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FOOD TECHNOLOGY

Development of candy "paçoca" from pequi almond

Núbia Francisca de Oliveira Prado[1] **Rafaela Anunciação Siqueira**[1] **Rosana Maria Pereira Silva**[1] **Danusa Silva da Costa**[1] **Caroline Cagnin**[2] **Geovana Rocha Plácido**[1*]

[1]Departamento de Ciência de Alimentos, Instituto Federal Goiano (IF Goiano), 75901-970, Rio Verde, GO, Brasil. E-mail: geovanarochaplacido@yahoo.com.br. [*]Corresponding author.
[2]Departamento de Ciência dos Alimentos, Universidade Estadual de Londrina (UEL), Londrina, PR, Brasil.

ABSTRACT: The pequi has an almond with interesting chemical characteristics, such as considerable proportions of proteins and lipids that can be applied in several products aiming to use this agro-industrial residue. This research tookadvantage of the almond for the development of sweet paçoca with different concentrations of pequi almond, containing 0% (PA), 25% (P1), 50% (P2), 75% (P3), and 100% (P4) in place of peanuts. The paçocas were evaluated for proximate parameters and water activity, mineral content, color parameters, microbiological characteristics, and texture profile. The results for aw ranged from 0.48 to 0.52. In the proximate composition, it was observed that with the increase of the almond flour there was a difference in the ash, moisture, and protein contents. Due to the almond roasting process, the paçocas of pequi presented the darkest color. Pequi almond paçocas showed better protein value than peanut paçoca and higher levels of P and Mg. In addition, they present better elasticity, chewability, and cohesiveness.
Key words: *Caryocar brasiliense* Camb., minerals, new products, residue, texture.

Desenvolvimento de doce de paçoca de amêndoa de pequi

RESUMO: O pequi possui uma amêndoa com características químicas interessantes, como proporções consideráveis de proteínas e lipídios que podem ser aplicadas em diversos produtos visando o aproveitamento desse resíduo agroindustrial. O objetivo deste trabalho foi aproveitar a amêndoa para o desenvolvimento de paçoca doce com diferentes concentrações de amêndoa de pequi, contendo 0% (PA), 25% (P1), 50% (P2), 75% (P3), e 100% (P4). As paçocas foram avaliadas quanto aos parâmetros centesimais e atividade de água, teor de minerais, parâmetros de cor, características microbiológicas e perfil de textura. Os resultados para aw variaram de 0,48 a 0,52. Na composição centesimal, observou-se que com o aumento da farinha de amêndoa houve diferença nos teores de cinzas, umidade e proteína. Devido ao processo de torrefação da amêndoa, as paçocas de pequi apresentaram cor mais escura. A paçoca de amêndoa de pequi apresentou melhor valor proteico que a paçoca de amendoim e maiores teores de P e Mg. Além disso, apresentaram melhor elasticidade, mastigabilidade e coesividade.
Palavras-chave: espectroscopia de reflectância difusa, sensores hiperespectrais, forragem, agricultura de precisão.

INTRODUCTION

The Cerrado is the second largest biome in Brazil, standing out for its occupation, which represents an average of 24 to 25% of the national territory, and harboring numerous native species that are studied to generate economic income for both local populations and large industries (BATLLE-BAYER et al., 2010). Although, the Cerrado is recognized for having enormous biodiversity, unfortunately, this is a biome that is among the most endangered ecosystems in the world, so the most reused ecosystems and application of its fruits are of paramount importance for income generation and consequent preservation of the environment (LIMA et al., 2021).

Pequi (*Caryocar brasiliense* Camb.) is the fruit of the pequizeiro, a cerrado tree that has a rounded shape and is composed of the epicarp, mesocarp and endocarp (TORRES et al., 2016). The pequi almond, morphologically called endocarp, is the least known among the almonds popularly consumed. Although, it is not widespread, it can be put to good use both in cooking and in the production of cakes, sweets, and several other dishes. Oil can be extracted from pequi almonds, have about 50%, and used as a source of protein, have about 20% (SOUSA et al., 2011).

