx alata* Vogel) is the most valued portion of the fruit. Almonds are highly appreciated, especially by the gastronomic media, enhancing recognition and acceptance by society, which has become increasingly discerning of the foods they consume (Egea & Takeuchi, 2020).

The nutritional potential and functional appeal of baru almonds have been widely explored by food science. It is considered a food source with a unique chemical composition in terms of proteins (31.8%), lipids (22.4%), vitamins (such as vitamin E content of 21.40 mg/ 100 g), minerals (mainly potassium) and fiber (12.6%). Furthermore, baru almonds contain significant amounts of bioactive compounds with antioxidant activity, e.g. phenols, phytates, and tannins (Egea & Takeuchi, 2020; Lima et al., 2021; Viana et al., 2023). Baru almonds have already been used in vegetable beverages (Silva et al., 2020), cereal bars (Lima et al., 2021), cocoa cream (Campidelli et al., 2022), and cookies (Viana et al., 2023).

Another vegetable raw material that stands out is ora-pro-nóbis (*Pereskia aculeata* Miller — OPN). OPN is a non-conventional food plant that is a species widely used by vegan and vegetarian consumers due to its high protein content. From OPN leaves, it is possible to extract mucilage, which has a dark gelatinous appearance, is soluble in water and alcohol, has good hydration and solubilization, and has excellent technological properties (Masugossa et al., 2023).

OPN mucilage contains approximately 15.0% proteins, 0.6% lipids, 2.5% fibers, and 63.4% carbohydrates (Nascimento et al., 2023). The polysaccharide arabinogalactan predominates in mucilage, resulting in the potential to be used as a hydrocolloid, which can be applied as a thickener, gelling agent, emulsifier, stabilizer, and a source of protein in the food industry (Oliveira et al., 2019). This nutritional profile associated with the technological properties of OPN mucilage shows that this species is an alternative source of food ingredients.

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The demand for foods that provide health benefits and nutrients is increasing along with population growth. Therefore, there is a constant search for plant-based foods to compose special diets. This study aimed to develop and evaluate spread with different concentrations of peanuts, baru almonds, and OPN mucilage and evaluate its chemical, technological, and bioactive characteristics.

2 MATERIAL AND METHODS

2.1 Material

The OPN leaves were collected at the Instituto Federal Goiano, Campus Rio Verde in Goiás, Brazil (17°48'17.1"S 50°54'23.2"W). The roasted baru almond was obtained in Caiapônia, also located in Goiás, and was used in the skin. Roasted and shelled unsalted peanuts, 100% cocoa powder, cocoa nibs, and 100% natural xylitol were purchased in local shops in Brasília/DF (Brazil).

2.2 Obtaining the ora-pro-nóbis mucilage

A batch of 1,200 g of OPN leaves was sanitized with 20 ppm sodium hypochlorite. The leaves were cut and homogenized in water in a ratio of 1.2:4 (leaves: water, m/v) and the suspension was heated at 60°C for 40 min (Lima Junior et al., 2013). Then, the suspension was filtered through sieves (10 mesh) and the supernatant (mucilage) was lyophilized and stored in a freezer at -18°C.

2.3 Proximate composition and caloric value

The proximate compositions of OPN mucilage were performed according to Association of Official Analytical Collaboration (AOAC, 2005), on a dry basis. The moisture (method number 935.29); ash (method number 923.03); protein (micro-Kjeldahl method N x 6.25, number 920.87); and lipid content (Soxhlet method, number 920.85) were determined. The carbohydrate content was obtained by the difference of 100 to the other components. The caloric value was calculated based on the Atwater caloric coefficients.

2.4 Spread development

Two control formulations were developed, one based on peanuts and the other on baru almonds. The test formulations were added with 0.05, 0.10, 0.15, and 0.20% OPN mucilage to the amounts of peanuts and baru almonds (concentrations obtained from preliminary tests). Table 1 presents the formulations of the spreads developed.

The peanuts and baru almonds were ground separately using a food processor (Walita, PowerChop, 750W) with knife-type metal blades for approximately 20 min for the baru almonds and 15 min for the peanuts. Afterward, the other inputs were incorporated and homogenized in a food processor for 5 min. The samples were stored in polypropylene containers at room temperature until analysis.

2.5 Spread characterization

2.5.1 Chemical characterization

The moisture, protein, ash, carbohydrate content, and caloric value of the spreads were determined according to the previous subsection, on a dry basis. Lipids were determined according to Bligh and Dyer (1959). Minerals (phosphorus, potassium, calcium, copper, manganese, magnesium, zinc, and iron) were determined using the perchloric nitric acid digestion method at 50°C for 15 min and 100°C to digest all the material. The reading was carried out on an atomic absorption spectrophotometer at 248.3 nm.

2.5.2 Water activity

The water activity of samples was determined in a LabTouch Novasina® water activity analyzer (Novasina, Model LabTouch, Switzerland) at room temperature.

2.5.3 Firmness

The firmness of spreads was determined using a Texture Analyzer (CT3-100, Brookfield Engineering Lab, Massachusetts, USA) with a capacity of 500 N. The texture analyzer probe (TA 17 cone 24 mm D. 45°) was adjusted to penetrate the spreads in containers to a depth of 25 mm at a rate of 2.0 mm/s. The container measured 5 cm in diameter. The firmness value was expressed in Newton (N).

2.5.4 Differential scanning calorimetry

The thermal characteristics of spreads were determined by differential scanning calorimetry (DSC) (Shimadzu, model DSC-60, Japan). DSC analysis was performed with the heating rate of 10°C/min, at the temperature range from 25 to 300°C, and a nitrogen atmosphere flow rate of 50 mL/min.

2.5.5 Determination of antioxidant activity

The extract used to analyze antioxidant activity was prepared according to Larrauri et al. (1997) with adaptations: 1 g of

Table 1. Formulations of spreads with different levels of peanuts, baru almonds, and ora-pro-nóbis mucilage.

