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Influence of water cooking on mineral content of brazilian sweet potato cultivars

Influencia de la cocción in agua sobre el contenido mineral de los cultivares de camote brasileñas

Influência da cocção em água no conteúdo mineral de cultivares de batata doce brasileiras

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Abstract

The objective of the study was to characterize the mineral profile of Brazilian sweet potatoes and to evaluate the influence of cooking by immersion in water on these micronutrients. The cultivars Amorano, Júlia, Valentina, UGA 29, UGA 34, UGA 45, UGA 49, UGA 79, UGA 80 and UGA 81 were investigated. The levels of sodium, potassium, calcium, magnesium, phosphorus, iron, zinc, copper and silicon were quantified in the samples of raw and cooked sweet potatoes, which presented statistical difference between the varieties. The genotypes that stood out were Júlia and UGA 45 with higher mineral contents, while Amorano and UGA 29 were characterized by lower contents. Water immersion cooking reduced sodium, potassium and iron contents for all Brazilian sweet potato cultivars, while Zn, Mn and Cu showed the least changes. It is concluded that cooking in water significantly reduces the mineral content of most Brazilian sweet potato cultivars.

Keywords: Sweet potatoes; Cooking; Minerals.

Resumen

El objetivo de este estudio fue caracterizar el perfil mineral de la camote brasileña y evaluar la influencia de la cocción por inmersión en agua sobre estos micronutrientes. Se investigaron los cultivares Amorano, Julia, Valentina, UGA 29, UGA 34, UGA 45, UGA 49, UGA 49, UGA 79, UGA 80 y UGA 81. Niveles de sodio, potasio, calcio, magnesio, fósforo, hierro, zinc, cobre y silicio se cuantificaron en las muestras de batata cruda y cocida, que presentaron diferencias estadísticas entre las variedades. Los genotipos que se destacaron fueron Julia y UGA 45, con mayores contenidos minerales, mientras que Amorano y UGA 29 se caracterizaron por niveles más bajos. La cocción por inmersión en agua redujo el contenido de sodio, potasio y hierro en todos los cultivares de camote brasileñas, mientras que Zn, Mn y Cu mostraron los cambios más pequeños. En conclusión, la cocción con agua reduce significativamente el contenido mineral de la mayoría de los cultivares de camote brasileñas.

Palabras chave: Camote; Cocción; Minerales.

Resumo

O objetivo do estudo foi caracterizar o perfil mineral de batatas-doces brasileiras e avaliar a influência do cozimento por imersão em água sobre esses micronutrientes. Foram investigadas as cultivares Amorano, Júlia, Valentina, UGA 29, UGA 34, UGA 45, UGA 49, UGA 49, UGA 79, UGA 80 e UGA 81. Os níveis de sódio, potássio, cálcio, magnésio, fósforo, ferro, zinco, cobre e silício foram quantificados nas amostras de batata-doce crua e cozida, que apresentaram diferença estatística entre as variedades. Os genótipos que se destacaram foram Júlia e UGA 45, com maiores teores minerais, enquanto Amorano e UGA 29 foram caracterizados por menores teores. O cozimento por imersão em água reduziu o teor de sódio, potássio e ferro em todas as cultivares de batata-doce brasileiras, enquanto Zn, Mn e Cu apresentaram as menores alterações. Conclui-se que o cozimento em água reduz significativamente o conteúdo mineral da maioria das cultivares brasileiras de batata-doce.

Palavras-chave: Batatas-doces; Cocção; Minerais.

1. Introduction

Sweet potato is a tuber dicotyledonous culture, cultivated worldwide, due to its importance in the human diet (Luis et al., 2013; Tang, Cai, & Xu, 2015). In addition, it is characterized by rusticity, ease of cultivation, wide adaptation to different types of climate and soil, drought tolerance, and low production costs (Santos et al., 2017; Suárez et al., 2016). The world average consumption of sweet potato is around 8.15 kg/person/year. In 2016, 105.190.501 tons were cultivated worldwide. In the same year, Brazil produced approximately 669.454 tons of this tuber, with revenues of US$ 140.1/ton (Food and Agriculture Organization of the United Nations [FAO], 2018).

