



Retention of β -carotene in biofortified sweet potato chips after processing

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ABSTRACT. Consumption of biofortified foods such as sweet potatoes with high content of β -carotene may reduce deficiency of this micronutrient. The development of biofortified sweet potato chips expands the distribution and offers an alternative to the consumption of this product. The aim of this study was to evaluate the thermal blanching methods (steam and in boiling water) in β -carotene retention in the production of dehydrated biofortified sweet potato chips with air circulation at 65°C. The raw material, the chips blanched in steam and in boiling water had a content of β -carotene of 501.86 ± 53.65 , 490.23 ± 30.00 and $473.91 \pm 11.43 \mu\text{g g}^{-1}$ (d.b.) respectively. The retention of β -carotene for steam and boiling water blanching was 97.7 and 94.4% respectively. The blanching conditions followed by drying used in the processing to obtain sweet potato chips were adequate as they resulted in β -carotene high retention.

Keywords: carotenoids; peroxidase activity; pro-vitamin A; retinol activity equivalents; snack food.

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Introduction

Despite efforts over the last few years to combat malnutrition, it is estimated that chronic malnutrition affects 161 million children under the age of five in the world. In addition, more than 2 billion people are affected by the lack of micronutrients or 'hidden hunger' worldwide, especially for lack of vitamin A, iodine, iron and zinc, among others (Muthayya et al., 2013; Food and Agriculture Organization of the United Nations/World Health Organization [FAO/WHO], 2014). This malnutrition can have an effect on growth, immune and reproductive functions, productivity and mental development. Micronutrient deficiencies affect all age groups, but children and women of reproductive age are more vulnerable (Piccoli et al., 2012).

In order to combat micronutrient deficiency, biofortified products are being developed to strengthen foods that are widely produced and are already part of the population's diet, providing access to more nutritious products without changing consumption habits (Nutti, 2011).

Among the biofortified foods, sweet potatoes stand out because, in addition to being a staple food source in developed and developing countries, the 'Beauregard' culture is rich in pro-vitamin A carotenoids (International Potato Center [CIP], 2006; Bengtsson, Namutebi, Alming, & Svanberg, 2008; Huang & Zhang, 2012; Oke & Workneh, 2013). According to Nicanuru, Laswai, and Sila (2015), portions of 100 g orange pulp sweet potato may contain 300 to 3000 μg retinol activity equivalent, and may satisfy the recommendations of daily intake, due to this high content of retinol activity equivalents. Thus, orange pulp sweet potatoes can be used to minimize vitamin A deficiency. However, fresh sweet potatoes are highly susceptible to mechanical damage and microbial deterioration, which hampers its preservation (CIP, 2006; Bengtsson et al., 2008; Huang & Zhang, 2012).

Therefore, sweet potato processing is required to extend shelf-life and offering a food with a high content of pro-vitamin A carotenoids (Marangoni Júnior, Ito, Ribeiro, Silva, & Alves, 2018). The most commonly used sweet potato processing methods are based on washing, peeling and cooking. However, other techniques may be employed, such as the dehydration process, resulting in sweet potato chips, sweet potato flakes, dehydrated sweet potato and sweet potato flour (Bechoff, Westby, Menya, & Tomlins, 2011; Huang & Zhang, 2012; Oke & Workneh, 2013). However, prior to the processing of sweet potato drying it is

necessary to apply the pre-treatment such as blanching. For the quality of the dried product is sometimes improved. Blanching is performed before dehydration to inactivate the enzyme peroxidase, which can lead to the formation of unacceptable colors and flavors. Blanching has advantages such as removal of intercellular tissue air, texture modification, retention taste during storage (Fernando, Ahmad, & Othman, 2011). In addition, when the product is rich in carotenoids blanching can improve the preservation of this compound, due to the removal of air from the plant tissue and enzymatic inactivation.

However, since sweet potato is a raw material rich in carotenoids, the control of process conditions is very important, as carotenoids are susceptible to degradation. The main factors that influence the degradation of carotenoids throughout the processing are time, temperature, oxygen availability, enzymatic activity and water activity (Rodriguez-Amaya, Nutti, & Carvalho, 2011; Marangoni Júnior et al., 2018).

Several studies related to processing and retention of carotenoids have been performed, however, usually the processing method is partially informed, leading to a lack of information regarding retention of pro-vitamin A carotenoids and processing conditions (Rodriguez-Amaya, 1999; Lesková et al., 2006).

