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Elaboration of food products with biofortified sweet potatoes: Characterization and sensory acceptability

Elaboración de productos alimenticios con camote biofortificado: Caracterización y aceptabilidad sensorial

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ABSTRACT

Beauregard sweet potato is an orange color crop rich in β -carotene, a precursor of vitamin A. β -carotene improve immunity and decrease of incidence of degenerative diseases. The objective of this work was to introduce sweet potato in the diet through of some food products, such as bread, cake and sweets. The effect of processing on the chemical composition, as well as the quantification of phenols and total carotenoids, antioxidant activity, and sensory acceptability were evaluated. Cakes and coconut sweets presented higher levels of carotenoids. Higher phenolic and antioxidant activity were verified in cocoa sweets. All foods had good acceptability: 86% for bread, 83.3% for cake and 84,4%, and 86% for coconut and cocoa sweets, respectively. Servings of 95g of roasted sweet potato, 330g of bread, 182g of cake, 187g of coconut sweet and 391g end of cocoa sweet, would provide the recommended daily intake of vitamin A for children 10 years and older. It was concluded that the elaboration of foods containing sweet potato is a viable alternative to inserting biofortified foods into the human diet.

Key words: Antioxidant activity; Bread; Cake; Carotenoids; Phenols; Pro-vitamin A; Sensory analysis; Sweets.

RESUMEN

Los camote Beauregard son genotipos de color naranja, ricos en β -caroteno, precursores de la vitamina A. El β -caroteno ayuda a mejorar la inmunidad y reducir el riesgo de enfermedades degenerativas. El objetivo del trabajo fue introducir el camote en la dieta

a través del pan, pasteles y dulces tipo postre. Se evaluó el efecto del procesamiento sobre la composición química, así como la cuantificación de fenoles y carotenoides totales, actividad antioxidante y aceptabilidad sensorial. Las tortas y caramelos de coco mostraron mayores niveles de carotenoides y cacao, mayor actividad fenólica y antioxidante. Se confirmó una buena aceptabilidad, en la cual el pan presentó 86%, el torta 83,3%, y los dulces tipo postre de coco y de cacao 84,4% y 86% respectivamente. Las porciones de 95 g de batatas al horno, 330 g de pan, 182 g de torta, 187 g y 391 g de dulce de coco y dulce de cacao respectivamente, proporcionarían la ingesta diaria recomendada de vitamina A para niños de 10 años en adelante. Se concluyó que la preparación de alimentos que contienen batatas es una alternativa viable a la inclusión de alimentos biofortificados en la dieta humana. Palabras clave: Actividad antioxidante; Análisis sensorial; Carotenoides; Dulces tipo postre; Fenoles; Pan; Pro-vitamina A; Torta.

INTRODUCTION

Vitamin A deficiency is a serious nutritional problem that mainly involves developing countries¹. Children, pregnant and lactating women are considered the most vulnerable groups for this deficiency². In Brazil, it is estimated that 15.4% of children under 5 years of age are vitamin A deficient³. To overcome this problem, sweet potatoes, rich in pro-vitamin A carotenoids, have been developed in order to increase the availability of micronutrients and combat vitamin A deficiency⁴.

Biofortification is the term that refers to the breeding of staple crops to enhance the nutrient content and therefore, reduce micronutrient malnutrition⁵. In this approach, the "Harvest Plus" world program, which works in network with other entities, such as the Brazilian Company of Agricultural Research (EMBRAPA), Universities, Federal Institutes in Brazil, encourages the consumption of biofortified staples, such as rice, beans, sweet potatoes, cassava, maize and wheat, with high levels of iron, zinc and pro-vitamin A (β -carotene) by conventional breeding^{6,7}. Among these crops, the Beauregard sweet potato, developed in 1987 by the University of Louisiana in the US, is widely planted in several different countries. Because it is a biofortified cultivar, it has 10 times higher carotenoid contents compared to white pulp cultivars. Carotenoids are recognized for being precursors of pro-vitamin A⁸.

The sweet potato (*Ipomoea batatas*) is a vegetable that stands out for its easy cultivation, rusticity, adaptation to different soil types and climate, and low production cost⁵. Sweet potato can be used in food and feed, as well as in the food industries. In addition to vitamins and minerals, depending on the cultivar, sweet potatoes may have high levels of bioactive compounds, such as anthocyanins and carotenoids, which are recognized for their antioxidant activity and anti-mutagenic properties^{9,10}.