The sweet potato growing region is one of the factors that interfere on its shape, size and color of the peel and the pulp (Santos et al., 2017). The diversity of color is influenced by root composition, which includes the presence or absence of specific substances such as β-carotene, anthocyanins, phenolic compounds, dietary fiber, ascorbic acid and some minerals (Laurie, Van Jaarsveld, Faber, Philpott, & Labuschagne, 2012). The varieties which underscore, especially in developing countries are those of purple and orange pulp (Kim et al., 2015; Laurie et al., 2012). In Brazil, sweet potatoes of cream pulp predominate (Santos et al., 2017). The sweet potatoes of cream and orange pulp have been receiving more attention because they are sources of β-carotene, the main precursor of vitamin A (Burri, 2011). In addition, studies have shown that these tubers have higher levels of minerals such as iron, potassium, calcium and magnesium (Aywa, Nawiri, & Nyambaka, 2013; Sanoussi et al., 2016). However, there are significant differences in mineral content between different sweet potato genotypes, even with similar colorations (Ikanone & Oyekan, 2014; Singh & Kaur, 2016). Intrinsic and extrinsic factors are directly related to this effect. Some examples of intrinsic factors are pH, water activity, interactions between nutrients and the presence of antinutrients (phytates, tannins and oxalates). Among extrinsic factors are the type of crop (conventional or organic), location, soil organic matter, irrigation system, climatic conditions, stage of development, type of post-harvest storage and processing techniques (Gharibzahedi & Jafari 2017; Singh & Kaur, 2016; Suárez et al., 2016).

Sweet potato has a good nutritional profile. It contains relatively small amounts of simple sugars, mainly providing complex carbohydrates (Singh & Kaur, 2016). Despite being a source of starch, sweet potatoes are considered as an "anti-diabetic" food. Researches have shown that the phenolic compounds available in this tuberous root contribute to inhibit the activity of α-amylase and α-glycosidase enzymes. Thus, there is a hypoglycemic effect, which helps to stabilize blood sugar levels and reduce insulin resistance (Kaushik, Satya, Khandelwal, & Naik, 2010; Kunyanga, Imungi, Okoth, Biesalski, & Vadivel, 2012). Furthermore, sweet potato peptides have been shown to prevent body weight gain, elevation in serum triglyceride levels, besides exhibit inhibitory activity of angiotensin I converting enzyme (ACE) in rats (Ishiguro et al., 2012; Ishiguro, Kurata, Sameshima, & Kume, 2016).

Sweet potatoes are generally consumed cooked, fried or roasted, varying according to regional habits. Moreover, it can be used as raw material in obtaining several products, such as sweets, flours, starches and alcoholic beverages (Ikanone & Oyekan 2014; Santos et al., 2017). These processing methods improve palatability and acceptability. However, they may alter chemical and nutritional composition (Ikanone & Oyekan 2014; Tang et al., 2015). The minerals present in sweet potatoes are not destroyed by heat, but are soluble in water, which can lead to leaching losses. This effect was demonstrated in a study investigating the influence of baking by immersion in water (25 minutes) in sweet potato minerals from Poland. The cultivars Rosalind and Courage had mineral content reduced by 8 and 18%, respectively (Gumul, Berski, Ziobro, Kruczek, & Areczuk, 2017). Another study evaluated the effect of boiling in water and frying on nutrient content in sweet potatoes from Nigeria (Ikanone & Oyekan 2014). The boiling process promoted higher retention of magnesium (1.86%) and did not affect copper content, although caused higher losses of iron (47.96%) when compared to frying. In other minerals, it was verified that fried sweet potato retained higher levels of zinc (32.06%), calcium (9.31%) and sodium (33.50%) when compared to those boiled in water. In light of this, the goal of this study was to characterize the mineral profile of Brazilian sweet potatoes and to evaluate the influence of cooking by immersion in water on these micronutrients.