The present study was carried out in order to evaluate the thermal blanching methods (steam and in boiling water) in carotenoid retention in the production of dehydrated biofortified sweet potato chips with air circulation at 65°C.

Material and methods

Raw material

The orange pulp sweet potato of the 'Beauregard' variety selected by Embrapa was cultivated at the Pau D'Alho farm in the city of Campinas - Brazil. The lot used in this study was harvested after a 4-month growth period and transported to the Institute of Food Technology - ITAL, located in the city of Campinas - Brazil. The lot was stored in a storage chamber at $25 \pm 1^\circ\text{C}$ and $75 \pm 5\%$ RH (relative humidity) for 11 days.

Processing of the chips

The sweet potato roots ('Beauregard' variety) used for the processing of the chips were washed, peeled and sliced with thickness between 1.0 and 2.0 mm. A comparison was made between two blanching methods: (i) samples were immersed in boiling water (98°C) and (ii) slices were placed in perforated trays and passed through a steam tunnel (100°C) with a line pressure of $4 \pm 1 \text{ kgf cm}^{-2}$ at different times, with a variation of 1 min. (Three replicates were performed for each method and blanching time). The blanching time was defined by the peroxidase activity analysis according to the method described below. After blanching, the sweet potato slices were dehydrated in a Proctor & Schwartz tray dryer, model K13964 (Lexington, USA) with air circulation flow of 1 m s^{-1} at 65°C for 5 hours. The sweet potato chips were cooled to room temperature and packed in PET/Al/LDPE (polyester/aluminum foil/low density polyethylene).

Peroxidase activity

Peroxidase activity was determined according to the method described by Enachescu-Dauthy (1995). Inactivation of peroxidase was performed in 1% guaiacol solution G5502 (Sigma-Aldrich Brazil LTDA), prepared by dilution to 10% alcoholic solution with distilled water, mixed in equal volumes with a solution of 1.5% hydrogen peroxide. The previously blanched sweet potato slices were arranged in petri dishes, followed by the addition of guaiacol solution until the slice was completely covered and held for 4 min. After the reaction time, the color of the slices was observed, considering a negative reaction when the slices were not darkened (red-brown), resulting in peroxidase inactivation, and a positive reaction when the slices showed red-brown color, indicating peroxidase activity. The tests were performed in triplicate.

Chemical composition of the raw material and chips

The moisture content of the raw material was performed in triplicate and determined according to the method n. 964.22 Association of Official Analytical Chemists (AOAC, 2012), in a vacuum oven (Gallenkamp, Leicestershire, United Kingdom) for 2 hours at 70°C until constant weight, determined in analytical balance (Sartorius analytic - A200S, Goettingen, Germany) with 0.0001 accuracy. The moisture content of the sweet potato chips was performed in triplicate and determined according to the method n. 984.25 AOAC (2012), in a cabinet oven with air circulation (Fanem - 515/4-C, Guarulhos, Brazil) for 16 hours at $103 \pm 1^\circ\text{C}$ until

constant weight, determined in analytical balance (Mettler Toledo – XP504, Barueri, Brazil) with 0.0001 accuracy.

The proximate analysis of the raw material and chips was performed in triplicate, based on the methods of AOAC (2012): protein method n. 920.152, ash method n. 925.51, lipid method n. 935.37 and fiber method n. 985.29. Carbohydrate amount was calculated by the difference between the number 100 and the sum of the results for moisture content, protein, ash, lipid and dietary fiber. Calories were determined according to Passmore, Nicol, and Rao (1975). The raw material and chips were evaluated with respect to water activity in a hygrometer based on psychrometry, with a resolution of 0.0001 (Aqualab®, Decagon Devices Inc, Pullman, USA). The analysis was performed in triplicate at $25.0 \pm 0.2^\circ\text{C}$.

Instrumental color

The raw material was evaluated regarding the internal color of the slices, using a colorimeter (model CR410, Konica Minolta, Reston, EUA) with a measuring area of 50 mm in diameter, while the chips were triturated in Trinto - Arno multiprocessor (São Paulo, Brazil) before the analysis. The values were the mean of ten consecutive readings. The results are described on the basis of L^* , a^* and b^* parameters, where L^* is the measure of lightness, a^* defines the components on the red-green axis and b^* the components on the yellow-blue axis.