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RABÊLO et al. (2008), used techniques for the extraction, drying, and roasting of the pequi almond, to analyze and evaluate the preferences and better acceptance concerning the roasting time of the almonds. The authors emphasized that almonds roasted in 30 minutes at 130 ºC showed better acceptance and had better sensory characteristics of color and texture. The pequi almond extraction process took place through pulping, cooking, and the use of a guillotine.

Paçoca is a traditional sweet from Brazil whose main ingredient is peanuts, roasted and ground. It is a product with enormous acceptability by the consumer market. In the production of paçoca, other ingredients are added: flour, sugar, cornmeal, honey, and fat, and, later, molding and pressing is carried out to give it a characteristic shape (WANG et al., 1999; LEMOS JUNIOR et al., 2016). Aiming the use of pequi almonds, seeking a way to attribute value to the agro-industrial by-product, the objective was to develop sweet paçocas with different concentrations of pequi almonds and analyze them in terms of their proximate composition, the proportion of minerals, texture, and color.

MATERIALS AND METHODS

The pequi used in the research were donated by family farmers located in the city of Jataí – GO – BR at latitude 17° 52’ 33’’ and longitude 51° 43’ 17’’. The pequi were sent to the Laboratório de Frutas e Hortaliças of the Instituto Federal Goiano – Campus Rio Verde and pulped. The endocarps were dried by natural drying at room temperature and in an airy environment for 15 days. Subsequently, they were cut in half with the aid of a guillotine and a stainless steel knife to remove the almond from the pequi. The almonds were placed in a plastic container with drinking water for 1 h, to soften and facilitate the manual removal of the skin that surrounds the pequi almond. After removing the skin, the almonds were sanitized in a 200 ppm active chlorine solution for 5 min and rinsed in running water.

The almonds were distributed on aluminum baking sheets and placed in an oven (Marconi model MA035) with air circulation at 70 °C for 4 h and 130 °C for 20 min, as described by RABÊLO et al. (2008). Afterward, the almonds were ground with the aid of a multiprocessor (Philips Walita Viva 750 W) until obtaining a fine flour with a granulometry of 60 mesh (LIMA et al., 2021).

Production of pequi paçoca

The production of pequi paçoca occurred as described by LIMA et al. (2015) with some modifications. In a multiprocessor the ingredients were placed individually for each formulation (Table 1) and they were beaten at speed 2 for two minutes, after which a volume of this mixture was placed and manually pressed to obtain the paçocas with the aid of cylindrical forms measuring 25 mm in diameter x 30 mm in height of PVC-polyvinyl chloride. The paçocas were named according to the percentage of peanut replaced, with the sample with 100% peanut as standard (PA), and the others 25% P1, 50% P2, 75% P3, and 100% P4.

After preparation, the samples were placed in plastic pots and kept in an airy environment until further analysis was performed. The manufacturing process took place by the norms of Manual de Boas Práticas RDC nº 275 (BRASIL, 2002).

Water activity

Water activity was quantified by Hygroplam equipment (Model Awl®) at 25 °C.

Centesimal composition

The proximate composition (moisture, ash, proteins, and lipids) was determined according to the AOAC (1995) and carbohydrates by difference. The total energy value was estimated from the Atwater conversion, considering the conversion of 4 $kcal.g^{-1}$ for proteins, 4 $kcal.g^{-1}$ for carbohydrates, and 9 $kcal.g^{-1}$ for lipids (MERRIL & WATT, 1973). Phosphorus, calcium, magnesium, copper, iron, manganese, zinc, and sodium contents were analyzed in the samples with

Table 1 - Formulation of standard paçoca and paçocas with different concentrations of pequi almond.