Ingredients (%)	Formulation					
	C1	C2	F1	F2	F3	F4
Peanut	70.00	-	25.00	30.00	35.00	40.00
Baru almond	-	70.00	44.95	39.90	34.85	29.80
Cocoa nibs	15.00	15.00	15.00	15.00	15.00	15.00
Xylitol	10.00	10.00	10.00	10.00	10.00	10.00
100% cocoa powder	5.00	5.00	5.00	5.00	5.00	5.00
Lyophilized OPN mucilage	-	-	0.05	0.10	0.15	0.20

OPN: ora-pro-nóbis.

each spread was homogenized in 40 mL of 50% methanol and left to rest for 60 min at room temperature. Then, it was centrifuged at 25,500 g for 15 min. The supernatant was transferred to a 100 mL volumetric flask. From the residue of the first extraction, 40 mL of 70% acetone was added. Soon after, it was homogenized and left to rest for 60 min at room temperature. It was centrifuged again at 25,500 g for 15 min and the supernatant was transferred to the volumetric flask containing the first supernatant. The volume was made up to 100 mL with distilled water.

The antioxidant activity was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2'-azino-bis [3-ethylbenzothiazoline-6-sulfonic acid]) methods. The antioxidant capacity was determined through the sequestration of the DPPH radical and the capturing ability of the ABTS radical (Lemos et al., 2012). The DPPH free radical scavenging capacity and capture of the ABTS radical were expressed relating to sample absorbance and absorbance without the sample.

2.5.6 Storage stability

The shelf-life of spreads was evaluated during storage for 60 days at room temperature (~27°C). Samples were collected at times 0, 30, and 60 days. Stability was monitored through hydrogen potential (pH), acidity, and color analyses.

The pH analysis was carried out according to the method of the Adolfo Lutz Institute (2008) using a digital pH meter (Kasvi, model K39-1420A). For acidity analysis, 50 mL of water was added to 5 g of each spread and 3 drops of phenolphthalein. The titration was carried out with 0.01 M sodium hydroxide solution until a pink color appeared. The results (units) were expressed as lactic acid. The colorimetric properties of spreads were determined using the Konica Chroma Meter CR — 400 colorimeters. The analysis was based on the International Commission on Illumination (CIE) L*a*b* system, defined in 1976, for determining the L* (lightness), a* and b* (chromaticity coordinates) values. From these values, the chroma parameter (intensity or purity of the color, C*), and the hue angle (true color, h°) were determined.

2.5.7 Statistical analysis

All determinations were done at least in triplicate. The data were analyzed using analysis of variance (ANOVA), and the average values obtained were compared using Tukey's test, with statistical significance (α) set at $p < 0.05$.

3 RESULTS AND DISCUSSION

3.1 Ora-pro-nóbis mucilage characterization

The yield of obtaining lyophilized OPN mucilage was 0.42%. Martin et al. (2017) obtained a yield of 1.6% and Kobayasi et al. (2023) achieved a yield of 4.2% using ethanol as a precipitating agent. In addition to the characteristics of the plant material, the method used to extract mucilage can influence the extraction yield and the chemical, physical, and nutritional characteristics. The OPN mucilage yield observed was lower than other mucilage, such as chia (10.9%) and linseed (5.3%), when hot water extraction was used (Lira et al., 2023), which may have occurred due to the moisture/dry nature of the material applied.

Table 2 presents the proximal composition, caloric value, and water activity of the mucilage obtained from the extraction of OPN leaves and developed spreads. According to Table 2, a high moisture value was observed for OPN mucilage (17.33 g/100 g), possibly due to its hygroscopicity, which absorbed moisture after the freeze-drying process.

The lipid (0.59 g/100 g) and protein content (17.17 g/100 g) obtained for OPN mucilage were smaller and higher compared with Oliveira et al. (2019) who reported 1.68 g/100 g of lipid and 8.89 g/100 g of protein contents, respectively. The low lipid content was also found in other types of mucilage, such as chia (0.91/100 g) by Fernandes and Salas-Mellado (2017). A high protein content is desirable as it can improve the mucilage's emulsifying capacity, increasing the colloidal system's viscosity and elevating the nutritional profile of food products (Silva et al., 2020). The low caloric value obtained for OPN mucilage is associated with the low lipid content found. Lipids generally

Table 2. Proximal composition (g/100 g), caloric value (kcal/100 g), and water activity of lyophilized ora-pro-nóbis mucilage and the developed spread formulations containing baru almonds, peanuts, and ora-pro-nóbis mucilage.

	OPN mucilage	Formulations					
		C1	C2	F1	F2	F3	F4
Moisture	17.33 ± 0.03	0.75 ± 0.22^{b}	1.05 ± 0.13^{ab}	1.11 ± 0.06^{a}	1.05 ± 0.12^{ab}	0.88 ± 0.11^{ab}	1.21 ± 0.07^{a}
Protein*	17.17 ± 0.56	21.92 ± 0.72^{c}	20.06 ± 0.19^{d}	22.46 ± 0.08^{c}	20.70 ± 0.34^{d}	26.01 ± 0.72^{a}	24.06 ± 0.72^{b}
Lipids*	0.59 ± 0.09	36.98 ± 0.98^{a}	29.41 ± 0.52^{c}	31.66 ± 0.00^{b}	31.31 ± 0.23^{b}	35.17 ± 1.38^{a}	35.67 ± 0.17^{a}
Ash*	37.17 ± 0.63	2.26 ± 0.03^{c}	3.14 ± 0.04^{a}	2.59 ± 0.40^{bc}	2.94 ± 0.15^{ab}	2.59 ± 0.16^{bc}	2.84 ± 0.07^{ab}
Carbohydrates*	27.74	38.53	46.86	42.43	44.22	35.89	36.95
Caloric Value	184.95	571.46	528.74	543.50	543.74	560.42	559.95
Water activity	ND	0.338 ± 0.002^{a}	0.340 ± 0.007^{a}	0.329 ± 0.006^{a}	0.350 ± 0.005^{a}	0.338 ± 0.004^{a}	0.344 ± 0.016^{a}

*Dry basis; OPN: ora-pro-nóbis; ND: not determined; C1: control formulation containing peanuts, cocoa powder, xylitol, and cocoa nibs; C2: control formulation containing baru almonds, cocoa powder, xylitol, and cocoa nibs; F1: formulation containing baru almonds, peanuts, 0.05 g of ora-pro-nóbis mucilage, and other ingredients; F2: formulation containing baru almonds, peanuts, 0.10 g of ora-pro-nóbis mucilage, and other ingredients; F3: formulation containing baru almonds, peanuts, 0.15 g of ora-pro-nóbis mucilage, and other ingredients; F4: formulation containing baru almonds, peanuts, 0.20 g of ora-pro-nóbis mucilage, and other ingredients. The average of three values with standard deviation (±), same letter in the line indicates that there is no significant difference between the means by Tukey's test ($p < 0.05$).

appear in small quantities in fruits and vegetables, which can also be related to the low caloric content found in these foods, as lipids are highly energetic molecules (9 kcal/g).