2. Materials and Methods

The experiment was installed in the Cedeteg Campus of the Midwest State University, in Guarapuava, Paraná, Brazil (25°23’42”S, 51°27’2”W, 1.120 m high). The division was made in randomized blocks with three repetitions and ten treatments. The genotypes came from the sweet potato Germplasm Bank of State University of Central-West, kept by the Olericulture Sector of the Agronomy Department. The following cultivars were researched: UGA 29 (peel and pulp white); UGA 34 (peel and pulp purple); UGA 45 (purple peel and white pulp); UGA 49 (peel and pulp white); UGA 79 (peel and pulp white); UGA 80 (purple peel and white pulp); UGA 81 (peel and pulp white); Amorano (purple peel and white pulp); Júlia (peel and pulp white) and Valentina (peel and pulp purple). Each replicate was composed of a three tuberous roots samples, with an average weight of 500 to 700 g.

The experimental soil area was prepared by plowing and harrowing. The planting beds were raised side by side, spaced 80 cm apart, with the aid of a duck nozzle. The soil chemical analysis did not identify the need for liming. The branches, taken from the parent plants of the different genotypes, were planted in the spring season in 50 cell trays. The intermediate and superior portions of the vegetative structures of the sweet potato plant (three internodes) were used. After 30 days, the seedlings were transplanted to the field, in plots composed of 6 seedlings of each genotype. Plants were arranged in plots with a useful area of 2.0 m^2, spaced 30 cm apart. Irrigation used was sprinkler type, being performed once a day for 30 minutes in the first month after planting or when necessary, since the pluviometric regime in this period was quite intense. Planting fertilization consisted of 40 kg ha^{-1} of nitrogen, 80 kg ha^{-1} of phosphorus and 90 kg ha^{-1} of potassium (Silva, Lopes, & Magalhães, 2004) and replacement fertilization was performed 60 days after planting, with 100 g $portion^{-1}$ of fertilizer 20-00-20 (kg nitrogen-kg phosphorus-kg potassium, respectively, in 100 kg of fertilizer). Weed control was done by manual weeding until 45 days after transplanting. After this period, plants covered the beds and control was no longer necessary. No phytosanitary controls were carried out. Harvest was performed after 157 days of planting in the field, at the end of the summer, and with commercial maturation stage to consumption. After harvesting, sweet potatoes were stored in raffia bags, duly identified and stored at room temperature (22 °C) until analysis.

Sweet potatoes (10 kg) with better visual appearance were used. Those with defects and/or presenting very different size and appearance were excluded. The samples were then washed in running water, followed by sanitization in sodium hypochlorite solution (150 ppm) for 15 minutes. The tips of the tuberous roots were discarded and the medial part cut into cylinders approximately 3 cm of length. For cooking, the sweet potatoes (100 g) were immersed in 1 L of boiling water (100 °C) and cooked until the material showed no resistance to drilling by stainless steel knife. They were manually peeled, cut (2 cm x 1 cm). The raw and cooked samples were dehydrated in a ventilated oven with forced air circulation (Solab®, Brazil) for 24 hours for the analysis.

The mineral content was quantified in raw and cooked sweet potato samples. The dried samples were then ground with a manual grinder into powder and sieve to get very fine powder. It was then weighed and digested in HNO_3 + H_2O_2 mixture. Samples were prepared as follows: processed with mixture of 0.5 g sample plus 5 mL HNO_3 (65% Merck) and 3 mL H_2O_2 (35%, Merck Millipore) in the microwave digestion system (Speedwave®, Berghof, Germany). After digestion, samples were diluted to 100 mL with ultrapure water. Since the final acid concentration of the samples was quite high (4% HNO_3). The concentration of the elements (Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorus (P), Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu) and Silicon (Si)) was determined with the use of Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique (Thermo Scientific® – iCAP 6000 Series, Fremont, *California, USA*). The concentrations of the different elements in these samples were determined using the corresponding standard calibration curves obtained by using standard solutions of the elements of interest (Merck). Duplicate analyses were performed on each sample.

The percentage of mineral suitability was obtained by calculating the amount of the mineral, considering a mean portion of 200 g, in relation to daily requirement (Institute of Medicine [IOM], 1997; 2002; 2004), according to the equation:

$$\%\ \text{adequacy} = \frac{\text{Average of mineral content in 200 g of cooked sweet potato}}{\text{Daily recommendation value}} \times 100$$

The results were analyzed using analysis of variance (ANOVA). The means were compared by Tukey's Test and Student's t Test at 5% significance level ($p \leq .05$). The Software R was used to perform the statistical calculations.