Ingredients (%)	0%	25%	50%	75%	100%
Peanut (g)	50	37.5	25	12.5	-
Pequi almond (g)	-	12.5	25	37.5	50
Sugar (g)	29	29	29	29	29
Cassava flour (g)	20	20	20	20	20
Salt (g)	1	1	1	1	1

the aid of an Atomic Absorption Spectrophotometer, according to AOAC method 985-35 (1998).

Color

The color was measured using a colorimeter (Colorimeter Color Flex EZ) with direct reading of the reflectance of the L* coordinates (luminosity) that varies from zero (black) to 100 (white), the values of a* vary from -a* (green) to +a* (red) and the values of b* range from -b* (blue) to +b* (yellow) (HUNTERLAB, 2008).

Microbiological assessment

Microbiological evaluations were performed from thermotolerant coliform counts as described by AFNOR Validation 3M 01/02-09/89C (2016) and detection of Salmonella spp, described by AOAC 2011.03.

Texture profile analysis

The determination of the instrumental texture profile (TPA) was performed by a Texture Analyzer (CT3TM Brookfield, USA) equipped with a 25 kg load cell. The equipment was programmed with pre-test speed: 1.0 mm/s, test speed: 2.0 mm/s and post-test speed: 2.0 mm/s; 45% compression and a 5 s rest period between the two cycles; trigger force (trigger) 1.0 N, and data acquisition rate of 200 points per second (determined by pre-tests). The evaluations were carried out on 6 specimens per treatment. From the force x deformation diagram, data on hardness, adhesiveness, cohesiveness, elasticity, chewiness, gumminess, and fracturability were generated.

Statistical analysis

Data from the physical-chemical evaluations were submitted to analysis of variance (ANOVA) and comparison by Tukey's test at a 5% significance level using the Statistica® software version 7.0.

RESULTS AND DISCUSSION

The water activity (Aw) showed a significant difference considering a level of 5% among all paçoca formulations (Table 2). The increase in pequi almond flour caused an increase in Aw for formulations P2, P3, and P4. Despite the increase in Aw in the formulations with higher proportions of pequi almonds, it can be inferred that pathogenic bacteria, yeasts, and molds could not multiply, as Aw presented values lower than 0.85. In addition, spoilage bacteria and bacteria, in general, could not develop in paçocas, as the analyzed Aw presented a value lower than 0.60 (RAHMAN, 2019). Commercial paçocas analyzed by LIMA et al. (2015) presented Aw values of 0.429 and 0.295, and paçoca with cashew nut kernels presented Aw values of 0.425, a value close to that reported in this research.

The low water activity of peanut paçocas and paçocas with the addition of pequi almond demonstrated the lack of possibility of the development of microorganisms. This possibility is even lower when we prove the use of good manufacturing practices in the development of paçoca formulations, as thermotolerant coliforms (at 45 °C) and salmonella were not reported in the samples (Table 3). All formulations were presented according to the microbiological standards established by RDC nº 12 (BRASIL, 2001).

Peanut paçoca, with the addition of pequi almond and pequi paçoca showed a significant difference in ash content, with an increase in the amount of total ash as the proportion of pequi almond in the formulations increased (Table 2). This result collaborates with the proportion of minerals analyzed (Table 4). The ash values of this research were lower than those reported by SOUSA et al. (2011) and

Table 2 - Mean and standard deviation of the proximal composition and water activity of standard paçocas and paçocas with different concentrations of pequi almonds.

