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Influence of the Use of Sucralose in Cupuassu Candy Preparation

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Abstract The production of sweetened products has gained space due to the constant concern with the effect of the high concentrations of sugars in the human body. So, the objective of this work was to elaborate cupuassu candy, with commercial sucrose and partial substitution of sucrose by sucralose sweetener, as well as to evaluate its physicochemical, microbiological and sensorial characteristics. Two formulations were made: conventional and sucralose added (*fit*). Powder X-ray diffraction, followed by refinement of the structures by the Rietveld method, was used to estimate the sucralose contained in the sugar *fit*. Were realized microbiological, physicochemical (pH, soluble solids, titratable acidity, total acidity and reducing sugars) and sensory analysis (color, aroma, taste, texture, acidity, overall impression and purchase intent). The *fit* sugar showed concentration of 4% sucralose. Among the physicochemical parameters of the formulations tested, only the soluble solids did not differ statistically. Candy met the microbiological standards required by law. When sensorially evaluated, a significant difference was observed for all the sensorial attributes evaluated in the acceptance test. Thus, the addition of the sweetener in candy cupuassu formulations is a good choice over the composition, exhibiting good acceptance by the consumer.

Keywords: *sweetener, fruit candy, Theobroma grandiflorum*

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1. Introduction

In recent years, the change in the dietary habits of society has been notable, directed towards the consumption of products with quality, convenience, diversification, and mainly healthy [1]. The peculiarity of these foods are the reduced levels of components such as: sugars, fat and sodium. Although sugars play a key role in human metabolism, high and more frequent consumption is detrimental to health [2]. Among the problems affecting the world population due to the high consumption of sugar are obesity, diabetes, occurrence of dental caries, among others, and not least the corporal aesthetics and well-being [3,4].

The partial replacement of sucrose by sweeteners, which stimulate sweetened sensation, in food products without compromising their physicochemical and sensorial characteristics, together with the reduction of caloric value, has been studied [5]. Among the most used sweeteners is sucralose, a sweetener with sweetening power about 600 to 800 times higher than sucrose, having stability in wide variation of pH, non-chemical interaction with ingredients and good solubility [2]. It can be used as a table top sweetener in dry formulations (powdered drinks and instant desserts), combined with aromas, preservatives, condiments, jellies, breads, pastries, pasteurized products and other [6]. Due to these characteristics, the use of commercial sweeteners for partial or total sucrose replacement is increasingly common.

The sweet paste, because it contains a high sugar content, is a promising food for sucralose partial substitution of sucrose, in order to add benefits to the final product. One of the fruits commonly used in this environment is the cupuassu (*Theobroma grandiflorum*) [7,8], being one of the main fruits of the Amazon region [9]. It is appreciated by its acidic pulp of intense aroma and creamy texture, which attribute unique sensorial characteristics, making it highly suitable for the production of juices, yogurt, ice cream, jam, filling for wafers and other processed products [10,11].

The cupuassu, being a seasonal fruit, implies in the processing and maximum use in the place of the harvest, so that the fruit can be consumed by long periods. In view of this, fruit pulp processing is a way of providing the raw material with several benefits and conveniences, in addition to high acceptability, minimum volume, high nutritional value and extended shelf-life [12].

Therefore, the objective of this work was to elaborate a cupuassu candy, with commercial sucrose and partial substitution of sucrose by sucralose sweetener, as well as to evaluate its physicochemical, microbiological and sensorial characteristics.

2. Materials and Methods

2.1. Materials

To prepare the candy, pasteurized and frozen cupuassu pulp obtained from local commerce in the city of Imperatriz-MA were used. Two formulations, one containing conventional sugar (composed of sucrose, only) and one with *fit* sugar (sucrose mixed with sucralose), also obtained from the city commerce, were prepared. The other ingredients used were food grade citric acid and pectin.

2.2. Methods

The process of making the sweets was carried out at the Laboratory of Vegetable Processing of the Federal University of Maranhão (UFMA) of the city of Imperatriz - MA. The pulp was thawed and transferred to an open pan, where the cooking was carried out at atmospheric pressure, mixing manually. Conventional (conventional sweet) sugar or sweet (*fit*) sugar was added according to the formulation, gradually with the other ingredients, and then concentrated to 70 to 72 °Brix. The two formulations were prepared in three replicates, as described in Table 1.