3.3 Characterization of spread

3.3.1 Chemical characterization

The moisture content of spreads ranged from 0.75 (C1) to 1.21 (F4) g/100 g. This low content helps to avoid microbiological deterioration, as the moisture content of food is associated with greater storage stability (Horuz et al., 2018). To prepare the spread, dry roasting baru almonds, and peanuts contributed to developing characteristic aromas and flavors, reducing moisture levels from around 1 to 8%, allowing for the desired texture (Eker et al., 2023).

The highest protein content was obtained with formulation F3 (26.01 g/100 g), which compared to control formulations C1 and C2 showed increases of 15.7 and 29.6%, respectively. As expected, the formulations where OPN mucilage was added demonstrated an improvement in protein content except for F2 possibly due to the replaced proportions of peanut and baru. Baru almonds have around 31.8 g/100 g of protein (Viana et al., 2023) while peanuts have around 23.7 g/100 g (Zhang et al., 2022). The test formulations (F1 to F4) proportionally increased the peanut content and reduced the baru almond content; however, the protein content was enhanced due to the increased amount of mucilage added, which presented 17.70 g of protein/100 g.

According to RDC no. 54 of November 12, 2012, established by the Brazilian Health Surveillance Agency (ANVISA), it is necessary to have at least 6 g of protein to be considered a "protein source" food, and at least 12 g of protein to be considered high protein (Brasil, 2012). Thus, all spread formulations developed in the present work can be qualified products with high protein content.

Regarding lipids, the consumption of these macronutrients has the function of providing energy during long-term exercise and recovering energy systems after exercise (Liu et al., 2024). Formulation C1 stood out with the highest lipid content (36.98 g/100 g), with no significant difference with formulations F3 (35.17 g/100 g) and F4 (35.67 g/100 g), since these spreads have peanuts as their main ingredient, which has a lipid content of 45.70 g/100 g (Zhang et al., 2022). The lowest lipid content was observed in formulation C2 (29.41 g/100 g). This is because the baru almond has a lipid content of around 22.40 g/100 g (Viana et al., 2023).

The ash content was higher in baru-control spread (C2) as it is the formulation with the highest amount of baru almonds. In addition, this base raw material was used with the shell, which has a more significant amount of minerals that affect the high ash content. Although the ash content is higher in OPN mucilage than the other ingredients, the added quantities were insufficient, not affecting the higher ash contents of spread formulations.

As for the total energy value, the calorie values ranged from 528.74 to 571.46 kcal/100 g. The energy value of the peanut-control spread (C1) presented the highest caloric value because peanuts have a high lipid content, 45.70 g/100 g (Zhang et al., 2022) which contributes most to this parameter. The energy value of the baru-control spread (C2) presented the lowest caloric value because the baru-control spread contains around 22.40 g/100 g of lipid content (Viana et al., 2023). Lise et al. (2021) found a reduction in energy value in processed mortadella meat when they added OPN mucilage in proportions of 0.05 and 0.10%.

Table 3 demonstrates the mineral values present in the developed spread formulations. In general, the F1 spread had a higher content of minerals such as phosphorus, magnesium, sulfur, copper, and zinc. The increase in these minerals in F1 spread occurred due to OPN mucilage. Among the other formulations tested (F2, F3, and F4), it was the one that contained the highest amount of baru almonds. Junqueira et al. (2019) determined the mineral analysis of OPN mucilage and found a high concentration of calcium (3.35/100 g), followed by potassium (2.42 g/100 g), phosphorus (1.13 g/100 g), magnesium (0.45 g/100 g), and sulfur

Table 3. Mineral composition of the developed spread formulations containing baru almonds, peanuts, and lyophilized ora-pro-nóbis mucilage.

Mineral	Formulations					
	C1	C2	F1	F2	F3	F4
N (100 g/kg)	4.10 ± 0.13^{c}	3.74 ± 0.03^{d}	4.19 ± 0.01^{c}	3.86 ± 0.06^{d}	4.86 ± 0.13^{a}	4.48 ± 0.13^{b}
P (100 g/kg)	0.33 ± 0.00^{e}	0.40 ± 0.00^{bc}	0.43 ± 0.00^{a}	0.41 ± 0.00^{b}	0.36 ± 0.00^{d}	0.39 ± 0.00^{c}
K (100 g/kg)	0.27 ± 0.03^{c}	0.37 ± 0.00^{a}	0.33 ± 0.00^{b}	0.33 ± 0.00^{b}	0.34 ± 0.00^{ab}	0.34 ± 0.00^{b}
Ca (100 g/kg)	0.51 ± 0.00^{a}	0.44 ± 0.00^{b}	0.25 ± 0.00^{d}	0.25 ± 0.00^{d}	0.24 ± 0.00^{e}	0.33 ± 0.00^{c}
Mg (100 g/kg)	0.10 ± 0.00^{a}	0.09 ± 0.00^{b}	0.09 ± 0.00^{ab}	0.09 ± 0.00^{ab}	0.10 ± 0.00^{a}	0.09 ± 0.00^{ab}
S (100 g/kg)	0.19 ± 0.00^{c}	0.23 ± 0.00^{a}	0.24 ± 0.00^{a}	0.20 ± 0.00^{b}	0.20 ± 0.00^{b}	0.20 ± 0.00^{b}
Fe (100 mg/kg)	24.66 ± 0.07^{e}	25.51 ± 0.07^{a}	24.71 ± 0.07^{e}	24.91 ± 0.07^{d}	25.11 ± 0.07^{c}	25.31 ± 0.07^{b}
Mn (100 mg/kg)	1.02 ± 0.02^{e}	2.51 ± 0.02^{a}	2.17 ± 0.02^{c}	1.84 ± 0.01^{d}	2.25 ± 0.01^{b}	1.83 ± 0.02^{d}
Cu (100 mg/kg)	0.50 ± 0.01^{e}	0.84 ± 0.02^{b}	0.96 ± 0.01^{a}	0.95 ± 0.00^{a}	0.82 ± 0.14^{c}	0.65 ± 0.04^{d}
Zn (100 mg/kg)	2.24 ± 0.01^{d}	2.34 ± 0.01^{b}	2.87 ± 0.02^{a}	2.29 ± 0.01^{c}	2.28 ± 0.02^{c}	2.26 ± 0.01^{cd}
B (100 mg/kg)	1.99 ± 0.08^{b}	1.68 ± 0.00^{c}	1.61 ± 0.09^{c}	1.30 ± 0.00^{d}	1.93 ± 0.09^{b}	2.24 ± 0.08^{a}