Analysis	----------Treatments----------				
	100%PA	25%P1	50%P2	75%P3	100%P4
Aw	0.48±0.01[c]	0.42±0.01[e]	0.47±0.01[d]	0.49±0.01[b]	0.52±0.01[a]
Ash total (%)	1.76±0.03[e]	1.88±0.10[d]	2.32±0.01[c]	2.63±0.10[b]	2.88±0.02[a]
Moisture (%)	2.89±2.01[d]	3.15±0.37[c]	3.15±0.60[c]	3.35±1.44[b]	3.39±0.36[a]
Crude protein (%)	14.33±1.51[e]	14.53±0.76[d]	15.04±0.45[b]	14.80±0.40[c]	15.11±0.61[a]
Total lipids (%)	38.40±0.99[c]	45.23±0.12[a]	45.19±0.11[b]	32.36±0.12[e]	36.01±0.51[d]
Total carbohydrate (%)	42.61±0.01[b]	35.21±0.03[d]	34.31±0.05[e]	46.86±0.07[a]	42.60±0.07[c]
Total energy value (kcal/100g)	573.36±0.01[c]	606.03±0.10[a]	604.07±1.03[b]	537.88±0.69[e]	554.98±2.56[d]

*Means followed by the same lowercase letter in each row did not differ significantly by Tukey's test at the 5% level.

Table 3 - Results of microbiological evaluations of standard paçocas and paçocas with different concentrations of pequi almond.

Attributes	Treatments				
	100%PA	25%P1	50%P2	75%P3	100%P4
Coliforms at 45°C (UFC/g)	<1x10^1 est.	<1x10^1 est.	<1x10^1 est.	<1x10^1 est.	<1x10^1 est.
Salmonella spp.	Absent/25g	Absent/25g	Absent/25g	Absent/25g	Absent/25g

ARAÚJO et al. (2018) for pequi almonds, 4.54 and 5.8%, respectively. This difference may be a result of the paçoca processing.

The moisture content was different among all paçoca formulations, corroborating the aw data, similar behavior presented by LIMA et al. (2015) and SANTOS et al. (2001) (Table 2). Both described higher values of moisture for paçocas made with an increment of nuts and lower moisture content in paçocas made only with peanuts.

The proportion of proteins in peanut paçocas and paçocas with pequi almonds was different, and the greater the increase in the almond, the greater the proportion of proteins in the food. Crude protein in the PA formulation (14.33%) was lower than in the P4 formulation (15.11%), which may be an advantage for the consumption of this product. LIMA et al. (2015) evaluated the protein content in paçoca with cashew nut kernels (16.59%) and compared it with two commercial brands (14.19 and 16.90%), reporting values close to those found in the present study.

The total lipid content showed a difference between the formulations analyzed in the study. For formulation P1 and P2, the values presented were higher than the others, in these formulations, the increment of the pequi almond increased in the proportion of lipids, this can be explained by the high proportion of lipids present in the pequi almond, around 50% (SOUSA et al., 2011; ARAÚJO et al., 2018) that collaborated with the lipids present in peanuts, which has approximately 42.74% of lipids (SANTOS et al., 2001), confirming an increase in the number of lipids in paçoca.

As for the energy value, all the paçoca formulations differed significantly. The formulations that showed a higher proportion of lipids also had a higher energy value, as described by LIMA et al. (2021) when studying paçocas de Baru almonds, reporting that the greatest impact on the energy value of foods is related to the proportion of lipids compared to the impact of carbohydrate and protein contents.

Phosphorus content (Table 4) increased with the increment of pequi almond in paçocas. SOUSA et al. (2011) and ARAÚJO et al. (2018) determined higher values for pequi almonds, 2.2%, and 1.6%, respectively. This difference may be the result of planting pequi in different regions since the soil has a different proportion of minerals according to the region and climate of the place of planting. According to the SCIENTIFIC COMMITTEE ON FOOD (2006) phosphorus, reported as phosphate,

Table 4 - Mean and standard deviation of the results of the minerals determined in the standard paçoca and paçocas with different concentrations of pequi almond.

