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Development of functional cookies with Cerrado fruits and residues: sensory analysis, nutrients, and bioactive compounds

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Abstract

In this study, we determined the nutritional and functional characteristics of cookies supplemented with chichá almond, gurguéia nut, and soursop residue using two developed cookie formulations and one standard formulation. Acceptance and purchase intention were evaluated. As the chichá almond 6 and gurguéia nut 2 formulations were sensorially viable, descriptive quantitative analysis, centesimal composition and caloric value, mineral levels, microbiological quality, bioactive compound levels, and antioxidant capacity were evaluated. In the hedonic scale test of the standard cookie, the chichá almond-6 and gurguéia nut-2 cookies obtained scores above 7 ("I liked it") from 86.18%, 96.35%, and 93% of the evaluators, and 70.79%, 94.36%, and 83.2% of them said they would purchase the product, showing a statistically significant difference between formulations. The chichá almond 6 cookie presented higher ash, protein, lipid, copper, phosphorus, magnesium, potassium, selenium, and zinc levels, and lower carbohydrate levels and total energy values, as well as a higher total phenolic compound, total flavonoid, and condensed tannin levels. The gurguéia nut 2 cookie showed higher vitamin C and antioxidant activity. The use of residue and Cerrado fruit flour proved to be viable in cookie production, conveying sensorially desirable, nutritional, and functional characteristics.

Keywords: Antioxidant compounds; integral cookie; soursop; chichá almond; gurguéia nut.

Practical Application: Cerrado fruits and residue generated in fruit pulp production are excellent raw materials for the preparation of products such as cookies and are used as an alternative to avoid the impact of residue disposal in the environment. Cookies supplemented with fruit pulp residue and Cerrado nuts and almonds can increase the consumption of nutrients and bioactive compounds that are associated with health benefits. They can be incorporated into the diet since this type of food is generally well accepted across all age groups.

1 Introduction

In Brazil, the modernization of agriculture and industrialization has increased the importance of fruits in the national agribusiness. A large proportion of these fruits are processed by the pulp and juice industries, and about 40% of these raw materials become industrial residue (Souza & Correia 2010). Since the volume of residue generated is countless tons, adding value to these byproducts is of economic, social, scientific, and technological importance (Farias Silva et al., 2016).

Soursop is a tropical plant of the family Annonaceae, species *Annona muricata* L. In natural medicine, parts of the soursop (bark, roots, leaves, pulp, and seeds) that contain nutrients rich in bioactive compounds with antioxidant action have been used as anti-inflammatory and anticancer agents (Moghadamtousi et al., 2015). It is also one of the most commercially accepted Brazilian tropical fruits for its sensory characteristics (Junqueira & Junqueira, 2014).

Chichá almond *(Sterculia striata* A. St. Hil & Naudin) is an endemic Brazilian species, popularly known as chichá-do-cerrado and amendoim-do-campo, that is found in the north, northeast, central-west, and southeast regions of Brazil (Flora do Brasil, 2017). They have high lipid, carbohydrate, protein, dietary fiber, calcium (Ca), zinc (Zn), and iron (Fe) contents, and are a source of nutrients available in national and international markets (Silva & Fernandes, 2011; Fráguas et al., 2015).

Gurguéia nut (*Dipteryx lacunifera Ducke*), also known as castanha-de-burro, fava-de-morcego and garampara, is native to the mid-north region of Brazil and is mainly found in the southern and central-southern Cerrado region of the states of Piauí and Maranhão. These nuts are rich in lipids, proteins, ashes, and dietary fibers (Carvalho et al., 2008; Queiroga Neto et al., 2009), in addition to bioactive compounds.

According to the Brazilian Association of Cookie, Pasta, and Industrialized Bread & Cake Industries (Associação Brasileira das Indústrias de Biscoitos, Massas Alimentícias e Pães & Bolos Industrializados, 2019), the cookie intake in Brazil in 2019 was 7.021 Kg per inhabitant. Thus, the addition of flours with fruit residues, which are rich in nutrients, bioactive compounds, and dietary fibers, could be considered a viable option to enhance

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cookie production, by adding high nutritional and functional value to the products (Uthumporn et al., 2015). In addition, cookies are widely consumed due to their convenience and low cost (Köten, 2021).