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3. Results and Discussion

The average levels of minerals of the different cultivars of raw and cooked Brazilian sweet potatoes and their respective recommendations for ingestion are presented in Table 1. The mineral content varied widely among sweet potato cultivars ($p < .05$). The raw and cooked sweet potato genotypes that stood out with the highest levels were Júlia (K for raw and K, P and Zn for cooked) and UGA 45 (Na and Ca for raw and Na and Fe for cooked). The cultivars with the lowest amounts of minerals were Amorano (Na, Mg and P for raw and Ca, Mg, P and Zn for cooked) and UGA 29 (Na, K, Fe and Cu for raw and K and Zn for cooked). Research suggests that these variations among genotypes can be influenced by several factors, such as agricultural and processing practices employed (Nassar, Sabally, Kubow, Leclerc, & Donnelly, 2012; Vizzotto, Pereira, de Castro, Raphaelli, & Krolow, 2017). It is also possible that observed differences are related to the ability of each variety to absorb the soil mineral content (Aywa et al., 2013; Laurie et al., 2012), as well as characteristics of each cultivar (Bethke & Jansky 2008). Considering the daily contribution of minerals (IOM, 1997; 2002; 2004), a 200 g/day portion of cooked sweet potatoes reaches the following recommendation: 0.39% Na, 27.81% K, 12.6% Ca, 30.1% Mg, 34.8% P, 19.5% Fe, 9.4% Zn, 29.4% Mn and 115.8% Cu. Regarding the tolerated intake limit, there is no current data to establish a safe upper level for the intake of K, Si and Mg. In the case of Mg, UL is determined only by supplementation (350 mg/day) and does not consider food or water intake (Lima et al., 2016). Thus, none of the analyzed cultivars causes toxicity. In the human organism, minerals perform a key role in the metabolism, since they are part of the structure of teeth and bones (Ca, Mg, P, Mn and Si) and enzymes (Mg, Fe, Zn, Mg and Cu), helping on cellular repair (P, Cu and Si) and in the transmission and signaling of nerve cells (Na, K, Ca, Mg and P). Other functions include control of blood pressure (K and Ca), formation of erythrocyte (Fe) and platelet cells (Ca), regulation of blood glucose levels (Cr), maintenance of the immune system (Ca, Mg, Zn , Cu, and Si) and brain functioning (Mn and Cr) (Gharibzahedi & Jafari 2017).

Na and K contents were reduced in all cooked sweet potato cultivars. On the other hand, Ca and Mg contents increased ($p < .05$) in Valentina, UGA 29, UGA 34, UGA 80 and UGA 81 and reduced to Júlia, UGA 45, UGA 49 and UGA 79.

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Table 1

Elemental concentration (mg 100 g^{-1}) in raw and cooked sweet potato Brazilian compared to Recommended Dietary Allowances (RDA), Adequate Intake (AI) (mg/day) and values Tolerable Upper Intake Level (UL) (mg/day)

