Quality of granola prepared with dried caju-do-cerrado (*Anacardium othonianum* Rizz) and baru almonds (*Dipteryx alata* Vog)

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Abstract The use of Brazilian Cerrado fruits and research into their nutritional potential are important for socioeconomic development and the sustainable preservation of the environment. The use of these fruits in products such as granola encourages the inclusion of healthier and more-natural foods in the diet. This study was undertaken to evaluate acceptability, microbiological, physical and nutritional characteristics and the stability of granola made from dried caju-do-cerrado and baru almonds. Granola containing Cerrado fruits had high levels of protein content (117.4 g/kg), dietary fiber (115.3 g/kg) and iron (32.1 mg/kg) and had lower moisture (57.0 g/kg), water activity (0.3), sodium (577.7 mg/kg), lipids (150.2 g/kg) and energy value (3952.2 kcal/kg) than did the control. After storage for 100 days, the granola presented adequate microbiological conditions, with acceptability scores higher than 7 assigned by 85.5 % to 95.2 % of the judges and a crunchy texture. The high nutritional potential of granola containing Cerrado fruits, coupled with its stability over 100 days of storage, may contribute to the appreciation and consumption of these fruits and meet the growing demand for healthier, more natural foods.

Keywords Fruit · Cereal products · Nutritional quality · Acceptability · Texture

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Introduction

The Brazilian Cerrado is the world's richest savanna flora, with several species producing edible fruits that stand out in terms of agricultural, economic and nutritional potential. This biome contributes significantly to the supply exotic native fruit, which has increased in worldwide interest owing to its nutritional value and unusual flavours (Roesler et al. 2007).

Among these Cerrado native fruits are the caju-do-cerrado and baru. The caju-do-cerrado (*Anacardium othonianum* Rizz) is a species of cashew apple whose pseudo-fruit is about 86 % water and contains 369 mg/kg of vitamin C and 43 g/kg of fiber (Silva et al. 2004; Silva et al. 2008). The baru (*Dipteryx alata* Vog) contains an almond (seed) in which proteins predominate (258.1 g/kg), with considerable essential amino acid content (403.2 g/kg of protein). The almond is also high in lipids (419.7 g/kg), with an emphasis on unsaturated fatty acids, especially oleic acid (483.7 g/kg of lipids), as well as fiber, vitamins and minerals (Roesler et al. 2007; Correa et al. 2008; Fernandes et al. 2010; Freitas and Naves 2010).

The nutritional potential of the caju-do-cerrado and the baru almond would encourage a greater inclusion of these Cerrado fruits in the human diet. However, it is necessary to investigate these foods as components of health-promoting food preparations (Partelli et al. 2010).

Granola is a fiber-rich product that is made by mixing cereals, whole grains, dried fruit and nuts. The heterogeneity and the combination of these foods makes it possible to include other ingredients, thus providing granola with large amounts of dietary fiber, energy, vitamins and minerals, proteins, carbohydrates and unsaturated fatty acids (Amaya-Farfan et al. 2005; Waterhouse et al. 2008).

Native fruit species of Brazil are of potential interest in the agro-industry and given the nutritional characteristics, variety of uses and the possible contribution to conservation and the sustainable use of the caju-do-cerrado and baru. The objective of this study was to evaluate the microbiological quality,

acceptability, physical and nutritional characteristics and stability of granola made with dried caju-do-cerrado and baru almonds.

Materials and methods

Materials

Basic ingredients needing for the granola preparation including raw caju-do-cerrado and roasted baru almonds were all commercially available in the State of Goiás, Brazil. Dried caju-do-cerrado was obtained through the osmotic dehydration of the pseudo-fruits in laboratory (Martins et al. 2008).

Granola preparation

The granolas were made according to the Ministry of Science and Technology (2001), with modifications (Table 1). Oat flakes made up 40 % of the control granola and their quantity varied in the Cerrado nut granolas depending on the concentrations of dried caju-do-cerrado. The oat flakes and corn flakes were toasted separately at 180 °C for 40 min with manual agitation. The Brazil nuts (manually cut into slices approximately 0.3 cm thick) and the sesame seeds were roasted for 10 min at 180 °C with manual agitation.