To meet the needs of a population increasingly concerned with quality of life, food industries have developed functional products (containing bioactive compounds) that are safe for ingestion and provide a health benefit (Shahzad et al., 2021).

From this perspective, the objective of this study was to develop, sensorially analyze, and determine the nutrient and bioactive compound composition of functional cookies made with chichá almond and gurguéia nut flour and soursop residue.

2 Materials and methods

2.1 Raw materials

Chichá almonds were supplied by Chácara São Carlos, located in Teresina, Piauí, Brazil. Gurguéia nuts were purchased from the Vão dos Negros farm, in Landri Sales, Piauí, Brazil. Soursop residue was obtained from the Fruta Polpa company, in Teresina, Piauí, Brazil. The raw materials were packed in 1.0 kg polyethylene bags and kept at -18 °C until flour production. Other raw materials were purchased from local stores.

2.2 Flour production

The soursop residue was dried in a ventilated oven (314D242 model, São Paulo, Brazil) for three hours at 60 °C. The gurguéia nuts and chichá almonds were manually extracted from their shells. The flours were produced by triturating the raw materials in a blender (Problend 4) for ten minutes and then sifting through a 5-mesh sieve.

2.3 Cookie production

An adapted standard formulation was used in the production of the functional cookies (Santos et al., 2014) and two formulations were developed (Table 1). The formulations with the highest acceptance were the chichá almond (CC-6) and gurguéia nut (GC-2) cookies.

Table 1. Raw materials and quantities used to prepare the cookies.

Raw materials	Type of cookie		
	SC (%)*	CC-6 (%)**	GC-2 (%)***
Gurgueia nut flour	-	-	5–25
Chichá almond flour	-	15–35	-
Soursop residue flour	-	5–25	5–25
Whole wheat flour	-	25–65	25–65
Refined wheat flour	35.50	10–25	10–40
Crystal sugar	39.74	15–45	15–45
Honey	-	5–25	5–25
Free-range chicken egg	9.09	15–40	15–40
Butter	14.95	15–55	15–55
Chemical yeast	0.71	1–5	1–5

*Standard cookies (SC); **Chichá almond cookies (CC-6); ***Gurguéia nut cookie (GC-2).

The raw materials were weighed, manually mixed, and homogenized. The dough was rolled out using a roller and cut with a star-shaped cutter. The raw cookies were distributed in a rectangular pan greased with butter and refined wheat flour and baked in an oven at 200 °C for 15 to 20 min. After baking and cooling at room temperature, the cookies were packed and stored in hermetically sealed glass containers for subsequent analyses (Figure 1).

2.4 Sensory analysis

The development and sensory analysis of the cookies were conducted in the Laboratory of Product Development and Sensory Analysis of Food (LASA). The sensory analysis was performed by 116 non-trained evaluators, after signing an Informed Consent Form. Sensory analysis tests were performed as described by Dutcosky (2013). The samples were monadically offered in balanced complete blocks, coded with random three-digit numbers, in two sessions with four repetitions. A hedonic scale of 9 points was used to analyze product acceptance, while purchase intention was determined by the five-point scale test, and the quantitative descriptive analysis (QDA) was performed by a team of five trained sensory evaluators.