Carotenoids

The quantifications of total carotenoids and β -carotene of raw material and sweet potato chips were performed as described by Rodriguez-Amaya (2001). About 3 g of sample were weighed, followed by the addition of hyflosupercel (Synth, Brazil) and 10 mL of deionized water. The pigments were extracted in disintegrator (MA 102, Marconi, Piracicaba, Brazil) with volumes of 50 mL of acetone, sequentially, until the sample is colorless. The combined extract was transferred to petroleum ether, the acetone removed by addition of deionized water, and the final volume adjusted to 50 mL with petroleum ether (Synth, Brazil). The assays were performed in triplicate and all extraction steps were protected from light.

For the determination of total carotenoids, 1 mL of the extract was diluted to 10 mL with petroleum ether, and the absorbance was obtained at 453 nm in a UV-VIS spectrophotometer (Cary 50, Varian, Santa Clara, USA). In the quantification, the absorption coefficient of 2592 (absorbance units) was used.

For the analysis of β -carotene, an aliquot of 1 mL of the extract was dried under nitrogen flow and diluted in 5 mL of mobile phase, filtered on regenerated cellulose membrane with 0.45 μm pore size (Millipore). A chromatograph was employed (Agilent, Infinity 1260, Apple Valley, USA) using a diode arrangement detector at 453 nm. Carotenoid separation was performed on a Poroshell 120 EC-18, 4.6 x 50 mm, 2.7 μm column (Agilent, Apple Valley, USA) with a mobile phase composed of acetonitrile: methanol: ethyl acetate: triethylamine (79.95:10:10:0.05, $\text{v v}^{-1} \text{v}^{-1} \text{v}^{-1}$), in isocratic system and flow of 0.5 mL min^{-1} . The quantification was done with external standardization using 95% β -carotene C4582 (Sigma-Aldrich, USA), with a concentration of 1.20 $\mu\text{g mL}^{-1}$. The limit of detection was 24.1 $\mu\text{g 100 g}^{-1}$ and the limit of quantification was 26.8 $\mu\text{g 100 g}^{-1}$, considering dilutions and sample taking. Approximately 10 mg trans- β -carotene dissolved in 10 mL of petroleum ether was used to prepare the analytical standard. The concentration of the solution was obtained by absorbance reading at 453 nm in the petroleum ether solvent using the absorption coefficient of 2592 (absorbance units). Chromatographic grade methanol, acetonitrile and ethyl acetate were provided from Tedia (Fairfield, USA), while other chemicals were analytical grade.

The retention of total carotenoids and trans- β -carotene in the processing was calculated as described by Murphy, Criner, and Gray (1975) based on the following Equation 1:

$$\%Retention = \frac{\text{carotenoidscontentpergofdriedfood}(d.b)}{\text{carotenoidscontentpergofrawmaterial}(d.b.)} \times 100 \quad (1)$$

Retinol activity equivalent (RAE)

The retinol activity equivalent of the raw material and chips were calculated as described by Food and Agriculture Organization of the United Nations/International Network of Food Data Systems (FAO/Infods, 2012), where 12 μg of β -carotene corresponds to 1 μg of RAE.

Statistical analysis

The following tests were performed: normality of Shapiro-Wilk and Anderson-Darling, variance of Bartlett and Levene and Fisher, two sample t-test, ANOVA, Welch's ANOVA. Besides, multiple paired comparisons of Tukey averages, Games-Howell, Tamhane's T2.

Results and discussion

Peroxidase activity

The sweet potato slices were blanched by immersing in boiling water for 1 and 2 min. and in the steam tunnel for 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 min. Blanching done by immersion in boiling water was effective in the inactivation of peroxidase after 2 min. of treatment, while steam blanching with a line pressure of $4 \pm 1 \text{ kgf cm}^{-2}$ showed complete inactivation of the peroxidase after 10 min.

According to Parreño and Torres (2012), steam blanching produces 9 to 16 times less effluent than conventional blanching. In addition, the steam process results in higher energy savings, since the steam generated in the boiler enters directly into contact with the product, different from blanching in boiling water, in which most industrial scale equipments use steam to heat the water, promoting greater energy expenditure. Other benefits of steam blanching are the higher retention of color and nutrients, when compared to boiling water blanching.