All of the ingredients other than the linseed, dried caju-do-cerrado or black raisins were mixed into the syrup (prepared with brown sugar, honey and water, 45 to 47° Brix) while it was still hot. The homogeneous mixture was distributed in layers about 1 cm thick into aluminum pans and placed in 180 °C electric oven (Consul, Canela 54 CF150A, São Paulo, SP, Brasil) for 40 min, with manual agitation every 10 min, until the mixture was golden and formed lumps, indicators of

crispness. Finally, the linseed and dried caju-do-cerrado or black raisins were added to the mixture while it was still hot.

After reaching approximately 25 °C the granolas were packed in polyethylene bags, sealed and placed in cardboard boxes.

Microbiological analyses

The granolas were analyzed for the presence of *Salmonella* sp., *Bacillus cereus* count, coagulase-positive staphylococci and total coliforms at 45 °C (ANVISA 2001). Yeasts and molds were also analyzed (Downes and Ito 2001). Analyses were performed in triplicate.

Sensory analyses

The granolas were evaluated for overall acceptability (flavor, aroma, texture and appearance) at the Sensorial Analysis Laboratory. The microbiological quality of the granola was assessed before the acceptance test. Untrained panel granola consumers of both sexes ($n=72$) were solicited from the staff and student population of the Federal University of Goiás (UFG) according to procedures approved by the Committee on Human Ethics Research. To evaluate the overall acceptability, the granolas were served in 10 g portions with room temperature in individual booths with red light. The samples were presented in a monadic, sequential, randomized and complete block. The appearance of granolas was judged independently of the characteristics of flavor, aroma and texture and evaluated in a complete block. The samples were served the daylight. A 9-point hedonic scale was used to evaluate the samples, with a score of 1 representing the attributes most disliked and a score of 9 for the most liked (Stone and Sidel 2004). Scores of approximately 6 were considered acceptable.

Physical and chemical analyses

The Cerrado fruit granola that enjoyed the greatest acceptance among the testers and controls underwent a chemical analysis in triplicate, with the exception of dietary fiber which was performed in quadruplicate. The moisture content of granolas was determined in a 105 °C oven (Instituto Adolfo Lutz 2005). The protein was analyzed by the semi-micro Kjeldahl method, using a factor of 6.25 for the conversion of nitrogen content into raw protein (AOAC 2005). Lipids were determined according to the method of Bligh and Dyer (1959). For ash analysis, the samples were incinerated in a 550 °C oven (AOAC 2005). The dietary fiber was estimated using the method of Prosky et al. (1988). Total carbohydrates were calculated by difference. The total energy was calculated on the basis of the Atwater conversion factors (Merril and Watt 1973). The granolas were analyzed for calcium, iron, zinc, sodium, magnesium, potassium and phosphorus. Except for

Table 1 Ingredients and proportions used in the control granola and the 5, 10 and 15 % dried caju-do-cerrado with 10 % baru almond granolas

Ingredients (%)	Granola Formulations			
	Control	Granola 5 % ^a	Granola 10 % ^a	Granola 15 % ^a
Oat flakes	40	45	40	35
Roasted cashews	5	-	-	-
Brazil nuts	5	-	-	-
Roasted baru almond	-	10	10	10
Dried caju-do-cerrado	-	5	10	15
Black raisins	10	-	-	-

^a Percentage of dried caju-do-cerrado by granola type

Each formulation also contained wheat germ, corn flakes and brown sugar (8 % each), sesame and linseed (2,5 % each), honey (5 %) and corn oil (6 %)

phosphorus, the minerals were quantified by atomic absorption spectrophotometry (Perkin Elmer Analyst 200 spectrometer, U.S.A.). Phosphorus was analyzed using colorimetry (AOAC 2005). The water activity (A_w) was analyzed in triplicate, using an Aqualab CX – 2 hygrometer. The reading was made after balancing the samples at a temperature of 25 °C.

The texture was determined in sextuplicate, using 100 g samples. We used a Kramer HDP KS5 5-Blade Shear Cell coupled to a TAXTplus Texture Analyzer (Stable Microsystems, Surrey, U.K.) with a 50 kg load cell and a compression speed of 2 mm/s until reaching a deformation of 30 % in relation to the initial height of the sample. The parameters associated with texture, force and work, were obtained from the highest peak of the force versus compression height curve. Crispness was evaluated by considering the behavior of this curve, together with the moisture content and the water activity of the samples (Takeuchi et al. 2005; Ruodaut et al. 2002).