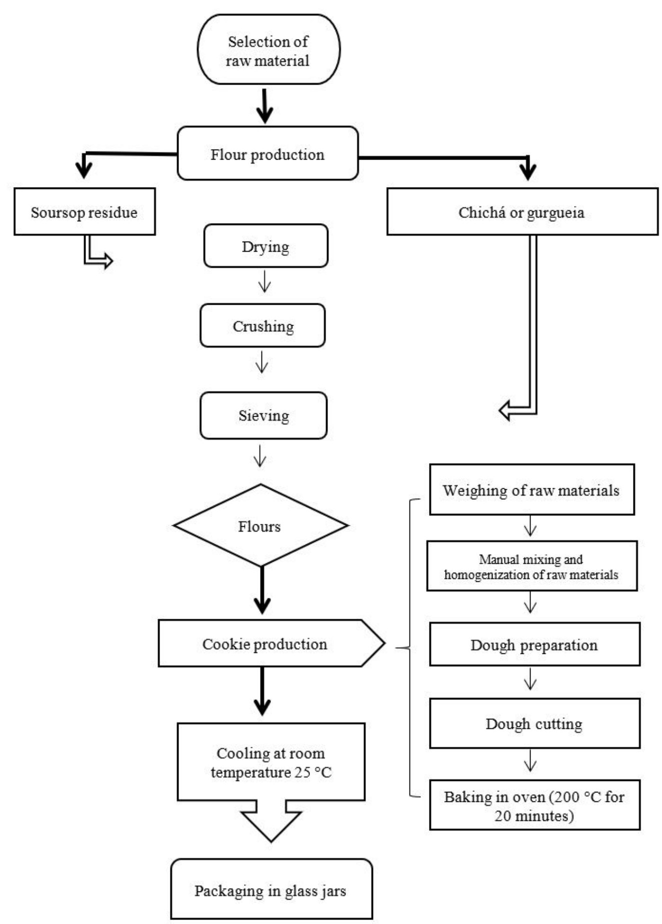

Figure 1. Flowchart of the production of functional cookies supplemented with soursop, chichá almond, and gurguéia nut residues.

2.5 Microbiological analysis

Microbiological analyses were performed at the Center for Studies, Research and Food Processing (NUEPPA) of the Agricultural Sciences Center of the UFPI. Positive coagulase *Staphylococcus* and *Salmonella* spp. were determined at 55 and 45 °C, according to the Methods Manual for Microbiological Food Analysis (Silva et al., 2007), and the results were analyzed according to the microbiological food analysis methods manual (Silva et al., 2007) and the current legislation on microbiological standards for food (Brasil, 2001).

2.6 Centesimal composition and total energy value (TEV)

The analyses were performed in the Laboratory of Food Bromatology and Biochemistry (LABROMBIOQ) of the Department of Nutrition of the UFPI. Moisture, ash, protein, lipid, and carbohydrate contents were determined according to the methods described in the AOAC analytical standards (Association of Official Analytical Chemists, 2005). TEV was estimated according to the Atwater conversion values proposed by Watt & Merrill (1963).

2.7 Mineral levels

Mineral levels were quantified by a researcher from ITAL Campinas, SP, using an inductively coupled plasma optical emission spectrometer (ICP-OES) equipped with a 27 MH solid-state radiofrequency (RF) source. The system uses liquid argon with a minimum purity of 99.996% (Air Liquide, Brazil) as plasma gas. The optimized ICP-OES operating conditions were RF power 1.20 Kw, nebulization flow rate 0.70 L min^{-1}, auxiliary argon flow rate 1.0 L min^{-1}, argon flow rate 12 L min^{-1}, reading time 7.0 s, stabilization time 15 s, three replicates, and wavelengths Ca (317.933), Cu (324.754), Fe (259.940), Na (589.592), P (213.618), Mg (279.953), Se (196.026), Mn (257.610), K (766.491), and Zn (206.200). Analytical curves for the minerals were prepared from diluted analytical standards.

2.8 Determination of bioactive compounds and antioxidant activity

The extracts were prepared according to the methodology adopted by Rufino et al. (2010). The solvents used for antioxidant compound extraction included methanol (50%), acetone (70%), and distilled water in a 2:2:1 ratio.

The content of phenolic compounds was determined by the spectrophotometric method using the Folin-Ciocalteau reagent (Singleton & Rossi, 1965); results were obtained by comparison with the standard gallic acid curve and were expressed as mg of gallic acid·100 g^{-1} of sample. Flavonoids were determined by the spectrophotometric method reported by Kim, Jeong, and Lee (2003) and modified by Blasa et al. (2006). Total condensed tannin content was obtained by a spectrophotometric method (Price & Scoyoc et al., 1978) using vanillin as a reagent. Vitamin C was determined by Tillman's method Vitamin C was determined by Tillman's titrimetric method modified by Benassi & Antunes (1988). Antioxidant activity was analyzed by DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical capture and the results were expressed as Trolox µmol/100 g.