Table 1. Formulations of cupuassu candy mass with commercial sucrose and partial substitution of sucrose by sucralose sweetener

Ingredients	Conventional	Fit
Cupuassu pulp	50% *	50% *
Conventional sugar	50% *	25%*
Fit sugar***	-	25% *
Pectin	1.2% **	2% **
Citric acid	0.5% **	0.5% **

*In relation to the total mass; ** In relation to the mass of sugar; ***Mixture of sucrose and sucralose.

After processing, the products were packed in plastic containers, previously sanitized with alcohol (70%) with a capacity of 250 g, and then cooled in a cold-water bath for 15 minutes and then stored in a refrigerator (~12 °C).

2.2.1. Physicochemical Analysis

The formulations were analyzed for pH, soluble solids content, titratable acidity, total sugars and reducing sugars. The analyzes were performed in three replicates, according to the methodologies indicated by the Analytical Standards of the Adolfo Lutz Institute [13].

In relation to the statistical analysis, a completely randomized design experiment was used to evaluate two categories of candy, conventional and *fit*, in relation to the variables: pH, Acidity, Brix, Reducing Sugar and Total Sugar.

2.2.2. Sucralose Content

To estimate the sucralose content in *fit* sugar, powder X-ray diffraction was used using a Rigaku diffractometer, model Mini Flex II, with radiation Cu Kα (λ = 1,5418 Å). The voltage and electric current used was 40 kV e 30 mA, respectively, with graphite monochromator. The diffractogram was obtained in a 2θ continuous scan from 2 to 45 ° with a step of 0.02 ° and count time of 2 seconds per step. Then, the refinement of the structures was carried out by the Rietveld method, using the *General Structure Analysis System* (GSAS) version of 2008 [14]. To perform the adjustment of the baseline diffraction pattern, the Chebyschev polynomial was used [15]. The preferred orientation was corrected using the Spherical Harmonic model [16]. The unit cells, atomic positions, scaling factor, and peak profile were refined.

2.2.3. Microbiological Analysis

Microbiological analyzes were performed following the methodology proposed by the American Public Health Association [17], where the most probable number of total coliforms and thermotolerant (MPN g^{-1}) and yeast and mold counts (UFC g^{-1}) for all replicates were determined [1].

2.2.4. Sensory Analysis

Sensory analysis was performed using Sensory Analysis Laboratory of Higher Education Unit of the South of Maranhão (UNISULMA) of the city of Imperatriz-MA, where they were asked 80 untrained tasters to participate. Samples were served in pairs simultaneously (conventional and *fit*) encoded with random three-digit numbers in plastic containers using approximately 15 g.

The team profile was evaluated by applying a questionnaire to collect data on age, gender, schooling and consumption habits related to the product analyzed in this study. To do so, the taster was asked to indicate in a structured hedonic scale of 9 points, his judgment regarding the acceptance of the product, assigning grade 9 to "I liked very much" and 1 to "disliked very much", for the attributes: color, aroma, taste, texture, acidity and overall impression [18].

The acidity and sweetness were evaluated individually on an ideal scale, ranging from "+3" to "Stronger than ideal" and "-3" to "Well less strong than ideal". Also was evaluated the buying attitude for sweets, where the taster can choose from 5 options, ranging from "certainly would buy" to "certainly would not buy" [19].

2.2.5. Statistical Analysis

It was considered an experiment in a completely randomized design, where the types of sweets were treatments (1 and 2) to evaluate the physicochemical characteristics: pH, acidity (g/100g), soluble solids (°Brix), reducing sugars g glucose/100g) and total sugars (g glucose/100g). The Shapiro-Wilk normality tests and Bartlett's homogeneity of variance tests were performed to verify the possibility of performing the T-test for independent samples [20]. These assumptions have been accepted in all cases and the samples were evaluated by the above test.

It was also considered a randomized block experiment, in which the types of sweets refer to the treatments (1 and 2) and the tasters to the blocks, to evaluate the sensory attributes: color, aroma, taste, texture, acidity, overall impression and Buy intention. Similarly, ideal scales for acidity and sweetness were evaluated. As were discrete quantitative variables, the treatments were evaluated by the Wilcoxon t non-parametric test (two paired samples) with significance of 5%, in which there are no assumptions about the data distribution, as described in the literature [20]. The data were tabulated in Excel 2016 worksheets and the tests performed in the SAS program [21]. A significance of 5% was used for all tests.