	Treatments				
	100%PA	25%P_1	50%P_2	75%P_3	100%P_4
P (%)	0.15±0.01^e	0.20±0.01^d	0.28±0.01^c	0.39±0.01^b	0.42±0.02^a
Ca (%)	0.10±0.01^{ab}	0.13±0.01^a	0.11±0.01^{ab}	0.11±0.01^{ab}	0.09±0.01^b
Mg (%)	0.04±0.01^{bc}	0.056±0.01^{ab}	0.063±0.01^a	0.036±0.01^{bc}	0.03±0.01^c
Cu (mg/Kg)	5.67±1.15^a	8.67±1.52^a	7.67±1.52^a	8.33±1.52^a	6.33±2.51^a
Fe (mg/Kg)	146.33±19.85^a	124.33±13.50^a	134.33±6.11^a	131.67±5.68^a	131.67±14.15^a
Mn (mg/Kg)	15.00±1.00^a	18.00±1.00^a	18.33±2.08^a	17.00±1.00^a	18.00±1.00^a
Zn (mg/Kg)	23.00±6.55^a	27.33±2.08^a	25.67±1.52^a	35.67±2.51^a	28.67±9.61^a
Na (mg/Kg)	2166.67±28.67^a	2083.33±76.37^a	2090.00±36.06^a	2260.00±121.66^a	2116.67±125.83^a

[*]Means followed by the same lowercase letter in each row did not differ significantly by Tukey's test at the 5% level.

is an essential nutrient for physiological processes, including the cell’s energy cycle, regulation of acid-base balance, cellular structural component, participates in bone mineralization processes and teeth, and their food intake is of paramount importance.

As for the Ca concentration in the formulated paçocas, only the P1 formulation differed from the P4 sample, while the others were similar to each other. Similar results were reported by SOUSA et al. (2011), who determined a value of 0.09% of Ca in pequi almonds. It can be suggested that the processing of peanut paçocas and pequi almonds did not interfere with the calcium concentration already present in the pequi almond. CORMICK & BELIZAN (2019) described that calcium consumption is associated with preventing hypertensive disorders of pregnancy, lowering blood pressure, lowering LDL cholesterol levels, and preventing osteoporosis and colorectal adenomas.

Evaluating the magnesium content (Table 4) it can be seen that samples P1 and P2 were the ones that obtained the highest values about the other formulations. According to the NATIONAL INSTITUTES OF HEALTH (2017), the recommended daily dose of magnesium is 400 mg/day, which indicates that the consumption of 100 g of paçoca of formulations P1 and P2 can meet this recommendation and for formulations P3 and P4 supply 90% and 75%, respectively.

The copper, iron, manganese, zinc, and sodium contents did not show significant differences between the paçoca formulations. Copper contents were similar to those reported by SOUSA et al. (2011) and HIANE et al. (1992) who obtained values of 0.3 and 1.59 mg/Kg, respectively. When evaluating the iron content of the prepared paçocas, high levels were observed when compared to the studies by HIANE et al. (1992) who obtained values of 2.68% for pequi almonds, respectively.

As for manganese (Mn) and zinc (Zn) values, they were similar to those reported in the study by HIANE et al. (1992) who found, respectively, values of 1.44 and 5.36%. Sodium (Na) values were higher than the values reported by HIANE et al. (1992), 0.30%. It is important to emphasize that pequi almonds were produced from an agro-industrial residue and underwent cooking processes which could result in a change in their nutritional values, but it can be described that the product is a good source of minerals, principally Zn (ARAÚJO et al., 2018).

The paçoca color parameters were influenced by the increase in the concentration of pequi almonds (Table 5). The L^* value increased about the PA formulation in general, presenting lower luminosity concerning peanut paçocas. This was expected, since the almonds used for the elaboration of such formulations underwent cooking, changing the white color to a grayish color, due to the high temperature.

In the PA formulation, a^* coordinate was lower (6.60) than the formulations with pequi almonds. This means that paçocas made with pequi almonds are slightly reddish, a result that was different from that reported by LIMA et al. (2015), who produced paçoca with cashew nut almonds. The b^* coordinate for formulations P1, P2, P3, and P4 by Tukey’s test differed from each other. According to the results expressed, the paçoca of the pequi almond can be considered slightly yellowish, in the color parameter b^*.