Evaluation of stability

The Cerrado-fruit granola that was most acceptable to the judges and the control was evaluated for stability over a period of 100 days. During the storage period, microbiological analyses, acceptance tests with 84 participants and moisture, water activity and texture determinations were performed at 20-day intervals for six analysis periods from time zero (0 days) to time 5 (100 days) in accordance with the procedures described above.

Statistical analysis

The acceptability of the granolas was assessed by analysis of variance (ANOVA) and the Tukey test ($p \leq 0.05$). Student's *t*-test ($p \leq 0.05$) was used to evaluate the stability, physical and chemical characteristics of the granolas and the frequency of the sensory attribute scores was calculated at each sensory analysis point. The data for overall acceptance and appearance, moisture, water activity and texture were subjected to regression analysis. Statistical calculations were performed using the program STATISTICA (Version 7.0, StatSoft Inc., Tulsa, U.S.A.).

Results and Discussion

Microbiological quality and sensory evaluation

The microbiological conditions of control and test granolas were adequate (ANVISA 2001), indicating that ingredient quality was adequate and that good hygiene and food handling practices were followed during the preparation of the formulation.

All of the granolas were accepted by consumers. These results were confirmed by the frequency of the scores assigned by the judges. From 78 to 96 % of the judges gave the overall acceptance of the granolas a grade of 6 or higher. For appearance, the frequency of acceptability with scores above the cutoff point was 78 to 93 %. Only the granola with 15 % dried caju-do-cerrado had an average overall acceptance lower than that of the control. However, the appearance averages of the test granolas were lower than that of the control (Table 2). Intensification of fruit flavors due to dehydration might have enhanced the sensory characteristics of the granolas. Furthermore, the combination of Cerrado fruits with traditional granola ingredients may have contributed to the acceptance of the formulations with Cerrado fruits.

In line with the parameters obtained in the sensory analysis of the four granola preparations, the granola with 10 % dried caju-do-cerrado was selected for physical and chemical analysis since the fruit concentration is similar to that of the control, and there was no significant difference in the acceptability of the granolas with 5 and 15 % dried caju-do-cerrado.

Physical and chemical characteristics

Compared with the control, the granola containing 10 % dried caju-do-cerrado and baru almond had higher protein and dietary fiber levels and lower moisture, water activity, minerals (except iron), lipids, sodium and total energy content (Table 3).

The moisture values corresponding to the total water contained in food were similar to those reported by Granada et al. (2003), who found levels ranging from 52.3 to 82.7 g/kg in seven commercial brands of granola. The levels of water

Table 2 Sensory quality of control and 5, 10 and 15 % dried caju-do-cerrado with 10 % baru almond granolas

Granolas	Overall acceptance score	Frequency of acceptance (scores > 6)	Appearance scores	Frequency of acceptance (scores > 6)
Control	7.5 ± 1.26 ^a	95.8	7.7 ± 1.27 ^a	93.1
With 5 % dried caju-do-cerrado	7.1 ± 1.60 ^{a,b}	87.5	6.8 ± 1.49 ^b	80.6
With 10 % dried caju-do-cerrado	7.0 ± 1.57 ^{a,b}	83.3	7.1 ± 1.45 ^b	84.7
With 15 % dried caju-do-cerrado	6.5 ± 1.79 ^b	77.8	6.9 ± 1.79 ^b	77.8

The same letters in the same column indicate statistical similarity by the Tukey Test ($p \leq 0.05$)

Each observation is a Mean ± SD of the replicate experiments ($n=72$)

Table 3 Physical and chemical composition and Total Energy Value (VET) of the control and cerrado-fruit (10 % dried caju-do-cerrado with 10 % baru almond) granolas