Orange-fleshed sweet potato cultivars often have high β -carotene content in their composition, which, once ingested, is converted into pro-vitamin A by human organism, resulting in beneficial health effects¹¹.

Besides the nutritional value, the sensory quality is very important to encourage the consumption of biofortified foods and thereby, assuring its benefits. Furthermore, since vitamin A deficiency affects mainly preschool-aged children, the development of the products which attend to this public is essential. The most common categories of food products consumed by children are breakfast cereals, snacks, sweets, bakery and confectionery foods¹². To the best of our knowledge, to date, few studies regarding pro-vitamin A biofortification

in bakery foods have been published. These studies include: enrichment of sorghum cookies with biofortified sweet potato carotenoids with high acceptance as well as nutritional quality⁶; the evaluation of nutritional and quality traits in biofortified bread wheat genotypes, to enhance the level of micronutrients, focusing on zinc and iron content¹³.

Therefore, this study aims to describe the development of food products (bread, cake and sweets) made with biofortified Beauregard sweet potato crops. In addition, this study evaluated the effect of processing on the nutritional composition of these products as well sensory acceptability.

MATERIAL AND METHODS

Material

Beauregard sweet potatoes were grown in an experimental area located at the Federal Institute Farroupilha (IFFar) - campus Santo Augusto, Rio Grande do Sul state, Brazil. The sweet potatoes were harvested in March 2018. The sweet potatoes were selected, pre-rinsed in running water, washed out in chlorinated water at 200 ppm, followed by rinsing in running water. The physical-chemical analysis and processing of bread, cake, and sweets was conducted in food technology laboratories. Sweet potatoes were roasted with skin in an oven (ProGás[®]) for approximately 40 min at 200 °C, then, after the potatoes had cooled, they were peeled and mashed. Only the pulp was used in the formulations.

Table 1 shows the ingredients used for elaboration of the products, bread, cake, and sweets. Bread was prepared by mixing the ingredients using a planetary mixer (Arno[®]) for 10 min. Afterward, dough was processed with a bread kneader (MBBraesi[®]) until the gluten network had completely developed. Next, dough was taken for fermentation in an oven (ProGás[®]) at 27 °C - 35 °C with controlled humidity (70-75%) for 1 hour. Then, the breads were baked in a preheated oven (ProGás[®]) at 180 °C for 30 min (Figure 1A). Cakes were made by homogenization of the ingredients in a mixer (Arno[®]). Initially eggs, whole milk, butter and sugar were added and afterward, the sweet potato, flour and lastly the yeast were added. The mixture was submitted to baking process in preheated oven (ProGás[®]) to 180 °C for 30 min (Figure 1B).

Coconut and cocoa sweets were produced by mixing of the ingredients described in table 1. After, the ingredients were slowly cooked, stirring constantly until a point of brigadeiro, around 15 min. The obtained mass was cooled and modeled in the shape of balls as presented in figure 1 (C, D).

Table 1. Ingredients used in the preparation of biofortified bread, cake, coconut and cocoa sweet.

Ingredients	Bread (%)	Cake (%)	Coconut sweet (%)	Cocoa sweet (%)
Sweet potato	25	25	57	54
Wheat flour	42.8	28	-	-
Condensed milk	-	-	37.5	32
Sugar	13	16	-	-
Milk	12	26	-	-
Fresh eggs	4.8	1.5	-	-
Butter	1.2	2	1	1
Biological yeast	1.2	-	-	-
Grated coconut	-	-	4.5	-
Granulated Chocolate	-	-	-	14
Cocoa powder	-	-	-	4
Chemical yeast	-	1.5	-	-