N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; S: sulfur; Fe: iron; Mn: manganese; Cu: copper; Zn: zinc; B: boron; C1: control formulation containing peanuts, cocoa powder, xylitol, and cocoa nibs; C2: control formulation containing baru almonds, cocoa powder, xylitol, and cocoa nibs; F1: formulation containing baru almonds, peanuts, 0.05 g of ora-pro-nóbis mucilage and, other ingredients; F2: formulation containing baru almonds, peanuts, 0.10 g of ora-pro-nóbis mucilage, and other ingredients; F3: formulation containing baru almonds, peanuts, 0.15 g of ora-pro-nóbis mucilage, and other ingredients; F4: formulation containing baru almonds, peanuts, 0.20 g of ora-pro-nóbis mucilage, and other ingredients. The average of three values with standard deviation (±), same letter in the line indicates that there is no significant difference between the means by Tukey's test ($p < 0.05$).

(0.98 g/100 g). Lima et al. (2021) found a high concentration of potassium (9.43 g/100 g), followed by calcium (6.38/100 g), phosphorus (3.31 g/100 g), sulfur (3.19 g/100 g), and magnesium (2.16 g/100 g) in the baru almond. The F3 spread had the highest nitrogen content, in line with the protein content determined in this formulation, which was the highest among the other samples.

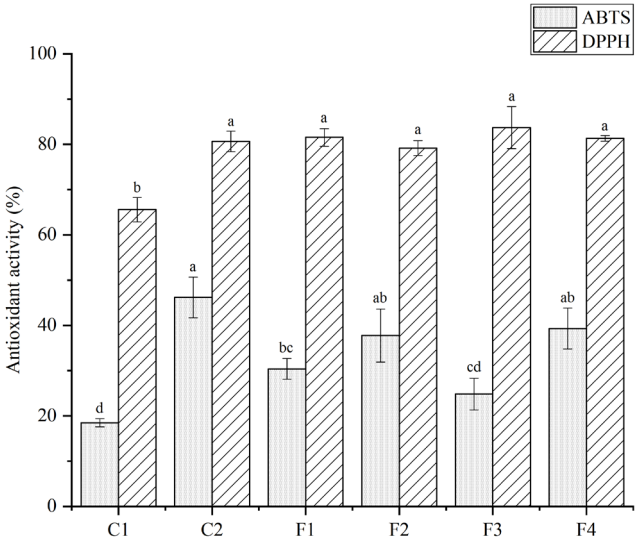
Considering the recommended daily intake (RDI) for minerals, the spread formulations developed in this work contributed especially to iron and zinc contents. Iron is an essential nutrient needed for oxygen transport and cellular respiration, and iron deficiency is the most common cause of anemia worldwide (Charlebois & Pantopoulos, 2023). Iron contribution to the F4 and C2 spreads was 36.14 and 36.42% in a 20 g portion, respectively. Zinc is an essential mineral that performs several functions in the body and the immune system, and its deficiency can lead to serious health consequences, such as growth retardation, reproductive dysfunction, weight loss, diarrhea, and alopecia (Maywald & Rink, 2022). The developed spreads demonstrated a contribution to the supply of zinc, emphasizing the F1 formulation, which was 8.14%.

The water activity parameter helps predict microbial growth and shelf life of spreads, as they are products with high protein and energy values. There was no significant difference in water activity values among the developed spreads (Table 2). All formulations analyzed showed low water activity (< 0.450), which is a positive factor, as it is considered that below 0.60 there is practically no development of microorganisms. The low water activity obtained in spreads prevents microorganisms' growth and spoilage reactions.

Table 4 presents the firmness values of the developed spread containing baru almonds, peanuts, and OPN mucilage. In texture analysis, factors such as formulation, oil content present in the composition of spread and processing, as well as the distribution and size of particles in food, can influence this determination. Formulation C2 had the highest firmness value (22.16 N), which may be due to its integral baru composition. Baru almonds and shells are fiber-rich materials, which may have interacted with other constituents, such as lipids and hydrocolloids, reducing their mobility. This may help to justify the increase in firmness in C2 spread, as it is the formulation with the largest amount of baru almonds. In addition to the shell, the visible presence of cocoa nibs in the samples may have caused a possible obstruction during penetration and removal of the probe from the analyzer.

Another factor that influenced the firmness of spread was the addition of OPN mucilage. Formulations F1 to F4 (with a gradual increase in the addition of OPN mucilage and a reduction in the amount of baru almond) did not show a significant difference from the peanut-based control. This means that although the high presence of baru almond tends to increase firmness, it does not occur due to the presence of OPN mucilage, thus ensuring that the technological characteristics of spread are maintained. Lise et al. (2021) also found that adding 0.1% chia mucilage to replace chicken skin in mortadella did not significantly change firmness.

The lipid content has an inverse impact on the spread firmness. Wagener and Kerr (2018) observed that the firmness of walnut spread was increased by reducing the oil content



ABTS: 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid); DPPH: 2,2-diphenyl-1-picrylhydrazyl);.C1: control formulation containing peanuts, cocoa powder, xylitol, and cocoa nibs; C2: control formulation containing baru almonds, cocoa powder, xylitol, and cocoa nibs; F1: formulation containing baru almonds, peanuts, 0.05 g of ora-pro-nóbis mucilage, and other ingredients; F2: formulation containing baru almonds, peanuts, 0.10 g of ora-pro-nóbis mucilage, and other ingredients; F3: formulation containing baru almonds, peanuts, 0.15 g of ora-pro-nóbis mucilage, and other ingredients; F4: formulation containing baru almonds, peanuts, 0.20 g of ora-pro-nóbis mucilage, and other ingredients.