Physical and chemical composition (g/kg)	Control Granola	Cerrado-fruit Granola
Moisture	72.2±0.73 ^a	57.0±3.86 ^b
Proteins	105.8±1.89 ^b	117.4±1.46 ^a
Lipids	173.2±1.99 ^a	150.2±2.36 ^b
Ash	19.1±0.13 ^a	16.6±0.07 ^b
Dietary fiber	87.0±12.85 ^b	115.3±3.12 ^a
Total carbohydrates	539.3±15.40 ^a	532.6±5.61 ^a
VET (kcal/kg)	4139.5±45.41 ^a	3952.2±45.88 ^b
Calcium (mg/kg)	409.7±5.51 ^a	368.3±2.31 ^b
Iron (mg/kg)	35.1±1.98 ^a	32.1±0.57 ^a
Zinc (mg/kg)	29.0±0.49 ^a	26.7±0.11 ^b
Sodium (mg/kg)	674.3±27.30 ^a	577.7±2.89 ^b
Phosphorus (mg/kg)	3076.7±11.55 ^a	2670.0±34.64 ^b
Magnesium (mg/kg)	1093.3±23.09 ^a	868.3±37.82 ^b
Potassium (mg/kg)	3940.0±101.49 ^a	3270.0±117.90 ^b
Water activity	0.41±0.01 ^a	0.31±0.01 ^b

The same letters on the same line indicate statistical similarity by Student's *t*-test ($p \leq 0.05$)

Each observation is a Mean ± SD of the replicate experiments ($n=3$ or $n=4$ for dietary fiber)

activity related to the available water in the food were lower than 0.6, the maximum recommended for cereal-based foods to increase shelf life (Slade and Levine 1991).

Baru almond influenced the protein and lipid content of Cerrado-fruit granola (CFG) due to the higher protein and lower fat content of these almonds (257.6 and 403.1 g/kg, respectively), compared with cashew nuts (229.3 and 465.4 g/kg) and Brazil nuts (164.5 and 635.2 g/kg) in the control granola (CG). Freitas and Naves (2010) reported higher protein content and reduced lipid content in baru almonds (262.2 and 410.4 g/kg, respectively), compared with cashew nuts (188.1 and 420.6 g/kg) and Brazil nuts (141.1 and 649.4 g/kg).

It is important to point out that the baru almond can contribute to the protein quality of foods. Proteins from these almonds satisfy most of the essential amino acid needs of school children and adults, except for the lysine and the sulfur amino acids methionine and cysteine (Freitas and Naves 2010).

A lower lipid concentration, in addition to a higher fiber content, contributed to the lower energy value of CFG, compared with GC. However, the energy levels of these granolas were close to those found by Granada et al. (2003) in commercial brands (3733.2 to 4232.8 kcal/kg). The granolas under study may be considered high-fiber foods (above 60 g/kg) (ANVISA 1998) because of the predominance of ingredients

with high fiber content, such as oat flakes (7 to 12 % fiber) (Gutkoski and Trombeta 1999), baru almond and Brazil nuts (14 and 5 % fiber, respectively) (Freitas and Naves 2010), in addition to the use of dehydrated fruits.

The ash content of the CG was possibly influenced by the higher calcium content of the Brazil nut (Welna et al. 2008) and the higher amounts of sodium and zinc in the cashew nut (Fagbemi 2008), compared with the baru almond in the CFG (Fernandes et al. 2010). The different mineral contents of the nuts and dried fruit used in each of the granolas was probably also reflected in the higher levels of phosphorus, magnesium and potassium in the CG. Both granolas had considerable amounts of iron (> 30 mg/kg).

Stability

The microbiological conditions of the CG and CFG were adequate (ANVISA 2001) during the 100 days of storage. The mean scores for overall acceptability and appearance of granola were higher than 6 (Table 4). These results were confirmed by the frequency of sensory analysis scores assigned by the judges at all analysis points during storage. There were also no significant linear or quadratic effects ($p > 0.05$) for overall acceptance and appearance during the product storage period. Thus, the judges found no significant sensory changes in the granolas during this period.

In the CG, there was a linear increasing trend in moisture ($p \leq 0.05$) with storage time ($R^2 = 69\%$). However for the CFG this relationship was more tenuous because the model explained 61 % of the variation in moisture data. For the CG and CFG, the moisture values increased over time with levels of 72.2 and 57 g/kg at time zero and 85.8 and 75.6 g/kg at time 5, respectively.

During storage, water activity (A_w) varied from 0.39 to 0.44 in the CG and from 0.3 to 0.4 in the CFG. However, the model failed to explain these variations consistently ($29\% \leq R^2 \leq 37\%$). Although small changes occurred in granola A_w , the behavior of A_w during storage was similar to that of moisture, which tended to increase. However, A_w levels were low even during the storage period, which indicates a limited amount of water susceptible to microbe development and the occurrence of degradation reactions, with a positive effect on the maintenance of an acceptable microbiological and sensory profile.