3. Results

The X-ray diffraction pattern of the *fit* sugar used (Figure 1) showed intense peaks related to sucrose and, to a lesser extent, sucralose. In addition, the spectrum showed a good baseline, indicating no traces of amorphous interferences, as well as no peaks related to other substances. Good statistical parameters were obtained from the refinement by the Rietveld method (R_p = 7,95; R_{wp} = 10,18; S = 3,05). The sucrose mass was estimated at 95.9g/100g and sucralose at 4.0g/100g. The lower amount of sucralose in the blend is explained by its high sweetening power and therefore used in low concentrations in these products [22]. Considering this result, the sweet *fit* shows the concentration of 1g of sucralose/100g in the formulation. However, this result will differ significantly in the final product, because the raw material will undergo dehydration during cooking, concentrating the solids.

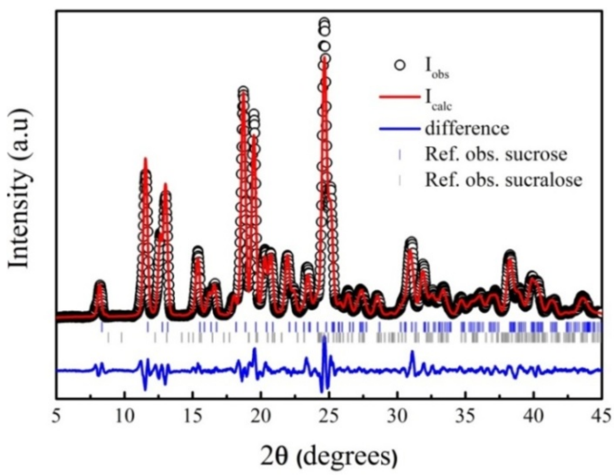

Figure 1. Rietveld refining of sugar fit, obtained from supplier

Table 2 presents the results of the physicochemical analysis of the conventional and *fit* formulations, as well as the cupuassu pulp used for its elaboration. It is observed that between the conventional and *fit* formulations there is a significant difference for the attributes pH, acidity and reducing and total sugars, while the soluble solids did not differ statistically.

The cupuassu pulp presented a low pH (2.97), being this characteristic of the fruit favorable for the elaboration of jellies and candy mass, since, it allows the formation of the gel. According to the pectin used, this parameter must be between 3.0 and 3.4 [23]. A similar result was observed in the study of twenty pulps of cupuassu, in which pH ranges between 2.80 and 3.58 [24].

The results of pH and titratable acidity of the products confirm a slight reduction of dissociated ions of both elaborated formulations, in relation to the cupuassu pulp. This reduction can be attributed to the addition of sucrose, which corrects it, displacing the ionic balance. The *fit* formulation, containing sucralose in the composition, showed a significant difference ($p \leq 0.05$) for pH and titratable acidity. This difference can be attributed to variables related to processing, such as temperature and cooking time.

The pH of both formulations is considered satisfactory, since they are below 4.5, making it difficult to proliferate several microorganisms, in addition to complying with the limits established by Brazilian legislation [25]. The acidity factor may still be directly related to the product acceptance result, since it does not differ significantly in relation to the original fruit taste.

A high content of soluble solids in cupuassu candies is observed, resulting from the addition of sucrose and / or sucralose. Even if we verified a variation between conventional and *fit* candies, it was not possible to observe significant differences at 5% probability by the Student's T test, since the soluble solids content was standardized (Table 2). These values are above 65%, being in accordance with the limit required by Brazilian legislation [26]. The high content of sugar in the sweets is a limiting factor for the growth of microorganisms, since only osmotic bacteria and yeasts, and xerophilic molds grow in high concentrations of sugars and low water activity, characteristics found in sweets [27].