Figure 1. Antioxidant activity of ABTS and DPPH methods for different spreads formulations.

Table 4. Firmness and thermal analysis parameters (with differential scanning calorimetry) of spread formulations containing baru almonds, peanuts, and ora-pro-nóbis mucilage.

	Formulations					
	C1	**C2**	**F1**	**F2**	**F3**	**F4**
Firmness (N)	11.21 ± 4.32^{b}	22.16 ± 4.89^{a}	14.17 ± 3.61^{ab}	10.14 ± 2.86^{b}	12.61 ± 3.71^{ab}	10.16 ± 1.39^{b}
T_0 (°C)	177.83	85.67	77.13	79.16	82.71	75.61
T_p (°C)	206.97	93.47	90.61	89.53	91.79	91.90
T_f (°C)	220.76	96.18	95.27	94.01	95.51	95.14
ΔH (J/g)	37.18	46.42	30.94	11.91	28.91	55.91

T_0: onset temperature; T_p: peak temperature; T_f: final temperature; ΔH: enthalpy; C1: control formulation containing peanuts, cocoa powder, xylitol, and cocoa nibs; C2: control formulation containing baru almonds, cocoa powder, xylitol, and cocoa nibs; F1: formulation containing baru almonds, peanuts, 0.05 g of ora-pro-nóbis mucilage, and other ingredients; F2: formulation containing baru almonds, peanuts, 0.10 g of ora-pro-nóbis mucilage, and other ingredients; F3: formulation containing baru almonds, peanuts, 0.15 g of ora-pro-nóbis mucilage, and other ingredients; F4: formulation containing baru almonds, peanuts, 0.20 g of ora-pro-nóbis mucilage, and other ingredients. The average of three values with standard deviation (±), same letter in the line indicates that there is no significant difference between the means by Tukey's test ($p<0.05$).

Table 5. Hydrogen potential, acidity, and colorimetric parameters of spread formulations containing baru almonds, peanuts, and ora-pro-nóbis mucilage during storage.

Parameter		Days		
		0	30	60
pH	C1	$6.66 \pm 0.04^{a,B}$	$6.57 \pm 0.06^{ab,B}$	$6.85 \pm 0.05^{a,A}$
	C2	$6.44 \pm 0.04^{cd,B}$	$6.40 \pm 0.00^{c,B}$	$6.56 \pm 0.02^{c,A}$
	F1	$6.38 \pm 0.02^{d,B}$	$6.47 \pm 0.06^{bc,AB}$	$6.54 \pm 0.02^{c,A}$
	F2	$6.49 \pm 0.03^{bc,B}$	$6.67 \pm 0.06^{a,A}$	$6.58 \pm 0.03^{bc,AB}$
	F3	$6.55 \pm 0.03^{b,AB}$	$6.50 \pm 0.00^{bc,B}$	$6.64 \pm 0.08^{bc,A}$
	F4	$6.64 \pm 0.04^{a,A}$	$6.63 \pm 0.06^{a,A}$	$6.72 \pm 0.10^{ab,A}$
Acidity	C1	$0.23 \pm 0.05^{ab,A}$	$0.24 \pm 0.03^{d,A}$	$0.18 \pm 0.02^{c,A}$
	C2	$0.22 \pm 0.08^{ab,B}$	$0.34 \pm 0.03^{bc,B}$	$0.69 \pm 0.07^{a,A}$
	F1	$0.14 \pm 0.03^{b,C}$	$0.44 \pm 0.01^{a,B}$	$0.53 \pm 0.03^{b,A}$
	F2	$0.24 \pm 0.00^{ab,B}$	$0.33 \pm 0.05^{c,B}$	$0.54 \pm 0.05^{b,A}$
	F3	$0.33 \pm 0.05^{a,B}$	$0.43 \pm 0.02^{ab,A}$	$0.26 \pm 0.03^{c,B}$
	F4	$0.22 \pm 0.03^{ab,A}$	$0.30 \pm 0.05^{cd,A}$	$0.22 \pm 0.03^{c,A}$
L*	C1	$30.39 \pm 1.65^{c,A}$	$32.89 \pm 0.05^{a,A}$	$20.65 \pm 0.72^{ab,B}$
	C2	$33.62 \pm 0.23^{ab,A}$	$31.12 \pm 3.38^{a,A}$	$11.48 \pm 0.50^{c,B}$
	F1	$28.63 \pm 0.86^{c,B}$	$31.72 \pm 0.63^{a,A}$	$23.71 \pm 1.06^{a,C}$
	F2	$30.47 \pm 0.55^{bc,A}$	$30.18 \pm 0.21^{a,A}$	$20.94 \pm 1.69^{ab,B}$
	F3	$35.09 \pm 1.63^{a,A}$	$32.79 \pm 0.27^{a,A}$	$17.89 \pm 0.67^{b,B}$
	F4	$33.97 \pm 1.27^{a,A}$	$31.21\pm 0.20^{a,A}$	$18.68 \pm 1.52^{b,B}$
a*	C1	$13.64 \pm 0.78^{a,A}$	$10.39 \pm 0.20^{a,B}$	$5.85 \pm 0.92^{a,C}$
	C2	$13.30 \pm 0.32^{ab,A}$	$6.04 \pm 1.14^{c,B}$	$5.49 \pm 0.18^{a,B}$
	F1	$10.20 \pm 0.69^{d,A}$	$8.46 \pm 0.47^{b,B}$	$4.96 \pm 0.17^{a,C}$
	F2	$11.06 \pm 0.24^{cd,A}$	$8.83 \pm 0.06^{b,B}$	$5.40 \pm 0.81^{a,C}$
	F3	$11.96 \pm 0.48^{bc,A}$	$9.50 \pm 0.18^{ab,B}$	$5.53 \pm 0.43^{a,C}$
	F4	$11.75 \pm 0.09^{c,A}$	$8.64 \pm 0.14^{b,B}$	$6.12 \pm 0.74^{a,C}$
b*	C1	$12.84 \pm 1.57^{ab,B}$	$16.52 \pm 0.20^{a,A}$	$7.60 \pm 1.14^{a,C}$
	C2	$13.06 \pm 0.35^{a,A}$	$10.96 \pm 3.28^{c,A}$	$8.77 \pm 0.58^{a,B}$
	F1	$9.19 \pm 0.98^{c,B}$	$13.17 \pm 0.71^{ab,A}$	$6.74 \pm 0.39^{a,C}$
	F2	$10.62 \pm 0.40^{bc,B}$	$13.12 \pm 0.15^{ab,A}$	$7.24 \pm 1.02^{a,C}$
	F3	$12.24 \pm 0.72^{ab,A}$	$14.28 \pm 0.31^{ab,A}$	$7.91 \pm 1.24^{a,B}$
	F4	$12.06 \pm 0.44^{ab,B}$	$13.81 \pm 0.10^{ab,A}$	$8.34 \pm 0.16^{a,C}$
h°	C1	$47.07 \pm 2.35^{a,C}$	$57.85 \pm 0.19^{bc,A}$	$53.00 \pm 0.34^{b,B}$
	C2	$44.48 \pm 0.40^{ab,C}$	$62.32 \pm 0.44^{a,A}$	$58.18 \pm 0.65^{a,B}$
	F1	$41.97 \pm 2.02^{c,B}$	$57.20 \pm 0.96^{bcd,A}$	$54.27 \pm 0.68^{b,A}$
	F2	$44.09 \pm 0.08^{ab,B}$	$56.06 \pm 0.13^{d,A}$	$53.31 \pm 2.09^{b,A}$
	F3	$45.63 \pm 0.71^{a,B}$	$56.37 \pm 0.66^{cd,A}$	$55.54 \pm 1.42^{ab,A}$
	F4	$46.28 \pm 0.43^{a,C}$	$57.97 \pm 0.62^{b,A}$	$54.30 \pm 1.17^{b,B}$
C*	C1	$18.02 \pm 1.72^{a,A}$	$15.63 \pm 0.81^{ab,A}$	$9.59 \pm 1.46^{a,B}$
	C2	$18.65 \pm 0.46^{a,A}$	$12.48 \pm 5.83^{b,A}$	$10.35 \pm 0.58^{a,A}$
	F1	$13.73 \pm 1.11^{c,B}$	$17.15 \pm 0.30^{ab,A}$	$8.37 \pm 0.41^{a,C}$
	F2	$15.34 \pm 0.45^{c,A}$	$16.30 \pm 0.03^{ab,A}$	$9.03 \pm 1.26^{a,C}$
	F3	$17.12 \pm 0.84^{ab,B}$	$19.52 \pm 0.28^{a,A}$	$9.91 \pm 0.85^{a,C}$
	F4	$16.84 \pm 0.26^{ab,A}$	$14.51 \pm 0.06^{ab,B}$	$10.32 \pm 1.12^{a,C}$