Table 6 presents the results obtained for the texture parameters of the standard paçocas and paçocas with different concentrations of pequi almonds. It is noteworthy that the gummy parameter was replaced by the chewiness parameter.

Springiness showed no significant difference between formulations P3 and P4 and between PA and P2. The lowest value considering the springiness was for the P1 formulation, which indicates that the increase in the number of pequi almonds in the paçocas caused an increase in this property. The manual processing of paçocas can explain the fact that P3 presents greater springiness concerning P4. It is observed that P1 has the lowest

Table 5 - Mean and standard deviation of the color parameters L^*, a^* and b^* determined in the standard paçoca and paçocas with different concentrations of pequi almond.

Color parameters	---Treatments---				
	100%PA	25%P_1	50%P_2	75%P_3	100%P_4
L^*	64.97±1.58^a	61.02±1.81^c	61.68±1.04^b	57.20±1.50^e	58.18±1.05^d
a^*	6.60±0.55^e	7.38±0.45^a	7.01±0.52^d	7.10±0.37^b	7.06±0.29^c
b^*	26.67±1.21^a	26.46±0.90^b	24.27±0.65^c	23.88±0.57^d	23.02±0.47^e

[*]Means followed by the same lowercase letter in each row did not differ significantly by Tukey's test at the 5% level.

Table 6 - Mean and standard deviation of texture parameters of standard paçoca and paçocas with different concentrations of pequi almond.

Texture parameters	Treatments				
	100%PA	25%P1	50%P2	75%P3	100%P4
Springiness (mm)	0.84±0.08[b]	0.23±0.05[c]	0.31±0.05[bc]	1.88±0.26[a]	1.47±0.05[a]
Hardness (N)	15.20±2.84[a]	2.59±0.82[b]	4.52±0.47[b]	7.88±3.89[ab]	8.08±1.36[ab]
Adhesiveness (mJ)	0.50±0.15[a]	0.10±0.01[a]	0.20±0.01[a]	0.10±0.01[a]	0.10±0.11[a]
Chewiness (mJ)	4.10±1.80[b]	0.10±0.01[b]	0.23±0.03[b]	3.50±0.24[b]	9.09±0.58[a]
Cohesiveness	0.18±0.06[b]	0.08±0.01[b]	0.08±0.01[b]	0.17±0.02[b]	0.69±0.10[a]
Fractability (N)	24.62±2.84[a]	4.90±0.82[b]	8.26±0.47[b]	14.10±3.89[ab]	8.97±1.34[b]

[*]Means followed by the same lowercase letter in each row did not differ significantly by Tukey's test at the 5% level.

capacity to recover from its original height when subjected to tension (SINGH et al., 2013).

The hardness varied significantly between the paçocas and the paçoca PA had the highest hardness about the paçocas of the pequi almond. There were no significant differences considering the adhesiveness for the standard paçoca samples and those enhanced with pequi almonds. Only formulation P4 differed significantly considering the chewability and cohesiveness parameters.

For the fractability parameter, the PA formulation had a value similar to P3. Showing that with the increase in the number of pequi almonds in the paçocas there was an increase in this property, but as the paçocas were pressed manually, this process can interfere with this property, contributing to the fact that P3 was greater than P4.

CONCLUSION

Pequi almond paçocas showed better protein value than peanut paçoca and a higher amount of phosphorus and magnesium. In addition, they had low counts of heat-resistant coliforms and an absence of salmonella. The pequi paçocas were darker concerning the peanut paçocas. Texture analysis showed that pequi paçocas showed better elasticity, chewability, and cohesiveness. The paçocas made from pequi residue is an alternative that allows the creation of new products avoiding waste, allowing the generation of income for small producers, and contributing to sustainability.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analysis, or interpretation of the data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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