The effect of blanching on plant tissues was discussed by Van Jaarsveld, Marais, Harmse, Nestel, and Rodriguez-Amaya (2006). According to the authors, the destruction of cell membranes of plants, through peeling or cutting, releases oxidative enzymes that come into contact with carotenoids and catalyze their oxidative degradation. Enzymatic oxidation may occur in the preliminary stages of thermal processing, such as peeling and cutting of raw foods.

According to Dutta, Chaudhuri, and Chakraborty (2005) and Rodriguez-Amaya, Kimura, and Amaya-Farfan (2008) the beneficial effect of blanching process on carotenoid stability during storage is usually attributed to the inactivation of the enzymes (peroxidase), which catalyze the destruction of carotenoids, despite causing small pigment loss due to thermal degradation as a result of blanching temperature.

Bechoff et al. (2011) evaluated the effectiveness of the blanching process for two orange pulp sweet potato cultivars. Blanching was carried out by the immersion in water at boiling temperature. *Ejumula* variety required a blanching time of 11 min. for the peroxidase activity test to be negative and *Kakamega* variety required a treatment time of 8 min. Nevertheless, 'Beauregard' variety of the current work showed a shorter immersion blanching time (2 min.) than the varieties studied by these authors. In addition, the steam blanching of the 'Beauregard' variety presented time (10 min.) similar to that of the authors, which is the most used method in the industry.

Chemical composition of the raw material and chips

The chemical composition of the sweet potato roots without the peels and the sweet potato chips are shown in Table 1. The raw material has high moisture content ($83.36 \pm 0.11 \text{ g } 100 \text{ g}^{-1}$) and the carbohydrates are present in a larger amount when compared to the other macro-nutrients evaluated ($13.15 \pm 0.08 \text{ g } 100 \text{ g}^{-1}$).

Table 1. Chemical composition of the raw roots of 'Beauregard' sweet potato and sweet potato chips.

Composition	Fresh sweet potato	Sweet potato chips steam blanching	Sweet potato chips boiling water blanching
Water activity	0.994 ± 0.001	0.394 ± 0.004^a	0.388 ± 0.005^a
Dry matter g 100 g^{-1}	16.65 ± 0.11	93.04 ± 0.06^a	93.02 ± 0.10^a
Moisture content g 100 g^{-1}	83.36 ± 0.11	6.96 ± 0.06^a	6.98 ± 0.10^a
Protein (Nx5.75) g 100 g^{-1}	0.82 ± 0.01	3.73 ± 0.01	ND
Ash g 100 g^{-1}	0.65 ± 0.01	3.35 ± 0.10	ND
Lipid g 100 g^{-1}	$< 0.1^1$	1.61 ± 0.03	ND
Dietary fiber g 100 g^{-1}	2.04 ± 0.02	13.12 ± 0.20	ND
Carbohydrate g 100 g^{-1}	13.15 ± 0.08	71.36 ± 0.21	ND
Calorie Kcal 100 g^{-1}	56	315	ND

Mean \pm standard deviation; ¹Corresponding to the quantification limit of the method under the analytical conditions used; ND = not determined. Different letters indicate statistical differences between samples at the 95% level.

The chemical composition of the raw material is similar to the results obtained by Suárez et al. (2016) who chemically evaluated 30 different sweet potato cultivars. However, the results of protein, ash, lipid, dietary fiber and carbohydrate fresh sweet potato are below the benchmark data sweet potatoes United States Department of Agriculture (USDA, 2016) which are 1.57, 0.99, 0.05, 3.00 and 20.12 g 100 g⁻¹ respectively, due to the higher moisture content presented in the studied sweet potato.

The chemical composition of the biofortified sweet potato chips presented an increase in the levels of protein, ash, lipid, dietary fiber and carbohydrate compared to the levels of fresh sweet potato, due to the removal of water resulting from the dehydration process applied to the chips.

Carbohydrates and dietary fiber are present in higher amounts in the biofortified sweet potato chips, being 71.36 ± 0.21 and 13.12 ± 0.20 g 100 g⁻¹ respectively. Lipids and calories content of the dehydrated biofortified sweet potato chips is lower in comparison to the commercial fried orange pulp sweet potato chips, which showed 31.2 g 100 g⁻¹ of lipids and 496 Kcal 100 g⁻¹.