As far as texture during storage was concerned, there was little variation in mean force/g sample applied to granola for a 30 % deformation, although this behavior was not explained by linear or quadratic effects. The values for work/g sample remained stable in most of the periods, with only a slight variation from 20 to 60 days of storage. There were no significant linear or quadratic effects ($p > 0.05$).

Regarding the force and work parameters, the changes in granola moisture and A_w content did not cause much change

Table 4 Sensory quality of control granola (CG) and the cerrado-fruit granola (CFG 10 % dried caju-do-cerrado with baru almond)

Sensory analysis	Overall acceptance				Appearance			
	CG		CFG		CG		CFG	
	OAS	% A (S>6)	OAS	% A (S>6)	AS	% A (S>6)	AS	% A (S>6)
T ₀ (day 0)	8.1±1.05 ^a	97.6	7.1±1.50 ^b	90.4	7.8±0.93 ^a	97.6	7.0±1.66 ^b	85.5
T ₁ (day 20)	8.0±1.06 ^a	97.6	7.3±1.21 ^b	95.2	8.0±1.01 ^a	97.6	7.0±1.48 ^b	88.1
T ₂ (day 40)	7.9±0.89 ^a	98.8	7.4±1.08 ^b	95.2	7.9±0.88 ^a	100.0	7.1±1.72 ^b	86.9
T ₃ (day 60)	7.9±0.96 ^a	98.8	7.3±1.21 ^b	94.1	8.2±0.83 ^a	100.0	6.9±1.45 ^b	86.9
T ₄ (day 80)	8.0±0.84 ^a	100.0	7.3±1.31 ^b	92.9	8.1±1.05 ^a	97.6	7.2±1.47 ^b	86.9
T ₅ (day 100)	8.0±0.99 ^a	98.8	7.3±1.43 ^b	92.9	8.0±0.99 ^a	98.8	7.2±1.44 ^b	88.1

OAS overall acceptance score; AS appearance scores % A (S>6): % of acceptance with scores above 6

Different letters in the same score line indicate a significant difference by Student's *t*-test ($p \leq 0.05$)

Each observation is a Mean $\pm$ SD of the replicate experiments ($n=84$)

in sample texture (Fig. 1). This is because the changes in moisture content and A_w were not sufficient to trigger softening of the ingredients, especially of the starches, thus avoiding a decrease in stiffness during storage of the granolas (Fagbemi 2008).

The performance of moisture and A_w over time is closely related to the susceptibility of the sample to loss of crispness (Leistner 2000; Leite et al. 2005). The granolas had many deformation peaks in the force/g sample vs. compression height curve over the whole storage period (Fig. 1). This result may indicate a noticeable sensation of crispness when the granolas begin to be chewed, even after the 60-day shelf life of commercial granola. Thus, the small changes in moisture during storage and A_w probably contributed to the maintenance of granola crispness at desirable levels.

Conclusion

The dried caju-do-cerrado and baru almonds substitutions to black raisins and Brazilian nuts in granola influence both overall acceptability and appearance. Although the presence of Cerrado fruits significantly lowered the acceptability compared to the control, granola with Cerrado fruits appears to be a promising alternative for healthier food, since acceptability scores were above the cutoff point and maintained crispness at desirable levels. Moreover, given its considerable protein, fiber and iron content, the granola made with 10 % dried caju-do-cerrado and 10 % baru almond has high nutritional potential. It is also characterized by lower moisture, water activity, sodium and fat levels than the control. During the storage period, the concentration of moisture and water activity of cerrado-fruit granola remained low, with little variation over 100 days of storage. This had a positive effect on microbiological quality, maintenance of a crisp texture and acceptability. These characteristics may contribute to the inclusion of Cerrado-fruit granola in the market place as consumer interest in more-natural foods and healthier food increases. This may also contribute to the rational use and sustainable preservation of the Brazilian Cerrado.

Fig. 1 Force/g application curves of sample and deformation of the control (a) and cerrado-fruit granolas (b) for different compression heights over 100 days of storage. Storage times - T₀: 0 days; T₁: 20 days; T₂: 40 days; T₃: 60 days; T₄: 80 days; T₅: 100 days

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