pH: hydrogen potential; L*: brightness; a* and b*: chroma; h°: hue angle; C*: saturation; C1: control formulation containing peanuts, cocoa powder, xylitol, and cocoa nibs; C2: control formulation containing baru almonds, cocoa powder, xylitol, and cocoa nibs; F1: formulation containing baru almonds, peanuts, 0.05 g of ora-pro-nóbis mucilage, and other ingredients; F2: formulation containing baru almonds, peanuts, 0.10 g of ora-pro-nóbis mucilage, and other ingredients; F3: formulation containing baru almonds, peanuts, 0.15 g of ora-pro-nóbis mucilage, and other ingredients; F4: formulation containing baru almonds, peanuts, 0.20 g of ora-pro-nóbis mucilage, and other ingredients. The average of three values with standard deviation (±), the same lowercase letter in the column indicates that there were no significant differences for each parameter between the means of each formulation and the same uppercase letter in the row indicates that there were no significant differences between the different storage times for each parameter evaluated in the same formulation, by Tukey's test ($p < 0.05$).

present in its composition—the same as found in this study in formulation C2.

Table 4 shows that the melting temperature occurred at similar values for all formulations except the peanut-based control (C1). The decrease in peak temperature in C1 with the increased concentration of added baru is due to the lower endothermic peak of baru. This behavior means that although different concentrations of OPN mucilage are added, the melting peak remains similar and has lower thermal stability.

Regarding enthalpy, it can be observed that it was reduced in formulations F2 and F3, indicating spreads that are less stable at temperature. During storage or transport, these spreads could undergo changes in their characteristics. Formulation F4 presented the highest enthalpy, suggesting that this formulation was the most thermally stable. Compared to other spreads, more heat is needed to denature the sample, indicating its storage stability. This storage stability may have been caused by the higher amount of OPN mucilage in this formulation, which has thermal stability up to 151°C (Oliveira et al., 2019).

Figure 1 shows the percentage of antioxidant activity of the different spreads measured by ABTS and DPPH. Since antioxidant activity often varies depending on different free radicals, it is recommended the application of at least two methods to estimate antioxidant capacity and ensure reliable results (Munteanu & Apetrei, 2021). ABTS and DPPH results were expressed as a percentage of discoloration once antioxidants transfer a hydrogen atom to a radical cation and cause discoloration of the solution. Therefore, the higher the percentage of discoloration, the greater the antioxidant activity.

Based on Figure 1, it is possible to verify that formulation C1 had the lowest antioxidant capacity in both methods. Regarding the results using the ABTS free radical capture method, C2 (46.2%), F2 (37.8%), and F4 (39.3%) spreads showed the highest antioxidant activity. These results have already been expected since these formulations contain baru almonds, which have high antioxidant activity compared to the other ingredients (Viana et al., 2023).

The DPPH free radical scavenging capacity ranged from 65.6 (C1) to 83.7% (F3) spreads. The results revealed that all samples presented antioxidant activity against radical scavenging, indicating the developed spreads with baru almonds and OPN mucilage (F1 to F4) as electron donors, capable of stabilizing the DPPH free radical. Furthermore, the different tested concentrations of the ingredients did not alter the antioxidant capacity. In general, it was observed that spreads formulated with peanuts, baru almonds, and OPN mucilage presented antioxidant activity, probably due to baru almonds.