Parameter	Amorano	Júlia	Valentina	UGA 29	UGA 34	UGA 45	UGA 49	UGA 79	UGA 80	UGA 81	AI	UL
Raw												
Macro-elements												
Na	3.60^{aE}	3.50^{aE}	6.05^{aC}	3.36^{aE}	4.58^{aD}	9.95^{aA}	6.45^{aC}	3.89^{aE}	4.87^{aD}	7.89^{aB}	1.500	2.300
K	851.56^{aB}	912.23^{aA}	789.60^{aC}	659.78^{aE}	754.46^{aC}	732.18^{aCD}	654.12^{aE}	689.62^{aDE}	760.83^{aC}	891.00^{aAB}	4.700	*
Ca	23.19^{aF}	78.29^{aB}	31.05^{bE}	22.68^{bF}	42.94^{bC}	114.35^{aA}	36.87^{aD}	114.79^{aA}	32.05^{bE}	20.27^{bG}	1.000	2.500
Mg	33.47^{aH}	69.53^{aC}	53.74^{bDE}	46.67^{bF}	57.20^{bD}	90.07^{aB}	52.16^{aE}	130.87^{aA}	41.58^{bG}	43.54^{bFG}	410	350
P	81.06^{aG}	102.91^{bF}	122.90^{aD}	143.01^{aC}	123.59^{aD}	172.60^{aB}	140.92^{aC}	181.21^{aA}	120.89^{aE}	121.44^{aED}	700^{a}	4.000
Micro-elements												
Fe	4.55^{aC}	1.83^{aF}	2.08^{aE}	1.25^{aG}	6.05^{aA}	3.21^{aD}	2.26^{aE}	1.90^{aEF}	5.58^{aB}	2.48^{aE}	8	45
Zn	0.40^{aEF}	0.51^{aD}	0.51^{aD}	0.51^{aD}	0.61^{aB}	0.57^{aC}	0.71^{aA}	0.60^{aB}	0.50^{aD}	0.38^{aF}	11	40
Mn	0.24^{aD}	0.40^{aB}	0.17^{bE}	0.26^{aD}	0.39^{aBC}	0.32^{aC}	0.55^{aA}	0.47^{aB}	0.29^{aD}	0.12^{aE}	2.3	11
Cu	0.72^{aA}	0.51^{aC}	0.43^{aD}	0.48^{aD}	0.57^{aB}	0.45^{aD}	0.58^{bB}	0.45^{aD}	0.51^{aC}	0.40^{aD}	0.9	10
Si	3.20^{aB}	0.01^{bH}	1.51^{aD}	0.73^{aF}	3.45^{aAB}	1.22^{bE}	0.79^{bF}	0.42^{bG}	3.70^{bA}	2.09^{aC}	*	*
Cooked												
Macro-elements												
Na	1.45^{bE}	1.25^{bG}	4.74^{bB}	1.39^{bF}	1.57^{bE}	8.77^{bA}	2.84^{bD}	1.83^{bE}	1.33^{bFG}	3.79^{bC}	1.500	2.300
K	733.47^{bC}	847.56^{bA}	681.85^{bD}	544.87^{bG}	566.62^{bF}	611.87^{bE}	548.79^{bG}	589.36^{bF}	615.53^{bE}	794.69^{bB}	4.700	*
Ca	20.45^{aG}	40.75^{bF}	45.99^{aE}	79.62^{aC}	187.87^{aA}	95.37^{bB}	24.58^{bG}	40.53^{bF}	55.21^{aD}	40.92^{aF}	1.000	2.500
Mg	31.28^{aE}	54.05^{bD}	73.61^{aB}	64.61^{aCD}	100.50^{aA}	64.87^{bCD}	39.88^{bE}	57.16^{bD}	76.41^{aB}	53.68^{aD}	410	350
P	96.00^{aF}	166.53^{aA}	101.25^{bE}	136.65^{bBC}	102.22^{bE}	113.06^{bD}	147.33^{aB}	126.68^{bC}	104.63^{bE}	125.11^{aC}	700^{a}	4.000
Micro-elements												
Fe	0.40^{bFG}	0.75^{bC}	0.82^{bC}	0.74^{bCD}	1.18^{bB}	1.60^{bA}	0.34^{bG}	0.51^{bEF}	0.82^{bC}	0.62^{bDE}	8	45
Zn	0.44^{aC}	0.72^{aA}	0.43^{aC}	0.46^{aC}	0.63^{aB}	0.40^{aC}	0.70^{aAB}	0.43^{aC}	0.49^{aC}	0.45^{aC}	11	40
Mn	0.23^{aD}	0.21^{aD}	0.68^{aA}	0.43^{aB}	0.47^{aB}	0.26^{aD}	0.09^{bE}	0.20^{aD}	0.48^{aB}	0.33^{aC}	2.3	11
Cu	0.58^{aBC}	0.60^{aB}	0.47^{aCD}	0.43^{aD}	0.44^{aD}	0.35^{aE}	1.07^{aA}	0.34^{aE}	0.51^{aC}	0.42^{aD}	0.8	10
Si	1.53^{bD}	0.45^{aH}	1.73^{aC}	0.92^{aFG}	0.95^{bF}	2.23^{aB}	1.27^{aE}	1.43^{aD}	4.47^{aA}	0.85^{bG}	*	*