2.10 Statistical analysis

The results were analyzed in the Statistical Package for the Social Sciences software version 25 (2020), expressed as means and standard deviation. The ANOVA multiple analysis and Tukey's test were used to verify differences between the means of the formulations considering a 5% significance level ($p \leq 0.05$) and a 95% confidence interval, respectively.

2.11 Ethical aspects

This study is part of a project entitled "Preparation of products using regional raw materials," approved by the Research Ethics Committee of the Federal University of Piauí under opinion No. 750.942. The research participants voluntarily signed the Consent Form, in accordance with Resolution no. 466 of the National Health Council (Brasil, 2012).

3 Results and discussion

In the hedonic scale test, CC-6 was scored above 7 ("I liked it") by the evaluators (96.55%), and GC-2 was never scored below 6 (93%). The comparison of CC-6 with GC-2 and SC showed that CC-6 obtained the highest acceptance. Lima et al. (2014) obtained similar acceptance results (97.94%) for cookies enriched with acerola residue and wheat flour. The purchase intention test showed that most subjects would purchase CC-6 (94.36%), GC-2 (83.2%), and SC (70.79%). The purchase intention scores for CC-6 and GC-2 were between 4 ("would probably purchase") and 5 ("would certainly purchase"), respectively, unlike the SC, which obtained 15% grade 2 (probably would not purchase) and 5.31% grade 1 (certainly would not purchase), showing significant differences ($p = 0.029$) between formulations.

In QDA, the trained evaluators characterized the CC-6 cookie as visually similar to a whole wheat/cracknel cookie, of light brown color, almond aroma, and flavor and slightly sweet, with a crunchy and soft texture. GC-2 was characterized as visually similar to a whole wheat cookie, light brown toasted color with pieces of chestnut, chestnut and soursop flavor, chestnut aroma, and crunchy texture.

CC-6 and GC-2 presented coliform counts at 55 °C of 9.4 most probable number (MPN) and 7.4 MPN, respectively. The legislation in force does not determine values for this microorganism. Coliform values at 45 °C were lower than 3.0 MPN/g (tolerance of 10 MPN/g); coagulase-positive *Staphylococcus* lower than 1×10^1 CFU/g (tolerance of 5×10^2 CFU/g); and absence of *Salmonella* sp. in 25 g (absence limit). Therefore, the results showed that the raw materials were adequately hygienic and sanitary and that the cookies were prepared with good handling practices, and therefore suitable for consumption.

The centesimal composition data and TEV for SC, CC-6, and GC-2 cookies are presented in Table 2.

The result showed a significant difference ($p \leq 0.05$) between SC, CC-6, and GC-2 cookie formulations. CC-6 and GC-2 presented mean moisture values within the range established by the Brazilian legislation (Brasil, 2005), which establishes a maximum value of 15% moisture in cookies. Felisberto et al. (2019) developed cookies that use young bamboo culm flour as a sugar and/or fat substitute and reported a moisture content between 4.97 and 5.50%. These values considered adequate, as well as the study. Low moisture content favors conservation and indicates a longer shelf life.

As for ash content, which represents the amount of minerals in the product, CC-6 had an ash content of 1.74%, GC-2 1.49%, while the standard was 1.02%. The legislation (Brasil, 2005) recommends a maximum of 3% ash, with the percentages obtained in this research therefore being within the recommended levels. Brites et al. (2019) developed millet flour cookies and reported a lower ash content (0.80%) than those observed in this study. Rosolen et al. (2018) analyzed cookies made with orange peel flour as a partial wheat flour substitute, obtaining an ash content variation of 0.82 to 1.51%, with higher ash contents (fixed mineral residue) being seen with higher orange peel flour concentrations.

CC-6 presented a protein content of 5.68%, higher than GC-2 (4.42%) and SC (3.81%). Freitas et al. (2014) obtained a mean of 3.77% when evaluating cookies with pumpkin seed and baru nut flour, a lower result than that found in the present study. The higher protein content in CC-6 is associated with the chichá almond, which is a source of this nutrient. Köten (2021) analyzed cookies supplemented with terebinth, and reported a protein content from 9.67 to 10.53%, indicating that turpentine increased this nutrient. Thus, both the cookies produced by Köten (2021) and those analyzed in this study showed increased protein levels, making them more nutritive.