3.3.2 Storage stability

Table 5 presents the pH values, titratable acidity parameters, and color of the developed spread formulations containing baru almonds, peanuts, and OPN mucilage for 60 days. The average values found for the pH for the different formulations showed significant differences during the days of storage evaluation, with pH varying from 6.38 (F1 at 0 days) to 6.85 (C1 at 60 days). All formulations showed an increase in pH over time, except F4. The values found in the foods developed in this study were close to neutrality (~7) within the 60 days of evaluation, which shows a positive result as this range helps in food conservation. Products with a more alkaline pH present a more conducive environment for the development of pathogenic microorganisms, thus accelerating their deterioration, and due to this process, sensory characteristics such as palatability, aroma, and texture may be impaired (Firmo et al., 2020). Lima et al. (2021) found similar pH results for baru almonds (6.24) and nutritional bars developed with baru almonds (6.31).

The titratable acidity in formulations C1 and F4 did not change over the 60 days of storage while formulations C2, F1, and F2, which contained greater amounts of baru almonds in their compositions, increased acidity over this same period. The increase in titratable acidity in almonds could have been caused by the breakdown of unsaturated acids present in lipid molecules (Lemos et al., 2012). However, C1, F3, and F4 spreads had lower acidity after 60 days of storage. Reis and Schmiele (2019) observed that in a storage period of 42 days, baru almonds stored in different packages showed a reduction in acidity, having an initial acidity of 1.04% and a final of 0.58%.

C2, F3, and F4 spreads presented high initial luminosity due to the higher proportion of baru almonds since they were used in the shell, which is dark in color. This effect was also proven by Lima et al. (2021), who found that as the percentage of almond presence in nutritional bars increased, the luminosity parameter decreased. The authors found a luminosity of 46.47 bars with 25% baru almonds and 32.32 bars with 100% baru almonds. The chroma a* values obtained showed a tendency towards red color (a+), and the chroma b* values showed a tendency towards yellow color (b+). Both chromas suffered a significant reduction after 60 days of storage, revealing that storage conditions influence color parameters. All samples exhibited darkening (lower L*) with storage time. Furthermore, the amount of mucilage added may have not affected the color.

4 CONCLUSION

Spreads with peanuts, baru almonds, and OPN mucilage presented an excellent nutritional profile, with increased protein, lipid, and mineral content, making them a promising alternative for those seeking alternative food products. The technological characteristics of these products were maintained in relation to the peanut-based control product, which is commercially available. The baru almond helped with the bioactive properties and the OPN mucilage, in addition to providing the product's characteristic firmness and thermal stability. OPN mucilage has proven to be an excellent emulsifying ingredient, directly affecting the texture properties and final quality of products with a high protein content. Regarding storage stability, spread from 30 days onwards showed changes in pH, acidity, and color parameters due to reactions caused in the product by being kept at room temperature and light. Different individuals, including athletes, can consume the developed spread in the present study, as well as specific population groups, such as lactose intolerant, those allergic to cow's milk protein, vegans, people with gluten restrictions, and those with celiac disease.

REFERENCES

Adolfo Lutz Institute. (2008). *Normas Analíticas do Instituto Adolfo Lutz: métodos químicos e físicos para análise de alimentos* (3th ed.). Adolfo Lutz Institute.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*(8), 911-917. https://doi.org/10.1139/o59-099

Brasil (2012). Resolução da Diretoria Colegiada Nº 54, de 12 de novembro de 2012. Dispõe sobre o Regulamento Técnico sobre Informação Nutricional Complementar. *Diário Oficial da União*. Retrieved from https://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2012/rdc0054_12_11_2012.html

Campidelli, M. L. L., Carneiro, J. de D. de S., Souza, E. C. de, Vilas Boas, E. V. de B., Bertolucci, S. K. V., Aazza, S., de Oliveira, R. R., Chalfun-Junior, A., Reis, G. L. dos, Seixas, J. N., Nelson, D. L., & Pereira, L. J. (2022). Baru almonds (Dipteryx alata Vog.) and baru almond paste promote metabolic modulation associated with antioxidant, anti-inflammatory, and neuroprotective effects. *Innovative Food Science and Emerging Technologies*, *80*, 103068. https://doi.org/10.1016/j.ifset.2022.103068

Charlebois, E., & Pantopoulos, K. (2023). Nutritional aspects of iron in health and disease. *Nutrients*, *15*(11), 2441. https://doi.org/10.3390/nu15112441

Egea, M. B., & Takeuchi, K. P. (2020). Bioactive Compounds in baru almond (Dipteryx alata Vogel): nutritional composition and health effects. In *Reference Series in Phytochemistry* (pp. 290-300). https://doi.org/10.1007/978-3-030-06120-3_12-1

Eker, T., Cabaroglu, T., Darıcı, M., & Selli, S. (2023). Impact of kernel size and texture on the in vivo and in vitro aroma compounds of roasted peanut and peanut paste. *Journal of Food Composition and Analysis*, *119*, 105260. https://doi.org/10.1016/j.jfca.2023.105260

Fernandes, S. S., & Salas-Mellado, M. de las M. (2017). Addition of chia seed mucilage for reduction of fat content in bread and cakes. *Food Chemistry*, *227*, 237-244. https://doi.org/10.1016/j.foodchem.2017.01.075

Firmo, A. Q., Sousa, M. M. de, & Cavalcanti, M. da S. (2020). Development and characterization of cashew nut drinks (Anacardium occidentale L.). *Research, Society and Development*, *9*(1), e84911645. https://doi.org/10.33448/rsd-v9i1.1645

Horuz, E., Bozkurt, H., Karataş, H., & Maskan, M. (2018). Simultaneous application of microwave energy and hot air to whole drying process of apple slices: drying kinetics, modeling, temperature profile and energy aspect Association of Official Analytical Chemists. *Heat and Mass Transfer*, *54*, 425-436. https://doi.org/10.1007/s00231-017-2152-y

Junqueira, L. A., Amaral, T. N., Félix, P. C., Botrel, D. A., Prado, M. E. T., & de Resende, J. V. (2019). Effects of change in PH and addition of sucrose and NaCl on the emulsifying properties of mucilage obtained from Pereskia aculeata Miller. *Food and Bioprocess Technology*, *12*(3), 486-498. https://doi.org/10.1007/s11947-018-2223-1