Note. Distinct capital letters in row are significantly different by the Tukey's Test between cultivars ($p < .05$); Distinct lower case letters in column show significantly different by the Student's t Test between the same raw and cooked cultivar ($p < .05$); RDA: Recommended Dietary Allowances (Institute of Medicine, 1997; 2002; 2004); AI: Adequate Intake; UL: Tolerable Upper Intake Level; *Not available; Na: Sodium. K: Potassium. Ca: Calcium. Mg: Magnesium. P: Phosphorus. Fe: Iron. Zn: Zinc. Mn: Manganese. Cu: Copper. Si: Silicon; Results reported in wet dry basis.

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After cooking, higher levels of P were observed in the cultivar Júlia. There was no influence on cooking for the varieties UGA 49, UGA 81 and Amorano. The other genotypes had P content reduced after cooking ($p < .05$). Amorano cultivar was the only one which did not change the content of Ca, Mg and P. Processing had little effect on the content of microelements of sweet potatoes. Nevertheless, Fe contents decreased ($p < .05$) in all genotypes after cooking, while Mn contents increased in Valentina cultivar and reduced in UGA 49. Only UGA 49 genotype showed cooking influence in Cu concentration, which increased the concentration. Si showed the highest variation after cooking. Higher contents of this mineral were observed in Júlia, UGA 45, UGA 49, UGA 79 and UGA 80, and smaller for Amorano, UGA 34 and UGA 81, with no significant difference between the other cultivars. In addition, there was no influence of cooking on Zn contents for any of the genotypes ($p > .05$). Bradbury, Bradshaw, Jealous, Holloway, & Phimpisane (1988) evaluated two sweet potato cultivars (83003-12 and 83003-13) found divergent results, since there was no influence of cooking ($p > .05$) on Na, K, Ca, Mg, P contents and M. However, the Zn content reduced after cooking.

Changes in macro and micronutrient composition after cooking are related to heat stability, boiling water solubility, and tuber availability (Bradbury et al., 1988). In the current paper, it is possible that thermal processing altered the cell wall of the sweet potatoes, favoring leaching to some minerals. Na and K are the most affected, since they have a greater capacity to move freely between intra- and extracellular fluids (Abdel-Kader, 1991; Gharibzahedi & Jafari 2017). Other aspects related to the presence of antinutritional factors may also influence loss of minerals during cooking. These compounds have high potential for complexation with Zn, Fe, Mg and Ca molecules. However, phytates and tannins are hydrophilic and thermolabile, which contribute to leaching (Benevides, Souza, Souza, & Lopes, 2011; Cilla, Bosch, Barberá, & Alegría, 2018). This may justify most of the observed results for Fe, Mg and Ca. Other mechanisms appear to be involved in the metabolism of minerals that have little or no processing influence. Similar conclusion is related to those who have had an increase in concentration after cooking. In these cases, the explanation may be related to a strong binding of metals to sweet potato macromolecules (Finglas & Faulks 1984). Comparable results to the current paper were verified in 12 varieties of sweet potatoes from Peru (Burgos, Amoros, Morote, Stangoulis, & Bonierbale, 2007). The genotype may also influence mineral content during cooking, as verified in English potatoes (Finglas & Faulks 1984).

4. Conclusion

The Brazilian sweet potato cultivars evaluated showed differences in mineral composition and are directly influenced by the thermal processing of cooking in water. Júlia and UGA 45 genotypes contain the highest levels of minerals, while Amorano and UGA 29 are the ones with the lowest content. Minerals such as Na, K and Fe are most influenced by thermal processing, and their levels are reduced in cooked tubers. Greater stability to cooking by immersion in water occurs for Zn, Mn and Cu, since they do not modify in most part Brazilian sweet potato cultivars. However, the results of the present study are limited as they cannot be extrapolated to other cultivars. It is recommended that the cooking time and temperature variables, as well as the analysis methodology be controlled in future studies.

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