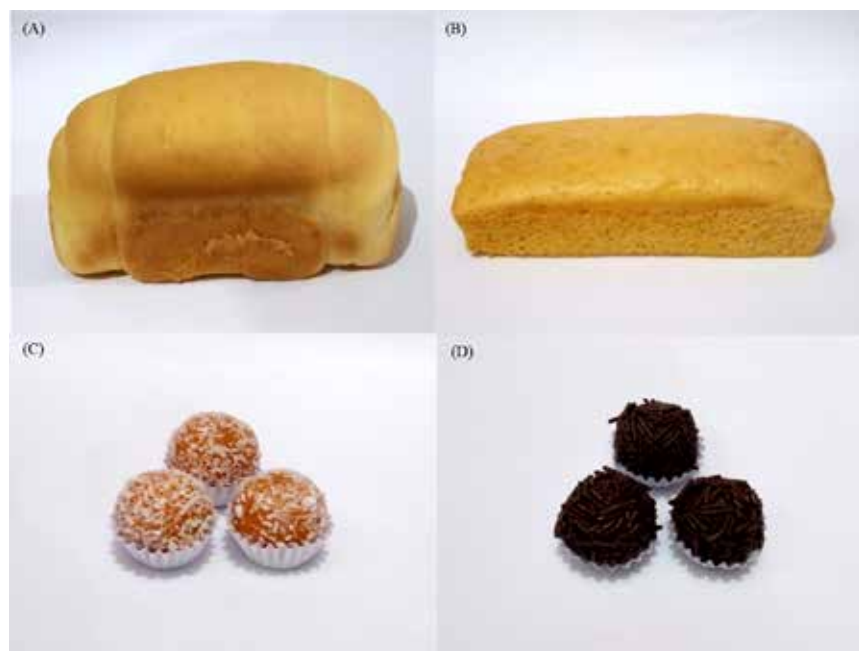


Figure 1: Bread (A), cake (B), coconut sweet (C) and cocoa sweet (D) made with Beauregard sweet potato.

Methods

Chemical composition

The determinations of humidity, ash, protein, lipids, fibers and carbohydrates by difference, according to the classical methods described by the Adolfo Lutz Institute Standards¹⁴,

were performed for elaborated food products and sweet potatoes. Caloric value was calculated using the method proposed by ANVISA¹⁵. Analysis were performed using analytical grade reagents from Sigma Aldrich® (St Louis, MO, USA) and distilled water.

Total carotenoids and phenolic content

Total carotenoids content was quantified using the spectrophotometric method proposed by AOAC¹⁶ and the results expressed as mg β -carotene.100g⁻¹ (mg β -carotene per 100g sample). Total phenolics were calculated using the methods proposed Vizzotto et al¹⁰ and results expressed in mg CAE.100g⁻¹ (mg of chlorogenic acid equivalent per 100g of sample).

Antioxidant activity

Antioxidant activity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical (Sigma[®]) and results expressed as μ gTE.g⁻¹ (Trolox equivalent per gram of sample) using the Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) (Sigma[®]) standard curve according to methodology adapted from Brand-Williams et al¹⁷.

Sensory analysis

Bread, cake and candies were individually evaluated using a nine-point hedonic scale test (1= extremely dislike, 9= extremely like). The samples were given randomly to 50 untrained panelists. The index of acceptability was calculated according to Fernandes et al¹⁸ by using the Equation (1):

$$IA (\%) = (\text{score} \times 100) / 9 \quad (1)$$

Preference (%) of the candies was evaluated by 40 untrained panelists through the paired comparison test of preference. Sensory tests were performed at the Sensory Analysis Laboratory, in IFFar- Institute Federal Farroupilha, Campus Santo Augusto, following the norms for sensory analysis from ABNT¹⁹ and IAL¹⁴. The survey was registered at Platforms Brazil (CAAE: 83198417.9.0000.5574).

Statistical analysis

All analyses were performed in triplicate and the means obtained were used to calculate the standard deviation. Results were analyzed using ANOVA, with a P \leq 0.05 considered significant. Post-hoc analysis was performed using Tukey's test (p \leq 0.05) (XLSTAT Pro [computer program]. Version 2015).

RESULTS

Chemical composition

Table 2 shows the proximal composition of roasted sweet potato and the products added with Beauregard sweet potato.

Moisture decreased in all products compared to the roasted sweet potato due to the cooking and baking process, which promotes water evaporation of the product. The protein content was higher in all food products compared to raw material, possibly due to the addition of wheat flour in the bread and cake formulation, and the addition of condensed milk in the candy formulation. The levels of lipids and carbohydrates also varied due to the addition of milk, eggs, butter and sugars in the product formulations. Fiber content was significantly higher than roasted sweet potato, mainly in the coconut sweet, probably due to the addition of coconut in the formulation. Consequently, the caloric value of the products also varied, being higher in bread, followed by cocoa and coconut sweets, cake and roasted sweet potato.