In terms of lipid content, CC-6 cookies presented a value of 18.1%, GC-2 17.9%, and SC 13.55%, being a source mainly of fatty acids ω-9 (oleic acid). Rosolen et al. (2018) analyzed orange peel flour cookies and obtained a variation from 12.73 to 16.95%, a value lower than the one determined.

CC-6 cookies had a carbohydrate content of 65.48%, which was lower than in GC-2 (71.214%) and SC (79.23%) cookies. Melo et al. (2017) also reported lower contents in cookies supplemented with cashew nut flour with sweetener, with a mean of 49.8%. Rosolen et al. (2018) reported higher carbohydrate levels in orange peel flour cookies, ranging from 71.59 to 75.15%. It is worth noting that fibers are also included in the 50% carbohydrate content obtained in CC-6 and GC-2.

In terms of total calories, CC-6, GC-2, and SC contained 448.26, 456.34, and 454.06 calories, respectively, showing that although the lipid content was higher in BF6, there was no increase in calories. This calorie content was lower than the one reported by Melo et al. (2017) in their cashew flour cookie, which had 551 calories.

Table 3 shows the mineral content of the prepared cookies.

Mineral analysis (Table 3) showed higher mineral contents in CC-6 and GC-2 than in SC, except for iron. CC-6 had higher copper, phosphorus, magnesium, selenium, and zinc levels, and GC-2 had higher calcium, manganese, and potassium levels.

Philippi (2018) stated that foods can be classified by their nutrient content based on the portion usually consumed with respect to the daily reference intake (recommended dietary intake or adequate intake) as a food-source, good-source, or an excellent-source. According to this classification, CC-6 and GC-2 cookies are excellent sources of copper, iron, magnesium, manganese, selenium, and zinc and sources of calcium and phosphorus. Table 4 shows their bioactive compounds and antioxidant activity.

CC-6 presented higher bioactive compound contents compared to GC-2 and SC, except for vitamin C and antioxidant activity, because GC-2 showed higher contents than CC-6 and SC. The high contents of bioactive compounds obtained in the functional cookies are associated with the soursop, chichá almond and gurguéia nut residue flours supplements. Fioravante et al. (2016) studied cookies made with caraguatá, a typical plant of the Brazilian Cerrado, and analyzed the composition of total phenolics (7.49 mg/100g), total tannins (270.71mg/100g), and the antioxidant activity (53.12 μmol Trolox/100g) and reported lower contents than the functional product analyzed in this study. According to Souza & Correia (2010), fruits are foods rich in bioactive compounds, particularly total phenolics.

In this study we report a content of 13.98 mg vitamin C/100 g in GC-2, higher than in a reported in a study by Silva et al. (2018) on pequi almond flour cookies (8.45 mg of vitamin C/100 g). Vitamin C is essential for the body as it is associated with collagen formation, iron absorption, inhibition

Table 2. Centesimal composition and total energy value (TEV) of the cookies.

Centesimal composition /TEV (g/100 g /Kcal/100)	Type of cookie		
	SC	CC-6	GC-2
	Mean ± SD*	Mean ± SD*	Mean ± SD
Moisture	2.39 ± 0.01[a]	9.21 ± 4.56[b]	5.78 ± 0.24[c]
Ashes	1.02 ± 0.01[a]	1.74 ± 0.01[b]	1.49 ± 0.00[c]
Proteins	3.81 ± 0.09[a]	5.68 ± 0.17[b]	4.42 ± 0.35[c]
Lipids	13.55 ± 0.30[a]	18.1 ± 70.18[b]	17.09 ± 0.09[c]
Carbohydrates**	79.226[a]	65.476[b]	71.214[c]
Calories	454.06[a]	448.26[b]	456.34[a]

Standard cookies (SC); Chichá almond cookies (CC-6); Gurguéia nut cookie (GC-2). *Mean of three repetitions. Equal subscript lower case letters for energy values presented no significant difference between means by the one-way ANOVA test: post Hoc multiple comparisons, the Tukey's test was used at 5% level, $p < 0.05$, CI95%; **Obtained by difference. Different subscript lower case letters show significant difference ($p < 0.05$) between the means for BP and BF6 by the Student's t-test at 5% level, $p > 0.05$, CI95%.