According to Table 2, both the total and the reducing sugars presented significant differences at 5% probability. It is possible to observe a decrease in the amount of reducing sugars of the conventional candy in relation to the *fit*, however, this reduction is not so great, due to the low concentration of sucralose in the product. The same result was found in the analysis of strawberry jam, where the percentages of sugar in the formulations with partial substitution of the sucrose were considerably smaller, in relation to the standard formulation [28]

Table 2. Results of physicochemical analysis of the cupuassu candy mass with commercial sucrose and partial substitution of the sucrose by the sucralose sweetener

Analysis	Cupuassu Pulp	Formulation	
		Conventional[2]	Fit[3]
pH	2.97 ± 0.00	3.63±0.06^b	3.80±0.02^a
Acidity (%)	2.00 ± 0.00	2.51±0.05^b	2.58±0.04^a
Soluble solids (ºBrix)	8.70 ± 0.00	71.85±2.02^a	70.60±6.08^a
Reducing sugars (% glucose)	3.33 ± 0.00	34.13±2.60^a	31.23±1.60^b
Total sugars (% glucose)	9.77 ± 0.51	83.51±0.11^b	87.62±1.48^a

[1]Mean values with different letters on the same line differ by independent Student's T test at 5% significance; [2]Conventional (1: 1, w/w, pulp: sucrose); [3]Fit (2: 1: 1, w/w, pulp: sucrose: fit sugar).

Studies indicate that sucralose is stable at high temperatures [6], however, reference [29] stated otherwise, that from 119°C, it undergoes changes, releasing HCl and water in the medium.

Microbiological analyzes of cupuassu candies showed absence of total coliforms (<3 NMP mL^{-1}) and mold and yeast counts (<10 CFU mL^{-1}), thus meeting the limits required by legislation [25]. This parameter indicates that the samples were processed in adequate hygienic sanitary conditions, thus guaranteeing the safety of the product and suitability for the sensorial tests.

The results of cupuassu candy acceptance, as for attributes: color, aroma, taste, texture, acidity, and overall impression, are presented in Table 3. For all evaluated attributes, notes were observed in the acceptance zone, above six, demonstrating the good acceptance of candies. According to the Wilcoxon t-test at 5% significance, the sensorial attributes did not differ between the samples, so it was decided not to indicate with equal letters. It should be noted that no differences were observed between the samples, that is, the use of the sweetener did not influence the sensory evaluation of candies. This result suggests that the partial replacement of sucrose by sucralose in the production of cupuassu candy is technologically feasible, since the products presented good properties of texture, color, taste, aroma among others as observed in the results of the sensorial analysis.

Table 3. Results obtained by means of the sensorial analysis of the cupuassu candy mass[1] with commercial sucrose and partial substitution of the sucrose by the sucralose sweetener.

Sensory Attributes	Conventional[2]	Fit[3]
Color	7.29 ± 1.29	7.46 ± 1.24
Aroma	6.96 ± 1.73	6.90 ± 1.57
Taste	7.46 ± 1.42	7.14 ± 1.75
Texture	7.51 ± 1.27	7.56 ± 1.30
Acidity	6.57 ± 1.84	6.40 ± 1.84
Global Impression	7.51 ± 1.36	7.43 ± 1.45
Purchase Intenção[4]	2.01 ± 1.07	2.25 ± 1.22

[1]Mean ± standard deviation; [2]Conventional (1:1, w/w, pulp:sucrose); [3]Fit (2:1:1, w/w, pulp:sucrose:fit sugar); [4]Scale ranging from 1 to 5, while others range from 1 to 9.

For the color attribute, the two formulations presented percentages higher than 7.00, demonstrating that the composition of the product did not affect the acceptance of the tasters. Regarding the aroma, the two formulations presented values slightly below 7.0, probably due to the cooking effect on the cupuassu pulp, thus reducing some of its characteristic volatile compounds. As for the texture attribute, the two samples were very close, with notes 7.51 and 7.56 for the conventional and *fit* candy, respectively. It is noted that modifications of this nature, carried out in the product, do not significantly alter these sensorial attributes.

Regarding taste, the conventional formulation presented a note slightly above the *fit*, with 7.46 and 7.14 respectively. As for the acidity attribute, the two formulations presented values between 6.00 and 7.00, showing that, for the taster, this attribute could improve.

Since the overall impression is an overview of the tasters in relation to the evaluated products, it can be stated that the two formulations are within the acceptance range, with 7.51 and 7.43 for the conventional and *fit* formulations, respectively. A similar result was found in the analysis of amla candy (*Emblica officinalis*) with sucrose, sucralose and aspartame, presenting notes between 6.5 and 7.4, thus keeping within the limits of acceptance [12].