Total phenols and carotenoids content and antioxidant activity

Table 3 shows the values for the levels of phenolic and total carotenoids as well as the antioxidant activity of roasted sweet potatoes and food products added with Beauregard sweet potato. The total phenolic content in

Table 2. Proximal composition (g) and caloric value (kcal) for each 100 g of roasted sweet potato and bread, cake and sweets added with Beauregard sweet potato.

Components*	Roasted sweet potato	Bread	Cake	Coconut sweet	Cocoa sweet
Moisture	77.4 \pm 1.1a	24.3 \pm 1.0e	41.8 \pm 0.6b	38.2 \pm 0.7c	32.6 \pm 0.7d
Ash	3.33 \pm 0.11a	0.92 \pm 0.04d	1.8 \pm 0.1c	1.96 \pm 0.08c	2.79 \pm 0.07b
Protein**	0.49 \pm 0.09d	4.94 \pm 0.26b	7.3 \pm 0.2a	2.54 \pm 0.12c	2.38 \pm 0.51c
Lipids	1.07 \pm 0.32bc	0.70 \pm 0.20c	3.3 \pm 0.9ab	4.70 \pm 1.23a	3.67 \pm 1.3a
Carbohydrates	17.5 \pm 1.4e	68.8 \pm 1.01a	45.8 \pm 1.0d	50.5 \pm 1.1c	58.4 \pm 1.1b
Fiber	0.27 \pm 0.03b	0.43 \pm 0.15b	1.57 \pm 0.21a	2.10 \pm 0.68a	0.22 \pm 0.02b
Calories (Kcal)	81.6 \pm 2.9d	301.0 \pm 4.0a	242.1 \pm 5.6c	254.5 \pm 6.7c	276.0 \pm 7.7b

Means \pm standard deviation of three repetitions. Means followed by the same letters on the line show no significant difference by the 5% Tukey test (p $<$ 0.05). *Dry basis. ** Factor: 6.25.

bread did not differ significantly from baked sweet potatoes, but it was lower compared to sweets and cakes. Regarding carotenoid content, all products differed statistically from the baked sweet potato. As for the antioxidant activity, we can observe that the values found for the products were lower than those found for sweet potatoes, though the cocoa sweet did not differ statistically from the baked sweet potato (Table 3).

Sensory evaluation

Products elaborated with Beauregard sweet potato were evaluated by sensory analysis using the hedonic scale test. Results regarding acceptance and preference are shown in figure 2 (A, B).

A product is considered acceptable in sensory properties when it scores above 70%¹⁸. The acceptability index for all products made with biofortified Beauregard sweet potato was above 80%, indicating excellent acceptability (Figure

2A). Sweet potato bread had 86.3% acceptability. When asked about the characteristics of the product the panelists reported that they appreciated the texture and taste of the bread. Also mentioned, that if this product was available they certainly buy it. Cake formulation had an acceptability of 83.3%. Positives comments about the texture and taste also were reported by the panelists.

Sweets showed 86 and 84.4% acceptability for cocoa and coconut sweets, respectively. Furthermore, the preference between the sweets was performed (Figure 2B) and the results indicated that the cocoa sweet was preferred by 62.5% of the panelists. Panelists reported that the cocoa minimized the characteristic taste of sweet potato. Comments like: "I did not like [the sweet] due to the characteristic sweet potato flavor" were reported by 37% of the panelists. However, according to the bilateral preference table, there was no significant difference in preference between sweets¹⁴.

Table 3. Total content of phenolic compounds, carotenoids, antioxidant activity and recommended daily intake (RDI) of vitamin A from roasted sweet potatoes as well as from elaborated products (bread, cake and sweets).

Products	Phenolic (mgCAE.100g ⁻¹) ¹	Carotenoids (mgβcaroteno.100g ⁻¹) ¹	Antioxidant activity (μgEqTrolox.g ⁻¹) ¹	RDI (g) ³
Roasted sweet potato	147.5±44.3d ²	3.79±0.14a	4307±4276a	95
Bread	151.3±2.5d	1.09±0.04c	766±34c	330
Cake	258.2±24.50c	1.98±0.16b	1192±69bc	182
Coconut sweet	622.5±39.85b	1.92±0.10b	2176±122b	187
Cocoa sweet	1228.9±25.2a	0.92±0.25c	4057±736a	391

¹Fresh weight. ²Means±standard deviation of three repetitions. Averages followed by the same letters in the column show no significant difference by the 5% Tukey test ($p < 0.05$). ³Product RDI in grams (g), considering conversion 1 RE (retinol equivalent) = 6 μg β-carotene and age range from 10 years to adults, which predicts ingestion of 600 RE (μg (retinol equivalent)) according to WHO / FAO²⁹, ANVISA¹⁵.