Table 3. Mineral content of the cookies.

Minerals (mg/100g)	Type of cookie		
	SC	CC-6	GC-2
	Mean ± SD	Mean ± SD	Mean ± SD
Calcium	21.4 ± 0.3[a]	42.8 ± 0.5[b]	50.9 ± 0.3[c]
Copper	0.071 ± 0.003[a]	0.396 ± 0.003[b]	0.337 ± 0.001[c]
Iron	3.17 ± 0.13[a]	2.54 ± 0.05[b]	2.80 ± 0.07[c]
Phosphorus	143 ± 2[a]	265 ± 2[b]	232 ± 2[c]
Magnesium	14.5 ± 0.2[a]	84.8 ± 1.1[b]	63.1 ± 1.4[c]
Manganese	0.251 ± 0.004[a]	1.23 ± 0.03[b]	2.30 ± 0.02[c]
Potassium	78 ± 1[a]	336 ± 3[b]	253 ± 1[c]
Selenium	0.043 ± 0.006[a]	0.048 ± 0.001[b]	0.027 ± 0.002[c]
Sodium	237 ± 4[a]	241 ± 7[b]	249 ± 2[c]
Zinc	0.47 ± 0.001[a]	2.07 ± 0.08[b]	1.37 ± 0.01[c]

Standard cookies (SC); Chichá almond cookies (CC-6); Gurguéia nut cookie (GC-2). Mean of three repetitions. Equal subscript lower case letters between types of cookies present no significant differences between means by the one-way ANOVA test: post Hoc multiple comparisons, the Tukey's test was used at a 5% level, $p < 0.05$, CI95%.

Table 4. Bioactive compounds and antioxidant activity of the cookies.

Bioactive compounds	Types of cookies		
	SC	CC-6	GC-2
	Mean ± SD*	Mean ± SD*	Mean ± SD*
Total phenolics (gallic acid mg/100g)	52.54 ± 0.00[a]	529.98 ± 0.00[b]	444.57 ± 0.00[c]
Total flavonoids (quercetin mg/100g)	Nd**	154.35 ± 0.00	145.67 ± 0.00
Condensed tannins (catechin mg/100g)	76.11 ± 0.00[a]	326.81 ± 0.00[b]	195.66 ± 3.36[c]
Vit C (mg vit C/100g)	Not performed	6.65 ± 0.00[a]	13.98 ±0.67[b]
Antioxidant activity (Trolox µmol/100g)	690.80 ± 0.00 [a]	1190.57 ± 0.00[b]	1217.35 ± 8.55[c]

*Mean of three repetitions. Equal subscript lower case letters between types of cookies present no significant differences between means by the one-way ANOVA test: post Hoc multiple comparisons, the Tukey's test was used at a 5% level, $p < 0.05$, CI95%. **Nd: Not detected.

of nitrosamine formation, immune defense, and antioxidant activity (Cavalari & Sanches, 2018).

Antioxidant action is directly related to the bioactive compounds present, their chemical structure, and the concentration of these phytochemicals in food. Bioactive compounds such as phenolics, flavonoids, tannins, and vitamin C are natural sources of antioxidants, substances that, when consumed, reduce the presence of free radicals responsible for several pathologies related to oxidative stress, such as noncommunicable diseases (NCDs) (Schiassi et al., 2018; Singh et al., 2018).

4 Conclusion

The developed cookies presented adequate hygienic and sanitary quality for consumption. They were sensorially accepted, indicating a potential market for the products, in addition to the use of a byproduct discarded in nature, thus minimizing the negative environmental impacts. CC-6 presented characteristics of whole wheat/cracknel cookies: light brown color, almond aroma and flavor, and slightly sweet with a crunchy and soft texture. GC-2 cookies were characterized as having a whole wheat appearance, light brown toasted color with pieces of chestnut, chestnut and soursop flavor, chestnut aroma, and crunchy texture. They showed higher protein, ash, lipid, and bioactive compound contents, highlighting their antioxidant activity compared to the standard cookie. Thus, the use of residue flours from the fruit pulp industry and regional raw materials proved to be feasible in cookie production, imparting desirable and functional characteristics to produce a healthier and more economical food.

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