Considering the importance of the characteristic acidity of cupuassu and the intention to investigate the ideal content of sweetness, the ideal scale test was performed with the same tasters, focusing only on these attributes. In Table 4 are the notes of comparison between the results of acidity and sweetness by the Ideal Scale. It is observed that both formulations are close to ideality, with values between 0 and 1.10, thus not presenting a significant difference, when evaluated by the tasters.

Table 4. Comparison between acidity and sweetness results by the ideal scale[1] with commercial sucrose and partial replacement of sucrose by sucralose sweetener.

Attributes	Conventional[2]	Fit[3]
Acidity	0.72 ± 1.43[a]	0.60 ± 1.43[a]
Sweetness	0.63 ± 1.34[a]	1.09 ± 1.36[a]

[1]Mean ± standard deviation; [2]Conventional (1:1, w/w, pulp:sucrose); [3]Fit (2:1:1, w/w, pulp:sucrose:fit sugar); Different letters on the same line show significant differences at the 5% probability level by the Wilcoxon t-test.

According to the notes attributed to acidity (Table 5), it is possible to observe that most tasters evaluated the conventional and *fit* sweets as ideal, 30 and 35, respectively. However, the note "*moderately stronger than ideal*" was the one that was repeated several times (19) for conventional candy, similarly the note "*slightly stronger than ideal*" (19), for the candy *fit*.

Table 5. Evaluation of the acidity and sweetness attribute by the ideal scale of formulations with commercial sucrose and partial replacement of sucrose by sucralose sweetener

Ideal scale	Acidity		Sweetness	
	Conventional (un)[1]	Fit (un)[2]	Conventional (un)[1]	Fit (un)[2]
+3	16	12	13	18
+2	19	16	16	25
+1	16	19	23	16
0	30	35	29	30
-1	13	9	12	7
-2	6	9	7	2
-3	0.00	0.00	0.00	2

[1] Conventional (1:1, p/p, pulp:sucrose); [2] *Fit* (2:1:1, p/p, pulp:sucrose:*fit* sugar).

For the sweetness attribute (Table 5), also evaluated by the ideal scale, the result was very similar with the acidity attribute, previously analyzed, with the highest percentages for ideality, being 29 for conventional candy and 30 for candy *fit*, followed by the note "*moderately stronger than ideal*" which was repeated several times (25) for the candy *fit*, and the note "*slightly stronger than ideal*" (23), for conventional candy.

Looking at Figure 2 it is clear that the two formulations showed good purchase intent, confirming the acceptance percentages presented in the sensory attributes analyzed. The conventional formulation had a higher purchase intent, between samples, in items "*definitely buy*" and "*probably buy*", having excelled only in items "*I doubt if buy*" and "*certainly would not buy*." However, most tasters evaluated the two products in a positive way, reflecting in the notes applied to the other attributes, and thus suggesting a commercially viable product.

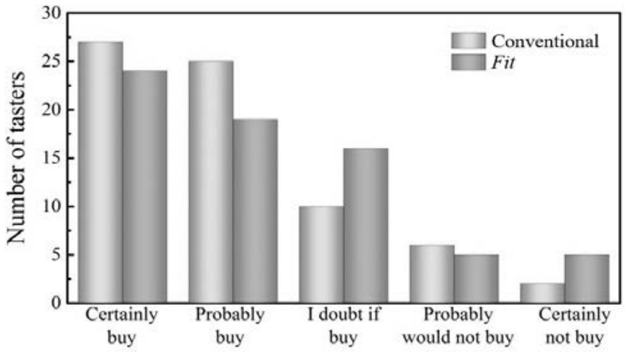

Figure 2. Intention to purchase the tasters for candy formulations with and without partial substitution of sucrose

4. Conclusion

The inclusion of sucralose affected physical and chemical parameters of pH, acidity, total sugars and reducers in *fit* formulation, which differed significantly in relation to the conventional one. However, these changes do not provide evidence of influence on the sensory characteristics of candies. Both formulations were maintained in the sensory acceptance zone for all evaluated attributes. The inclusion of sucralose in cupuassu candies, according to the experimental design used, proved to be a viable alternative to physicochemical parameters, which is within the limits established in the legislation, showing that the product is able for human consumption and sucralose is not detectable by the consumer.

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