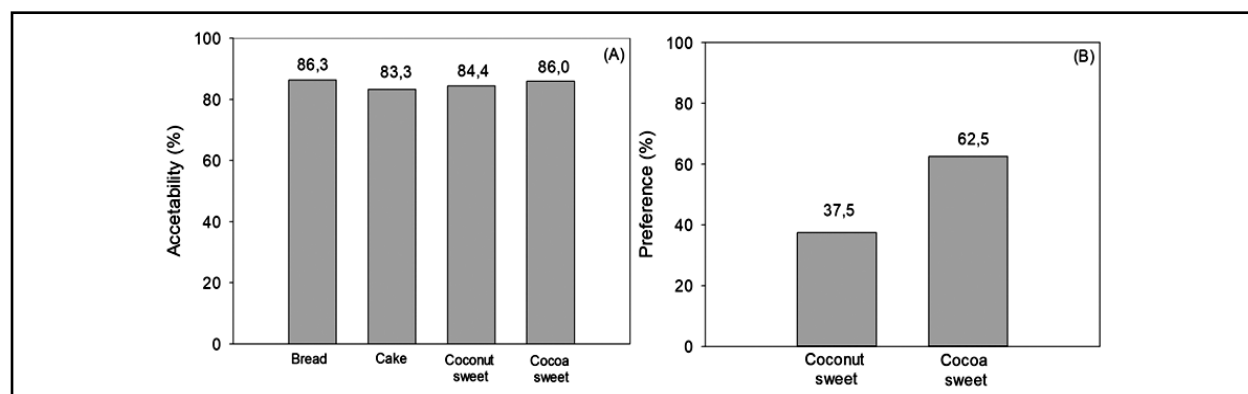


Figure 2: Sensory evaluation of products from biofortified Beauregard sweet potato: (A) acceptability (%). (B) Preference (%) between sweet formulations.

DISCUSSION

Chemical composition

The Beauregard sweet potato used in this study had higher levels of ash, lipids and calories compared to the values presented in the Brazilian Table of Food Composition for cooked sweet potato, which is 80.4% moisture, 0.4% ash, 0.6% protein, 0.1% lipid, 2.2% dietary fiber, 18.4% carbohydrate and 77 kcal²⁰. Variations in the nutritional composition of the Beauregard sweet potato were expected, as this cultivar was recently obtained through conventional breeding by the Louisiana Agricultural Experiment Station (USA)²¹. It is known that variations in the centesimal composition of different cultivars can be influenced not only due to genetic variation, but also to other factors such as climatic conditions and place of cultivation²².

There were significant variations in the results obtained for chemical composition of the roasted sweet potato and the products produced from it. This difference is attributed to the different ingredients added for the preparation of products, according to described in table 1. When evaluating brownies containing different levels of mashed orange-fleshed sweet potato, Selvakumaran et al²³ observed an increase in the constituents analyzed according to the amount of mash added in brownies. Only the protein content possibly decreased due to the replacement of wheat flour by sweet potato mash in the formulations.

Total phenols and carotenoids content and antioxidant activity

Vizzotto et al¹⁰ evaluated raw and roasted sweet potato genotypes and observed higher levels of carotenoids, total phenolic and antioxidant activity in roasted Beauregard sweet potato (250 °C/90 min). Dry heat processing can promote the concentration of bioactive compounds due to water evaporation. The content of total phenolic compounds and total carotenoids (147.5 mgCAE.100g⁻¹ and 3.79 mg β-carotene.100g⁻¹) presented in this study were lower than reported by Vizzotto et al¹⁰, 407.26 mgCAE.100g⁻¹ and 23.97 mg β-carotene.100g⁻¹, respectively. This variation may be due to different storage and preparation (time, temperature, oven, etc.) conditions in addition to factors, such as climate and place of cultivation^{10,22}.

The higher total phenolic content presented by sweets may be related to the addition of cocoa and coconut in the formulations, ingredients that present high levels of phenols in their composition^{24,25}.