Kobayasi, T. M., Palmieri, D. A., & Bertão, M. R. (2023). Caracterização química e atividade antioxidante da mucilagem em pó de ora-pro-nobis. *Journal of Biotechnology and Biodiversity*, *11*(1), 18-24. https://doi.org/10.20873/jbb.uft.cemaf.v10n3.kobayasi

Larrauri, J. A., Rupérez, P., & Saura-Calixto, F. (1997). Effect of drying temperature on the stability of polyphenols and antioxidant activity of red grape pomace peels. *Journal of Agricultural and Food Chemistry*, *45*(4), 1390-1393. https://doi.org/10.1021/jf960282f

Lemos, M. R. B., Siqueira, E. M. de A., Arruda, S. F., & Zambiazi, R. C. (2012). The effect of roasting on the phenolic compounds and antioxidant potential of baru nuts [Dipteryx alata Vog.]. *Food Research International*, *48*(2), 592-597. https://doi.org/10.1016/j.foodres.2012.05.027

Lima, D. S., Egea, M. B., Cabassa, I. de C. C., Almeida, A. B. de, Sousa, T. L. de, Lima, T. M. de, Loss, R. A., Volp, A. C. P., Vasconcelos, L. G. de, Dall'Oglio, E. L., Hernandes, T., & Takeuchi, K. P. (2021). Technological quality and sensory acceptability of nutritive bars produced with Brazil nut and baru almond coproducts. *Lwt*, *137*, 110467. https://doi.org/10.1016/j.lwt.2020.110467

Lima Junior, F. A., Conceição, M. C., Vilela de Resende, J., Junqueira, L. A., Pereira, C. G., & Torres Prado, M. E. (2013). Response surface methodology for optimization of the mucilage extraction process from Pereskia aculeata Miller. *Food Hydrocolloids*, *33*(1), 38-47. https://doi.org/10.1016/j.foodhyd.2013.02.012

Lira, M. M., Filho, J. G. de O., Sousa, T. L. de, Costa, N. M. da, Lemes, A. C., Fernandes, S. S., & Egea, M. B. (2023). Selected plants producing mucilage: Overview, composition, and their potential as functional ingredients in the development of plant-based foods. *Food Research International*, *169*, 112822. https://doi.org/10.1016/j.foodres.2023.112822

Lise, C. C., Marques, C., da Cunha, M. A. A., & Mitterer-Daltoé, M. L. (2021). Alternative protein from Pereskia aculeata Miller leaf mucilage: technological potential as an emulsifier and fat replacement in processed mortadella meat. *European Food Research and Technology*, *247*(4), 851-863. https://doi.org/10.1007/s00217-020-03669-8

Liu, Z., Liu, M., Meng, J., Wang, L., & Chen, M. (2024). A review of the interaction between diet composition and gut microbiota and its impact on associated disease. *Journal of Future Foods*, *4*(3), 221-232. https://doi.org/10.1016/j.jfutfo.2023.07.004

Martin, A. A., de Freitas, R. A., Sassaki, G. L., Evangelista, P. H. L., & Sierakowski, M. R. (2017). Chemical structure and physical-chemical properties of mucilage from the leaves of Pereskia aculeata. *Food Hydrocolloids*, *70*, 20-28. https://doi.org/10.1016/j.foodhyd.2017.03.020

Masugossa, M. J., Mendoza, V. da S., Ortega, N. de F., Yahagi, S. S., de Souza, C. J. F., & Argandoña, E. J. S. (2023). Use of Ora-pro-nóbis (Pereskia aculeata Miller) mucilage as a wall material in microencapsulation by complex coacervation. *Acta Scientiarum - Technology*, *46*(1), e64375. https://doi.org/10.4025/actascitechnol.v46i1.64375

Maywald, M., & Rink, L. (2022). Zinc in human health and infectious diseases. *Biomolecules*, *12*(12), 1748. https://doi.org/10.3390/biom12121748

Munteanu, I. G., & Apetrei, C. (2021). Analytical methods used in determining antioxidant activity: A review. *International Journal of Molecular Sciences*, *22*(7), 3380. https://doi.org/10.3390/ijms22073380

Nascimento, B. de S., Batista, G. A., Pravato, V. T., Alexandre, G. P. de L., Veríssimo, L. A. A., & Resende, J. V. (2023). Thermodynamic analysis of water vapor adsorption onto freeze-dried ora-pro-nobis (Pereskia aculeata Miller) mucilage. *Journal of Engineering and Exact Sciences*, *9*(6), 16200-01e. https://doi.org/10.18540/jcecvl9iss6pp16200-01e

Oliveira, N. L., Rodrigues, A. A., Oliveira Neves, I. C., Teixeira Lago, A. M., Borges, S. V., & de Resende, J. V. (2019). Development and characterization of biodegradable films based on Pereskia aculeata Miller mucilage. *Industrial Crops and Products*, *130*, 499-510. https://doi.org/10.1016/j.indcrop.2019.01.014

Reis, A. F., & Schmiele, M. (2019). Características e potencialidades dos frutos do Cerrado na indústria de alimentos. *Brazilian Journal of Food Technology*, *22*, e2017150. https://doi.org/10.1590/1981-6723.15017

Silva, K., Machado, A., Cardoso, C., Silva, F., & Freitas, F. (2020). Rheological behavior of plant-based beverages. *Food Science and Technology*, *40*(Suppl. 1), 258-263. https://doi.org/10.1590/fst.09219

Viana, H. N. A. C., Sganzerla, W. G., Castro, L. E. N., & Veeck, A. P. de L. (2023). Characterization of baru (Dipteryx alata Vog.) and application of its agro-industrial by-product in the formulation of cookies. *Journal of Agriculture and Food Research*, *12*, 100577. https://doi.org/10.1016/j.jafr.2023.100577

Wagener, E. A., & Kerr, W. L. (2018). Effects of oil content on the sensory, textural and physical properties of pecan butter (Carya illinoinensis). *Journal of Texture Studies*, *23*(4), 286-292. https://doi.org/10.1111/jtxs.12304

Zhang, D., Guo, X., Wang, Q., Zhao, L., Sun, Q., Duan, X., Cao, Y., & Sun, H. (2022). Investigation on lipid profile of peanut oil and changes during roasting by lipidomic approach. *LWT - Food Science and Technology*, *154*, 112594. https://doi.org/10.1016/j.lwt.2021.112594