Instrumental color

The results obtained for color measurement of the raw material and the chips are presented in Table 2. Regarding raw material, lightness value (L*) was 71.70, red intensity (a*) and yellow intensity (b*) were 26.52 and 51.10, respectively, indicating that these values are important parameters in the evaluation of orange pulp sweet potato cultivars.

The processing of the 'Beauregard' sweet potato to obtain the chips promoted an increase of red and yellow intensity, in comparison to the raw material, due to the concentration of the pigments. However, the steam blanched chips showed a more intense coloration than the boiling water blanched samples.

High values for a* (red) and b* (yellow) parameters is due to the high content of carotenoids present in the 'Beauregard' sweet potato chips.

According to Rodriguez-Amaya et al. (2011) carotenoids are responsible for the yellow, orange and red coloration of foods, and the higher their content in the food, the more intense its coloration. Color is a property of technological importance, since it is the attribute that directly influences the food acceptance.

Carotenoids

Total carotenoids, β-carotene content and RAE of fresh sweet potato, steam blanched and boiling water sweet potato chips as well as retention values of total carotenoids and β-carotene in the processing are shown in Table 3.

The quantification of carotenoids content of fresh sweet potato showed that among the 100% of total carotenoids present in the raw material, 79.6% corresponds to β-carotene, which is the most important carotenoid. According to Moura, Miloff, and Boy (2015) and Saini, Nile, and Park (2015) this carotenoid has the capacity to act as a precursor of vitamin A, presenting 100% of vitamin activity.

The results obtained for β-carotene in this study are close to those found by Laurie, Van Jaarsveld, Faber, Philpott, and Labuschagne (2012) which quantified a β-carotene content of 487.17 μg g⁻¹ (d.b.) in the 'Beauregard' cultivar grown in South Africa.

Table 2. Color characterization of the raw material used in the study.

	L*	a*	b*
'Beauregard' fresh sweet potato	71.70 ± 1.65 ^a	26.52 ± 2.39 ^{ab}	51.10 ± 3.53 ^b
Sweet potato chips blanched in steam	66.68 ± 0.96 ^b	27.29 ± 1.33 ^a	57.63 ± 2.61 ^a
Sweet potato chips blanched in boiling water	57.16 ± 5.20 ^c	24.03 ± 3.51 ^b	44.58 ± 5.07 ^c

Mean ± standard deviation; L*: lightness; a*: red intensity and b*: yellow intensity. Different letters indicate statistical differences between samples at the 95% level of confidence between the means by the test for two samples.

Table 3. Carotenoid content of the raw roots of 'Beauregard' sweet potato and sweet potato chips processed by two blanching methods.

	Raw material	Steam blanched chips	Boiling water blanched chips
Total Carotenoids μg g ⁻¹ (d.b)	630.33 ± 60.43 ^a	613.34 ± 6.66 ^a	595.90 ± 7.87 ^a
Total Carotenoids Retention (%)	-	97.3	94.5
β-carotene μg g ⁻¹ (d.b.)	501.86 ± 53.65 ^a	490.23 ± 30.00 ^a	473.91 ± 11.43 ^a
β-carotene Retention (%)	-	97.7	94.4
RAE μg 100 g ⁻¹ (w.b.)	696	3801	3675

Mean ± standard deviation; d.b. dry basis; w.b. wet basis. Different letters indicate statistical differences between samples at the 95% confidence level between the means by the test Games-Howell and T2 of Tamhane for total carotenoids and by the Tukey test for β-carotene. Retention values were calculated by dividing the carotenoids content of the processed product by the carotenoids content of the raw material (Equation 1).

The sweet potato used in this study had 696 μg 100 g^{-1} RAE. According to the Recommended Daily Intake (RDI) data set by FAO/WHO (2001) an adult person needs 600 μg of vitamin A or retinol activity equivalents per day, which is provided by 100 g of 'Beauregard' sweet potato. Bengtsson et al. (2008) evaluated the content of RAE of seven orange pulp sweet potato cultivars and the results ranged from 311 to 804 μg RAE 100 g^{-1} of fresh root. 'Ejumula' cultivar showed 755 μg RAE 100 g^{-1} of fresh root, which was the closest value to that obtained for 'Beauregard' cultivar used in the current work.