Beauregard sweet potato is considered a biofortified cultivar because it has high levels of β-carotene, 10 times greater than that found in white fleshed cultivars⁴. The results for total carotenoids obtained in this study were similar to those reported by Islam et al² that obtained values varying between 1.82 to 5.83 mg. 100g⁻¹ in orange-fleshed sweet potato cultivars grown in Bangladesh, however, lower than the results obtained by Vizzotto et al¹⁰ when evaluating Beauregard sweet potatoes.

As expected, the baking process led to a decrease in the carotenoids content. The susceptibility of carotenoids to degrade because of heat is well known²⁶. However, this degradation is not restricted only to the baking stage but also to the other preparation stages. The kneading process leads to water and oxygen incorporation in the dough, inducing oxidation of polyunsaturated fatty acids and therefore, oxidation of carotenoids²⁷. Rodriguez-Amaya et al²⁸ also reported that carotenoid loss may be related to the mode of preparation, aeration and time of exposure to elevated temperatures. Based on this statement, the decrease in carotenoid content observed in sweets can also be attributed to the aeration that occurs in product preparation. Nevertheless, cake and coconut sweet retained significant carotenoid contents, 1.92 mgβ-carotene 100g⁻¹ and 1.98 mgβ-carotene 100g⁻¹, respectively.

Waramboi et al²⁹ evaluated different flours obtained from orange-colored sweet potatoes submitted to the extrusion process and also observed that the use of high temperature and humidity had a negative effect on the total carotenoid content in both flours analyzed.

Studies about the incorporation of sweet potato in food products aimed at nutritional improvement have been widely performed and present interesting results^{6,27,30}. Samiha³⁰ evaluated the effect of incorporating different sweet potato flour contents in cake formulations (10, 20 and 30%) and obtained high β-carotene contents in cake formulations. Infante et al⁶ reported nutritional and sensory increase in cookies with sweet potato and sorghum flour. Nzamwita et al²⁷ aimed to evaluate the retention percentage of all-trans-β-carotene in breads, incorporating 10, 20 and 30% (w/w) of flour obtained from Beauregard sweet potato and obtained levels of β-carotene retention of 62.7, 71.4 and 83%, respectively, after roasting.

It can be observed that, from the carotenoid contents observed in the food products elaborated in this study (Table 2), and considering that 1 RE (retinol equivalent) is equivalent to 6 μg β-carotene^{15,31,32}, the required portion of food products to achieve the recommended daily intake (RDI) for children aged 10 years and adults would be 95 g for baked sweet potato, 330 g for bread, 182 g for cake, 391 g for cocoa sweet and 187 g for sweet coconut, portions that can be easily consumed, with emphasis on roasted sweet potato, cake and coconut sweets.

The antioxidant activity obtained from the Beauregard sweet potato was 4307 μgEqTrolox.g⁻¹, considered higher than value reported by Vizzotto et al¹⁰, 1770 μgEqTrolox.g⁻¹ in the same cultivar.

Sweets had a high antioxidant activity. Cocoa sweet stood out with 4057 μgEqTrolox.g⁻¹. The superior antioxidant activity presented by the added cocoa sweet may be results to the higher content of phenolic compounds (R²= 0-99). Cocoa is known as a source of phenolic compounds and other antioxidants that possibly interfere positively in the total phenolic and antioxidant results²⁴.

Sensory evaluation

Selvakumaran et al²³ reported an acceptability index between 76% and 85% for texture, flavor and overall acceptability of the orange sweet potato enriched brownies. This finding is also consistent with Samiha³⁰ which reported an increase in sensorial preference on the texture, taste and overall acceptability with increases in orange sweet potato flour substitution in cakes.

Besides these studies, increased sensory attributes due to orange sweet potato addition in their formulations also have been reported in cookies by Infante et al⁶. Pereira et al³³ produced panettonnes added with orange-fleshed sweet potato flour, obtaining good results in terms of flavor and aroma.

CONCLUSIONS

In gernal, the food products added with biofortified Beauregard sweet potato showed significant levels of fiber, total phenols, and total carotenoids. In addition, these products presented excellent acceptability, above 80%. Sweet potato and food products made with biofortified Beauregard sweet potato would achieve the recommended daily intake of vitamin A for children 10 years and older. Therefore, bread, cake and sweets presented in this study are a viable alternative for the insertion of biofortified sweet potato with vitamin A in food products to combat nutritional deficiency. The improvements in food products may encourage increased vitamin A consumption among children. These results are promising and future studies should develop a wider range of products from biofortified sweet potato.

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