Concerning the total carotenoids content of steam and boiling water blanched chips, 79.9 and 79.5% of total carotenoids corresponds to β -carotene, respectively. RAE of steam and boiling water blanched sweet potato chips were 3801 μg 100 g^{-1} e 3675 μg 100 g^{-1} , respectively. The losses of total carotenoids and β -carotene of steam bleached and boiling water chips presented no significant difference ($p < 0.05$) when compared to fresh sweet potatoes. Although, steam blanching is cheaper on an industrial scale.

Bengtsson et al. (2008) produced orange pulp sweet potato chips from *Ejumula* cultivar. Blanching process was performed with boiling water for 20 min. and after that the slices were dried in solar dryers with temperature ranging from 45 to 63°C for 10 hours, which led to trans- β -carotene retention of 91.1%. These results indicate the importance of using shorter blanching time, as well as shorter drying time, in order to obtain higher carotenoids retention, such as those determined in the present study.

β -carotene retention (around 94 and 97%) were higher than those reported by Wu et al. (2008) in a work with orange pulp sweet potato chips using *Yanshu* variety. The slices were blanched in the steam for 20 min. and dried at 50°C for 5 hours, resulting in retention of 64.64%.

Carotenoids retention from ten cultivars of orange pulp sweet potato was studied by Vimala, Nambisan, and Hariprakash (2011) who evaluated different processing methods, frying and drying in an oven (50-60°C for 24-48 hours). The retention in the drying process was 90-91% for total carotenoids and 89-96% for β -carotene, while the retention in frying was 77-85% for total carotenoids and 72-86% for β -carotene.

The effect of three processing methods (cooking in boiling water for 20 min., frying at 170°C and steam cooking for 10 min.) on the total carotenoids and β -carotene content in nine sweet potato cultivars was studied by Kim et al. (2015). The authors concluded that the frying process resulted in greater loss of total carotenoids and β -carotene than the other methods used. These results support the choice of the drying method in the present work to obtain the chips (tray dryer with air circulation flow), which provides higher carotenoids retention and lower caloric value when compared to the frying method.

According to Bechoff et al. (2009) losses of β -carotene in orange pulp sweet potato chips dehydrated for 2 hours at 42°C, without going through the blanching stage were low, being 13%. However, when comparing these losses of β -carotene with the losses of the steam bleached and boiling water sweet potato chips of this study, we can observe that the blanching step makes this loss even smaller, being 2.32 and 5.57%, respectively. In addition, the results of retention of β -carotene in the processing of sweet potato orange pulp from this study are superior to the results found in the literature as described in the review of Bechoff and Dhuique-Mayer (2017).

The Recommended Daily Intake (RDI) values for each population group, as well as the consumption equivalence of 'Beauregard' sweet potato chips to supply the RDI, are presented in Table 4, where 13 g of 'Beauregard' sweet potato chips can provide the need for recommended daily intake for children 1-10 years old, as shown in Table 4.

The results indicate that the biofortified sweet potato chips is a food option, which in small portions is able to meet the daily needs of pro-vitamin A carotenoids of poor populations, and can be introduced through community restaurants and school feeding programs.

Table 4. Portion of 'Beauregard' sweet potato chips required to supply the recommended daily intake for each population group.

Population group	Recommended daily intake (RDI) of RAE μg	Portion of sweet potato chips g	
		Steam blanching	Boiling water blanching
Adults	600	15.79	16.33
Pregnant women	800	21.05	21.77
Lactating women	850	22.36	23.13
Children 12-36 months old	400	10.52	10.88
Children 3-6 years old	450	11.84	12.24
Children 7-10 years old	500	13.16	13.61

RAE = Retinol activity equivalents, values from RDI (2001).

Conclusion

Complete inactivation of the peroxidase after 2 min. when the sweet potato slices were boiling water blanching and after 10 min. steam blanching. After drying the sweet potato chips boiling water blanching showed a less intense color than the steam blanching sweet potato chips as a function of the leaching occurring in the blanching immersion whitening in boiling water. The two blanching conditions followed by drying at 65°C resulted in high retention of carotenoids, resulting in sweet potato chips rich in vitamin A carotenoids. A small portion of 'Beauregard' sweet potato chips is able to supply daily intake of equivalent retinol activity needs from all population groups, including children and women of reproductive age who are most vulnerable to micronutrient deficiency.

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